Latest Pattern

disha
Nurturing Ambitions

4th Edition

CBSE Board PHYSICS

Solved Papers (2008-17) in Level of Difficulty Chapters with 3 Sample Papers

12 Class

Shipra Agarwal

Unique Presentation (Innovative Way to Master Physics)

Solutions developed by the most prestigious Author in Physics

2008-17 Past Papers

Errorless Solutions

43 Question Papers AI, Delhi, Compartment

12 Class

disha
Nurturing Ambitions

CBSE Board Physics
Solved Papers in Level of Difficulty Chapters with 3 Sample Papers
(Latest Pattern)

Shipra Agarwal

- Past Papers (AI, Delhi & Compartment 2008 Onwards)
- Errorless Solutions
- Unique Presentation

GP_3166

Corp. Office : 45, 2nd Floor, Maharishi Dayanand Marg, Corner Market,
Malviya Nagar, New Delhi-110017
Tel. : 011-26691021 / 26691713

Typeset by Disha DTP Team

DISHA PUBLICATION

For further information about the books from DISHA,

Log on to **www.dishapublication.com** or email to **info@dishapublication.com**

Content

Preface

"CBSE Board Physics Solved Papers in Level of Difficulty Chapters" is altogether a new approach for commanding Physics for Class 12 CBSE Board exams. The book is written in a very simple and lucid language. This edition covers solutions to all the questions that appeared in the years 2008 onwards in the CBSE Board exams for the Delhi, All India and Foreign regions. The book also includes the questions of the compartment papers.

The book provides a unique and innovative chapterization and has been divided on the basis of the types of the questions rather than the typical chapter-wise format. Some of the typical chapter names are: What is the definition of? How will you identify/ differentiate between? Why does the following phenomenon happen reason? What is the law/ rule/ principle of ? How will you establish relation/ deduce expression for ....? etc.

In all such chapters previous years questions from the complete syllabus of Physics, Class 12 viz. Electrostatics, Current electricity, Magnetism, Alternating Current and EM waves, Optics, Atoms and Nuclei, Electronics and Communication Systems.

The structure of the book has been designed on the basis of answers it provides to the following 5 questions:

1. What has been asked in the exam?
2. Why is this question important? Why this question is repeated many-a-times?
3. How do I answer this question in the best way?
4. Where (Delhi/AI/Foreign) did this question appeared?
5. When (year) was this question asked?

Another unique feature of the book is the quality of its solutions which will not be found anywhere.

The book also contains Moral VALUE based questions based on the pattern of the questions asked in the Board examination. The book also provides 3 Sample papers with detailed solutions.

The book will be an eye-opener for all class 12 students who will appear in the CBSE AI, Delhi and other state board examination. It is my guarantee that this will turn out to be the BEST TOOL FOR PRACTICING AND REVISING PHYSICS for Class 12 CBSE Board exams.

In the end I would like to thank Sanjeev Kumar Jha for working very hard to bring out the book in the present shape. Any suggestions for the improvement of the book are most welcome.

Shipra Agarwal

CHAPTER 1

What is the definition of ....?

(A) Electrostatics

1. Define electric flux.
[All India 2008, 2009, Delhi 2008C, 2012, 2012C, 2013C]
2. Define electric dipole moment of an electric dipole.
[All India 2008C, 2011, Foreign 2009, 2012]
3. Define the dielectric constant of a medium. **[Delhi 2011C]**
4. Define quantization of electric charge.
5. Define following terms :
   (i) Electric field
   (ii) Electric field intensity
6. Define electric potential energy. **[Delhi 2008C]**
7. Define electrostatic potential.
8. Define capacitance of a capacitor.
9. Define an equipotential surface. **[All India 2016]**

(B) Current Electricity

10. Define resistivity of a conductor. **[Delhi 2008, All India 2011]**
11. Define Ohm's law.
12. Define specific resistance.
13. Define mobility of a charge carrier. **[Foreign 2008, All India 2013C, Delhi 2014]**
14. Define relaxation time of the free electrons drifting in a conductor.
[All India 2012]
15. What is the emf of a cell ?
16. Define the term 'drift velocity' of charge carriers in a conductor.
[All India 2013C, Delhi 2014, 2016]

17. Define the term 'electrical conductivity' of a metallic wire.
[Delhi 2014]

18. State Kirchhoff's rules. **[All India 2015]**

(C) Magnetism

19. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current.
[Delhi 2009, All India 2014]

20. What is 'Bohr magneton'? **[All India 2010]**

21. Define the current sensitivity of a galvanometer.
[All India 2013, 2013C]

22. What are permanent magnets? **[Delhi 2013]**

23. Define force on a moving charge.

24. Define magnetic field strength.

25. Define magnetic susceptibility of a material. **[Delhi 2008]**

26. Define magnetic dipole moment. **[Delhi 2008C]**

27. Define potential energy in magnetic field.

28. What is hysteresis ?

29. Define magnetic permeability.

30. State Biot - Savart law. **[All India 2017]**

(D) EMI, Alternating current and EM waves

31. Define mutual induction between two long coaxial solenoids.
[All India 2008, 2014, Foreign 2008, 2009, Delhi 2009, 2012]

32. Define self inductance of a coil. **[Foreign 2009, Delhi 2009, All India 2010, 2013C, 2014, 2017]**

33. Define magnetic flux (ϕ)

34. Define eddy currents.

35. What is working principle of a.c. generator.

36. Define the quality factor in an a.c. circuit. **[Delhi 2009, 2016]**

37. Define power factor.

38. What do you mean by root mean square value of an A.C.

39. What do you mean by electromagnetic spectrum ?

40. Define capacitor reactance. Write its S.I. units. **[Delhi 2015]**

41. Define mutual inductance between a pair of coils. **[All India 2017]**

(E) Optics

42. Define power of a lens. **[Foreign 2010, 2012]**

43. Define magnifying power of a telescope.

[Delhi 2010C, 2012, All India 2013]

44. Define following terms :

(i) Reflection (ii) Refraction

45. Define the phenomenon of total internal reflection.

46. Define critical angle.

47. How is a wavefront defined ? **[Delhi 2008, All India 2016, 2017]**

48. What is plane polarised light? **[Delhi 2008]**

49. What are coherent sources? **[All India 2010C]**

50. Define the diffraction in wave optics.

51. Define Fresnel distance.

52. Define the terms 'threshold frequency' and 'stopping potential' in the study of photoelectric emission. **[Foreign 2010]**

53. Define intensity of radiation on the basis of photon picture of light. Write its S.I. units. **[All India 2012, 2014]**

54. Define work function.

55. Define the phenomenon of photoelectric effect.

56. Define the term 'intensity of radiation' in terms of photon picture of light. **[All India 2015]**

57. State Brewster's law. **[Delhi 2016]**

58. What is dispersion of light? **[Delhi 2016]**

(F) Atoms and Nuclei

59. Define the Q-value of a nuclear process. **[All India 2010C]**

60. Define the activity of a given radioactive substance.

[Delhi 2010, All India 2013]

61. Define the term radioactivity.

62. Define ionization energy. **[All India 2016]**

(G) Electronics and Communication Systems

63. Define the following terms:

(i) Input resistance

(ii) Current amplification factor, β of a transistor used in its CE configuration.

[Delhi 2008, 2009C, 2015, Foreign 2011, All India 2010C, 2011C]

64. What is a Light Emitting Diode (LED)? **[All India 2010]**

65. Define term output resistance used in transistor amplifiers. **[Foreign 2011]**

66. Define the terms 'depletion layer' and 'barrier potential' for a *p-n* junction. **[All India 2013C]**

67. What is diffusion current?

68. What is an amplifier? **[Delhi 2008]**

69. Define transducer.

70. What is meant by term 'modulation' ? **[Delhi 2009]**

71. What is space wave propagation? **[Delhi 2009, 2010]**

72. What is sky wave propagation? **[Delhi 2009, All India 2011]**

73. What is the ground wave communication? **[Delhi 2009, All India 2011, 2015]**

74. What is meant by 'detection of a modulated signal'? **[Delhi 2013C]**

75. Define modulation index. **[All India 2016]**

76. Define the terms (i) attenuation and (ii) demodulation used in communication system. **[Delhi 2016]**

SOLUTIONS

1. Electric flux is defined as the number of electric field lines crossing a unit area perpendicular to the area.

   Electric flux $\phi_E = \vec{E}.\overrightarrow{ds}$

2. Electric dipole moment of an electric dipole is the product of its either charge and the length of the electric dipole. It is denoted by p.

   $p = q \times 2l$

   Its unit is coulomb-metre.

3. The dielectric constant of a medium is the ratio of force experienced by the two unit positive charges when placed at unit distance from each other in vacuum to the force experienced by the same point charges separated by same distance in medium.

4. Quantization of electric charge:– Any charge exists in discrete lumps or packets of a certain minimum charge $\pm$e, where e is the charge of an electron. According to quantization of charge, the charge on a body can be only an integral multiple of charge on the electron, i.e.,

   $$q = \pm ne \text{ where } n = 1, 2, 3 \text{ .... and } e = 1.6 \times 10^{-19}\text{ C}$$

5. Electric field is defined as a region of space around a charge or a system of charges within which other charged particles experience electrostatic forces.

   Electric field intensity is a measure of the strength of the electric field. It is defined as the electrostatic force per unit charge.

6. Electric potential energy of a system of point charges is the total amount of work done in bringing various charges to their respective positions from infinitely large mutual separations.

   $$\text{Potential energy} = \frac{kq_1q_2}{r}.$$

7. Electrostatic potential at a point in the electrostatic field is defined as the work done in moving a unit positive charge from infinity to that point against the electrostatic force along any path. It is a scalar quantity.

8. Capacitance of a capacitor is the measure of the capacity of a device of storing charge.

   $$\text{Capacitance, } C = \frac{\text{charge}}{\text{voltage}}\frac{Q}{V}$$

   Its S.I. unit is farad (F).

9. An equipotential surface is that surface at every point of which, the electric potential is the same.

10. The resistivity of conductor is equal to the resistance offered by the conductor of unit length and unit cross-sectional area.

Resistance, $R = \rho \frac{\ell}{A}$ ρ = resistivity of the material.

11. Ohm's law: Temperature and other physical conditions remaining same, the electric current flowing through a conductor is directly proportional to its potential difference. i.e., $I \propto V$ or, $V = IR$ where R = resistance of the conductor.

12. Specific resistance (ρ) of a material is defined as the resistance of unit length and unit cross-sectional area of the conductor. Its S.I. unit is ohm-m.

Specific resistance, $\rho = \frac{m}{ne^2\tau}$

13. Mobility (μ) is defined as the drift velocity (V_d) per unit electric field E. i.e., $\mu = \frac{V_d}{E}$.

14. The average time difference between two successive collisions of drifting electrons inside the conductor under the influence of electric field is known as relaxation time.

15. E.m.f of a cell is defined as the maximum potential difference between the two electrodes of the cell when no current is drawn from the cell i.e., in open circuit.

16. The motion of free electrons in a conductor are continuous and random. They collide with positive metal ions and change direction during each collision. So thermal velocities are randomly distributed and average velocity is zero.

When a potential difference is applied across the ends of a conductor, electrons are drifted towards the positive terminal of the field, this velocity is called drift velocity (v_d).

Drift velocity, $v_d = -\frac{e\vec{E}\tau}{m}$

17. Electrical conductivity of a metallic wire refers to its ability to carry an electrical charge with minimum resistance.

The electrical conductivity of a metallic wire is defined as the ratio of the current density to the electric field it creates. It is represented by σ(sigma).

Electrical conductivity, $\sigma = J/E$

Its S.I. unit is (mho m^{-1}) or $(\text{ohm m})^{-1}$

18. Kirchhoff's first rule (Junction rule): The algebraic sum of the currents meeting at a point in an electrical circuit is always zero.

$$\sum I = 0$$

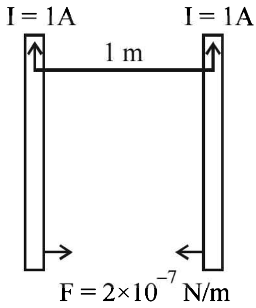
This law is justified on the basis of law of conservation of charge.

Kirchhoff's second law (Loop rule): In a closed loop, the algebraic sum of the emfs is equal to the algebraic sum of the products of the resistances and the current flowing through them.

$$\sum \varepsilon = \sum I R$$

This law is justified on the basis of law of conservation of energy.

19. The amount of current which when flowing (in same direction) through two infinitely long parallel wires separated by one metre produces an attractive force of 2×10^{-7} N/m is called one ampere.



The wires must have negligible circular cross-section and they must be placed in vacuum.

20. From Bohr's postulates

$$l = mvr = \frac{nh}{2\pi} \text{ where } n = 1, 2, 3.....$$

$$\therefore \quad \mu = \frac{e}{2m} \cdot \frac{nh}{2\pi} = n\mu_{min}$$

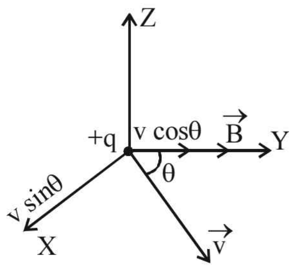
where $\mu_{min} = \dfrac{eh}{4\pi m}$ called Bohr magneton.

21. The current sensitivity of a galvanometer is defined as the deflection per unit current.

Current sensitivity, $I_S = \frac{\theta}{I} = \frac{NBA}{k}$

22. The magnets which have high retentivity and high coercivity are called permanent magnets. Magnetite or lodestone is a natural or permanent magnet.

23. Force on a moving charge : A moving charge is a source of magnetic field.



Let a positive charge q is moving in a uniform magnetic field $\vec{B}$ with velocity $\vec{v}$.' $F \propto q$

$F \propto v \sin\theta$, $F \propto B$

$\therefore \quad F \propto qBv\sin\theta \Rightarrow F = kq\,Bv\sin\theta$ [k = constant]

24. Magnetic field strength is defined as the force experienced by a unit charge moving with unit velocity perpendicular to the direction of magnetic field.

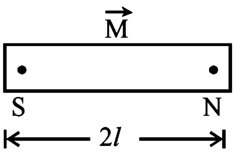
25. Magnetic susceptibility of a material is defined as the ratio of magnetisation to magnetic intensity.

Magnetic susceptibility, $\chi = \frac{M}{H}$

Aluminium is a paramagnetic substance having positive susceptibility.

Bismuth is a diamagnetic substance having negative susceptibility.

26. Magnetic dipole : Two unlike poles of equal strength separated by a small distance is called a magnetic dipole.



Magnetic dipole moment, $\overrightarrow{M} = m(2\vec{\ell})$ where m is the magnetic pole strength, 2ℓ is the distance between the two poles. It is directed from S to N pole. The S.I. unit is joule/tesla.

27. Potential energy of a magnetic dipole in a magnetic field,

$$U = -MB(\cos\theta_2 - \cos\theta_1)$$

If $\theta_1 = 90°$ and $\theta_2 = \theta$ then $U = -MB\cos\theta = -\overrightarrow{M}\cdot\overrightarrow{B}$

28. The phenomenon of lagging of magnetic induction B (or intensity of magnetisation, I) behind the magnetising force H when a specimen of a magnetic material is subjected to a cycle of magnetization is called hysteresis. Hysteresis is shown by ferromagnetic substance only.

29. **Magnetic permeability (μ_r) :** It is the ability of a material to permit the passage of magnetic lines of force through it. Relative magnetic permeability of a medium is the ratio of absolute permeability of the medium to the permeability of free space.

$$\mu_r = \frac{\mu}{\mu_0} = \frac{B}{B_0}$$

30. (a) Biot–Savart law states that the magnetic field (dB) due to the current element dl at any point P is

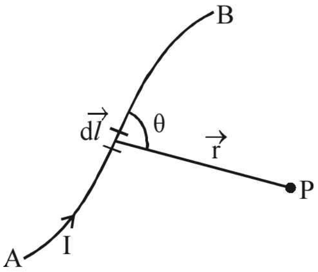
(i) directly proportional to the current, I i.e., $dB \propto I$

(ii) directly proportional to the length dl of the element i.e., $dB\ \mu\ dl$

(iii) directly proportional to sin θ, where θ is the angle between dl and r, *i.e.*, $dB \propto \sin\theta$

(iv) inversely proportional to the square of the distance r from the current element AB i.e., $dB\ \mu\ \frac{1}{r^2}$

Therefore, we have



$$dB\ \mu\ \frac{Idl\sin\theta}{r^2}$$

$$\therefore \quad dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

In vector notation,

$$dB = \frac{\mu_0}{4\pi}\frac{Idl \times r}{r^3}$$

31. Mutual induction is the phenomenan of generation of induced emf in a solenoid when current is changing in neighbouring coaxial solenoid.

32. Self-inductance of a coil is a property of a coil by virtue of which it opposes any change in self-flux linked with the coil.
When a current is passed through a coil, it produces a magnetic field. A flux is linked with the magnetic field produced by the coil. This flux is called self-flux.
magnetic-flux is directly proportional to the current flowing through the coil. If I is current flowing through a coil and 'ϕ' is the magnetic flux linked with its own magnetic field, then

$$\phi \propto I \quad \text{or,} \quad \phi = LI$$

where L is the proportionality constant and is known as self-inductance.

33. **Magnetic flux (ϕ) :** Magnetic flux through any surface held in a magnetic field $(\vec{B})$ is the total number of magnetic lines of force crossing the surface.

34. **Eddy currents :** Currents induced in the body of a conductor when the amount of magnetic flux linked with the conductor changes is called eddy current.

Magnitude of eddy current, $i = \dfrac{\text{induced e.m.f.}}{\text{resistance}}$

$$i = \frac{e}{R} = -\frac{d\phi/dt}{R} \quad \left[\because e = -\frac{d\phi}{dt}\right]$$

35. **Principle of ac generator :** A dynamo or generator is a device which converts mechanical energy into electrical energy. It is based on the principle of electromagnetic induction.

36. **Quality Q-factor** of the circuit is defined as the ratio of inductive reactance at resonance to the resistance R in the circuit

i.e., $Q = \dfrac{L\omega_0}{R} = \dfrac{1}{C\omega_0 R}$ i.e., $Q \propto \dfrac{1}{R}$

37. **The power factor :** The instantaneous power supplied by the source is given by,

$$P = VI\cos\phi \text{ where } V = \frac{V_0}{\sqrt{2}}, I = \frac{I_0}{\sqrt{2}}.$$

The quantity $\cos\phi$ is called the power factor.

38. **Root mean square value of an A.C. :** It is the steady current which when passed through a given resistor for a certain time, shall produce the same heat as the given A.C. shall do when passed for the same time.

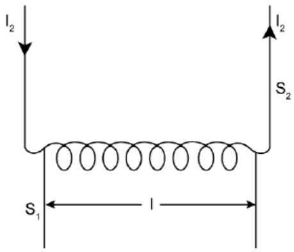
$$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707 I_0, \; E_{rms} = \frac{E_0}{\sqrt{2}} = 0.707 E_0$$

39. **Electromagnetic spectrum :** The electromagnetic waves have continuous wavelength starting from short gamma rays to long radiowaves. The orderly distribution of wavelength of e.m. waves is called electromagnetic spectrum.

40. In a purely capacitive circuit the current leads the applied emf by an angle $\pi/2$ and the impedance of the circuit is $1/\omega C$ and this is known as capacitor or capacitive reactance $Z = X_C = \frac{1}{\omega C}$.

The SI unit of capacitor reactance is ohm (Ω).

41. Mutual inductance is the property of two coils by the virtue of which each opposes any change in the strength of current flowing through the other by developing an induced emf.



42. The power of a lens is equal to the reciprocal of its focal length when it is measured in metre.

Power of a lens $P = \frac{1}{f\,(\text{in metre})}$. It unit is dioptre (D).

43. The magnifying power of a telescope is equal to the ratio of the visual angle subtended at the eye by final image formed at least distance of distinct vision to the visual angle subtended at naked eye by the object at infinity.

44. (i) **Reflection :** The phenomenon of returning of light into the same medium after being incident on a surface is known as reflection of light.

(ii) **Refraction :** When a beam of light is incident on a surface separating two transparent media, a part of light gets reflected back into the first medium while the rest enters the other.

The bending of light as it passes obliquely from one transparent medium to another is known as refraction of light.

45. **Total Internal Reflection :** The phenomenon of reflection of total light when the light traveling from an optically denser medium to a rarer medium strikes the interface at an angle greater than the critical angle is called total internal reflection.

46. **Critical angle :** The critical angle for the given pair of media is defined as the angle of incidence in the denser medium corresponding to which the angle of refraction is 90° in the rarer medium.

According to Snell's law,

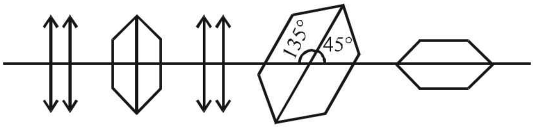
$$n_{12} = \frac{\sin i}{\sin r} \qquad \text{when } i = i_c,\ r = 90^\circ$$

$$\therefore\ n_{12} = \frac{\sin i_c}{\sin 90^\circ} = \sin i_c \qquad \therefore\ n_{12} = \frac{1}{\sin i_c}$$

47. A wavefront is defined as the continuous locus of all the particles of a medium which are vibrating in the same phase.

48. The plane polarised light is that in which the vibrations of light (electric field vector) are confined in a particular direction.

Let E_0 be the amplitude of the component coming out from 1st polaroid. As the third polaroid is placed between polaroids 1 and 2, bisecting the angle 45° between them.



Then the component of the electric field emerging from 3rd polariod is

$$E' = E_0 \cos 45^\circ = \frac{E_0}{\sqrt{2}}.$$

49. To observe interference fringe pattern, there is need to have sources of light which can produce light of constant phase difference are called coherent sources.

50. **Diffraction** : It is the phenomenon of spreading of light waves as they pass through a narrow opening.
All types of waves, be it sound waves, light waves, water waves exhibit the phenomenon of diffraction.

51. **Fresnel distance :** It is the distance travelled by a beam of light though an aperture of size 'a', before it starts to spread out due to diffraction. Fresnel distance, $Z_F = \frac{a^2}{\lambda}$

52. **Threshold frequency :** The minimum frequency below which there is no occurrence of photoelectric effect is called the cut-off or threshold frequency.
Stopping potential : The value of negative potential of anode at which photoelectric current in the circuit reduces to zero is called stopping potential.

53. Intensity means strength or power. Therefore the intensity of radiation is defined as the number of photons per unit surface area per unit time. The S.I. unit of intensity of radiation is joule/meter^2 second.

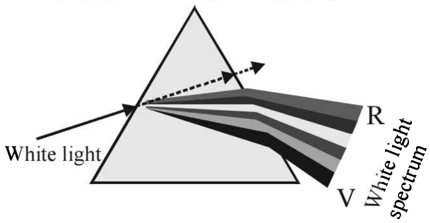
54. The minimum energy required to pull an electron out from the surface of the metal is called work function.

55. The phenomenon of emission of electrons when radiation of suitable wavelength is incident on a surface of metal is called photoelectric effect.

56. Intensity of radiation is defined as the number of photons falling per unit area in unit time.

57. **Brewster's angle** or angle of polarisation is defined as the angle of incidence at which light with a specific polarisation is perfectly transmitted without any reflection through a transparent dielectric surface. In other words, the light incident at Brewster's angle, when reflects back, is perfectly polarised.

58. The phenomenon of splitting of white light into its seven constituent colours is called **dispersion of light.**
When a narrow beam of sunlight is incident on a glass prism, the emergent light spilts into seven colours, namely, violet (V), indigo (I), blue (B), green (G), yellow (Y), orange (O) and red (R).



59. The Q-value of a nuclear process refers the energy release in the nuclear process, which can be determined using Einstein's mass energy relation, $E = mc^2$. The Q-value is equal to the difference of mass of products multiplied by square of velocity of light.

60. Activity is defined as the decay rate of the radioactive sample.

61. **Radioctivity:** It is a nuclear phenomenon in which an unstable nucleus undergoes decay. The phenomena of disintegration of heavy elements into comparatively lighter elements by the emission of radiations is called radioactivity.

62. The minimum amount of energy required to remove an electron from the outermost orbit of a neutral atom in its ground state is known as the **ionization energy** of that atom.

63. (i) **The input resistance,** r_i of transistor in CE configuration is defined as the ratio of small change in base-emitter voltage to the corresponding small change in the base current, when the collector emitter voltage is kept constant,

i.e., $$r_i = \left(\frac{\Delta V_{EB}}{\Delta I_B}\right)_{V_{CE} = \text{constant}}$$

(ii) **The current amplification factor** of a transistor in CE configuration is equal to the ratio of the small change in the collector current (ΔI_C) to the small change in base current when collector-emitter voltage is kept constant,

i.e., $$\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE} = \text{constant}}$$

ΔI_C = change in collector current

ΔI_B = change in lose current. Its value is very large ($\beta_{ac} >> 1$)

64. **Light emitting diode :** LED is a forward biased p-n junction which converts electrical energy into optical energy of infrared and visible light region.

65. **Output resistance :** The ratio of variation of collector emitter voltage (V_{CE}) and corresponding change in collector current (ΔI_C) when base current in collector remains constant, is called output chracteristic curve.

$$\therefore R_{output} = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B = \text{constant}}$$

66. Depletion layer is defined as the region around the p-n junction which is devoid of any charge carriers.

Barrier potential is defined as the fictitious battery which seems to be connected across the junction with its positive end on the n-type and the negative end on the p-type.

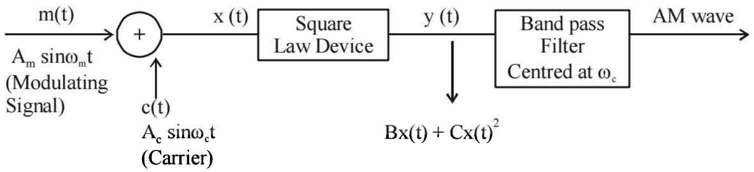
67. Holes being majority carriers on p–side move to n–side in a p–n junction and similarly electrons moving from n $\rightarrow$ p side constitute diffusion current.

68. An amplifier is a device which produces an enlarged copy of input signal.

69. An electrical transducer may be defined as a device that converts some physical variable (pressure, displacement, force, termperature etc) into corresponding variations in the electrical signal at its output

70. When low frequency message signal is superimposed on a high frequency the process is called modulation.

Block diagram of a simple modular for obtaining an AM signal.



71. **Space wave propagation :** It is also known as line of sight propagation (LOS). The radio wave transmitted by antenna directly reaches the receiving antenna travelling along a straight line. TV waves (80 MHz-200 MHz) propagate through space wave propagation.

72. **Sky wave propagation :** When radio wave propagates from one place of earth to other after reflection by ionosphere.

73. **Ground wave communication :** Ground waves are the radio waves whose frequencies ranged upto 1500 kHz that travel along the surface of the Earth. The propagation of the wave is guided along the Earth's surface and follows the curvature of the Earth.

The propagation of high frequency wave is not possible through ground waves for long distance communication because while progressing, ground waves induce current in the ground and bend round the corner of the objects on the Earth due to which the energy of the ground waves of high frequency is almost absorbed by the surface of the Earth after travelling a small distance.

74. Detection of a modulated signal means obtaining the signal from the modulated wave.

75. **Modulation index :** It is defined as the ratio of the amplitude of the message signal to the amplitude of the carrier wave.

Modulation index, $\mu = \frac{A_m}{A_c}$

For effective amplitude modulation, μ is kept to avoid distortion in the signal.

76. **(i)** **Attenuation:** is defined as the loss of strength of a signal while propagating through a medium.

(ii) **Demodulation** is the process of retrieval of information from the carrier wave at the receiver end. It is the reverse process of modulation.

□□□

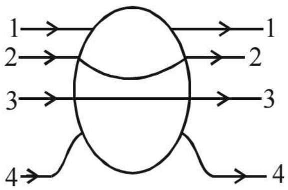
CHAPTER 2

How will you identify/ differentiate between....?

(A) Electrostatics

1. Differentiate between a dielectric and a conductor. **[Delhi 2012]**

2. A metallic solid sphere is placed in a uniform electric field as shown in figure. Which path is followed by the lines of force?

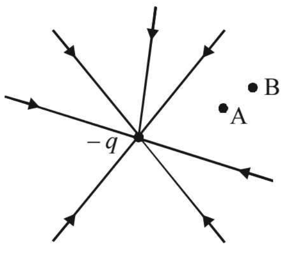


3. If an electron, moving with a finite velocity, enters a transverse electric field, then which path will the electron be take? **[Delhi 2012C]**

4. What is the geometrical shape of equipotential surfaces due to single isolated charge? **[Delhi 2013]**

5. Distinguish between electric potential and potential energy.

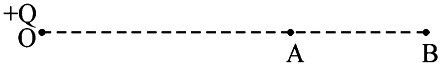
6. The field lines of a negative point charge are as shown in the figure. Does the kinetic energy of a small negative charge increase or decrease in going from B to A? **[All India 2015]**



7. Explain the difference in the behaviour of a (i) conductor and (ii) dielectric in the presence of external electric field. **[Delhi 2015]**

8. What is the direction of field for positive and negative charge densities ? **[All India 2016]**

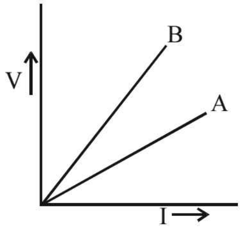
9. A point charge +Q is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero? **[Delhi 2016]**



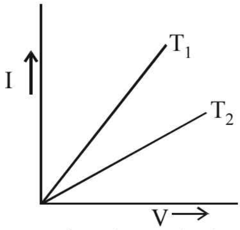
(B) Current Electricity

10. Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker? **[All India 2012]**

11. V-I graph for parallel and series combination of two metallic resistors are as shown in the figure. Which graph shows parallel combination?.



12. V-I graph for a metallic wire at two different temperature T_1 and T_2 is as shown in the following figure. Which of the two temperature is higher?



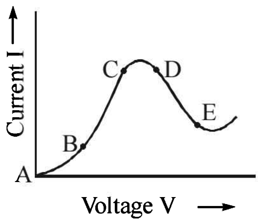
13. Distinguish between emf and terminal voltage of a cell.

[All India 2015]

14. Graph showing the variation of current versus voltage for a material GaAs is shown in the figure. Identify the region of

(i) negative resistance

(ii) where Ohm's law is obeyed. **[Delhi 2015]**



15. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more? **[All India 2017]**

(C) Magnetism

16. In what respect, is a toroid different from a solenoid? **[All India 2011]**

17. Which one of the following will have minimum frequency of revolution, when projected with the same velocity (v) perpendicular to the magnetic field (B): (i) α-particle and (ii) β-particle?

18. How does a voltmeter different from an ammeter?

19. The permeability of a magnetic material is 0.9983. Name the type of magnetic material it represents. **[Delhi 2011]**

20. The susceptibility of a magnetic material is -4.2×10^{-6}. Name the type of magnetic material it represents. **[Delhi 2011]**

21. The relative magnetic permeability of a magnetic material is 800. Identify the nature of magnetic material. **[Delhi 2012]**

22. The susceptibility of a magnetic material is -2.6×10^{-5}. Identify the type of magnetic material. **[Delhi 1012]**

23. Which of the following substances are diamagnetic?
Bi, Al, No, Cu, Ca and Ni **[Delhi 2013]**

24. Where on the surface of Earth is the horizontal component of Earth's magnetic field zero? **[Delhi 2013C]**

25. Which of the following substances are paramagnetic?
Bi, Al, Cu, Ca, Pb and Ni **[Delhi 2013]**

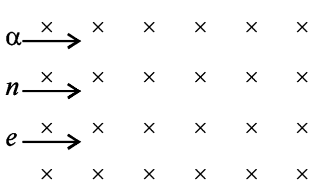
26. Differentiate among diamagnetic, paramagnetic and ferromagnetic substances.

27. What type of magnetic material is used in making permanent magnets?

28. In what way is Gauss's law in magnetism different from that used in electrostatics ? Explain briefly. **[All India 2015]**

29. In what way is the behaviour of a diamagnetic material different from that of a paramagnetic, when kept in an external magnetic field **[All India 2016]**

30. A neutron, an electron and an alpha particle moving with equal velocities, enter a uniform magnetic field going into the plane of the paper as shown. Trace their paths in the field and justify your answer. **[Delhi 2016]**



(D) EMI, Alternating Current and EM Waves

31. What is the difference between self induction and mutual induction?

32. Name the main component which changes a.c generator into d.c. generator.

33. What is the phase difference between the voltage across the inductor and capacitor in an a.c circuit? **[Delhi 2008C]**

34. Which of the following has the shortest wavelength?
Microwave, ultraviolet ray, X-ray. **[All India 2010]**

35. Which part of electromagnetic spectrum has largest penetrating power? **[Delhi 2010]**

36. Which part of electromagnetic spectrum is absorbed from sunlight by ozone layer? **[Delhi 2010]**

37. Which part of electromagnetic spectrum is used in radar system? **[Delhi 2010]**

38. Name the electromagnetic radiation used to destroy cancer cells. **[Foreign 2010]**

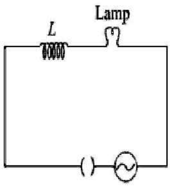
39. Name the electromagnetic radiations used for studying crystal structure of solids.

40. Name the electromagnetic radiations used for viewing objects through haze and fog.

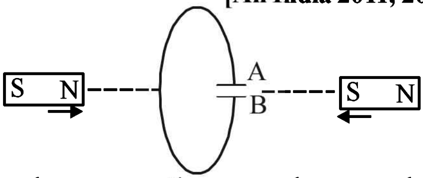
41. Name the parts of the electromagnetic spectrum which is
(a) suitable for radar systems used in aircraft navigation
(b) used to treat muscular strain
(c) used as a diagnostic tool in medicine.
[Delhi 2015]

42. Identify the part of the electromagnetic specturm which is :
(a) suitable for radar system used in aircraft navigation.
(b) produced by bombarding a metal target by high speed electrons. **[All India 2016]**

43. A lamp is connected in series with an inductor and an AC source. What happens to the brightness of the lamp when the key is plugged in and an iron rod is inserted inside the inductor ? **[All India 2016]**



44. Predict the polarity of the capacitor in the situation described below: **[All India 2011, 2017, Delhi 2011]**

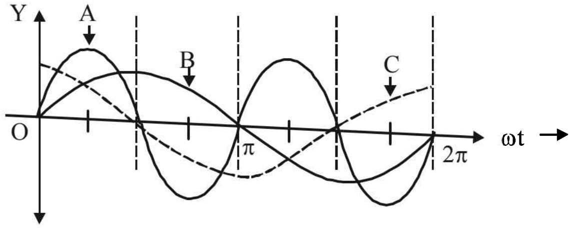


45. Identify the electromagnetic waves whose wavelengths vary as

(a) 10^{-12} m $< \lambda <$ 10^{-8} m

(b) 10^{-3} m $< \lambda <$ 10^{-1} m **[All India 2017]**

46. A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in one cycle is shown in the following graph:



(a) Identify the device 'X'.

(b) Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? **[All India 2017]**

(E) Optics

47. How is the working of a telescope different from that of a microscope? **[Delhi 2012]**

48. What is the difference between primary and secondary rainbow?

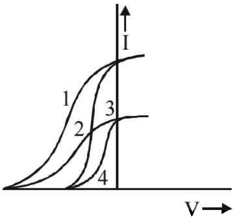
49. What is the difference between the virtual images formed by concave mirror and convex mirror?

50. Differentiate between a ray and a wavefront. **[Delhi 2009]**

51. State briefly two features which can distinguish the characteristic features of an interference pattern from those observed in the diffraction pattern due to a single slit. **[Delhi 2009, All India 2011C, Delhi 2013C]**

52. Two narrow slits are illuminated by a single monochromatic source. Name the pattern obtained on the screen. One of the slits is now completely covered, what is the name of the pattern obtained now on the screen? **[Delhi 2011C]**

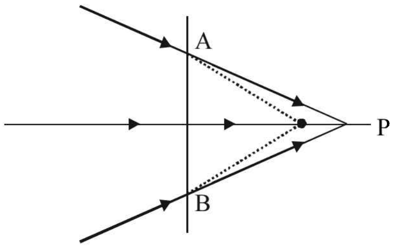
53. The given graph shows the variation of photoelectric current (I) versus applied voltage (V) for two different photosensitive materials and for two different intensities of the incident radiation. Identify the pairs of curves that correspond to different materials but same intensity of incident radiation. **[Delhi 2013]**



54. Which material has highest work function?

55. Is there any difference between light waves and matter waves?

56. The line AB in the ray diagram represents a lens. State whether the lens is convex or concave. **[All India 2015]**



57. Two monochromatic beams, one red and the other blue, have the same intensity. In which case (i) the number of photons per unit area per second is larger, (ii) the maximum kinetic energy of the photoelectrons is more? Justify your answer. **[All India 2015]**

58. In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light ? **[All India 2016]**

59. Compare the interference pattern observed in Young's double slit experiment with single slit diffraction pattern, pointing out three distinguishing features. **[Delhi 2016]**

60. State two differences between interference and diffraction patterns. **[All India 2017]**

61. You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope? **[Delhi 2009, All India 2017]**

Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

62. Name the phenomenon which shows the quantum nature of electromagnetic radiation. **[All India 2017]**

(F) Atoms and Nuclei

63. When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$. Identify the spectral series to which the emission lines belong. **[All India 2013]**

64. What is the difference between Rutherford's model and Bohr's model of an atom?

65. Which has greater ionising power, alpha or beta particle?

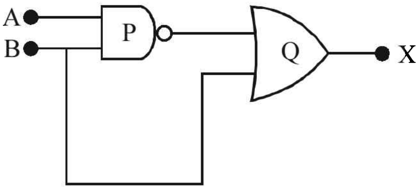
66. What is difference between e^- and β– particle?

67. Distinguish between nuclear fission and fusion. **[Delhi 2015]**

(G) Electronics and Communication Systems

68. Distinguish between an intrinsic semiconductor and P-type semiconductor. **[Delhi 2008]**

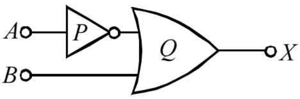
69. Identify the logic gates marked 'P' and 'Q' in the given logic circuit. **[All India 2010, Delhi 2014]**



70. The truth table of a logic gate has the form given here. Name this gate and draw its logic symbol. **[All India 2010C]**

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

71. Identify the logic gates marked *P* and *Q* in the given logic circuit.

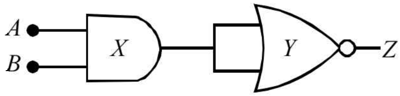


[All India 2010]

72. Name any semiconductor device which operates under the reverse bias in the breakdown region. **[All India 2011]**

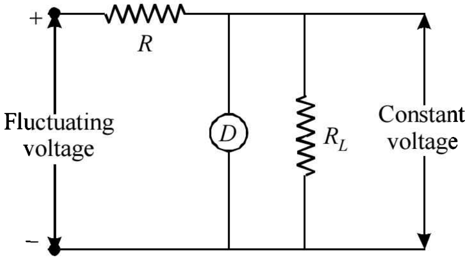
73. How is forward biasing different from reverse biasing in a *p-n* junction diode? **[Delhi 2011]**

74. Identify the logic gates X and Y in the figure. **[All India 2011C]**



75. Carbon and silicon both have four valence electrons each then, how are they distinguished? **[Delhi 2011C]**

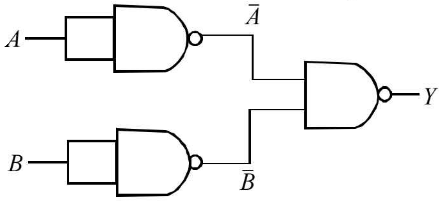
76. Name the device, D which is used as a voltage regulator in the given circuit.



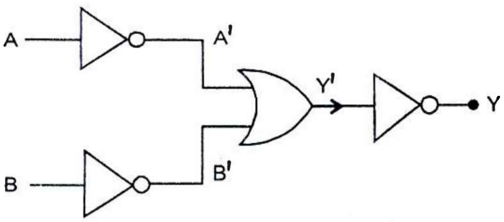
[Delhi 2011C]

77. Write two characteristic feature to distinguish *n*-type and *p*-type semiconductor. **[All India 2012]**

78. In the circuit shown in the figure, identify the equivalent gate of the circuit and make its truth table. **[Delhi 2011, All India 2013]**



79. In the circuit shown in the figure, identify the equivalent gate of the circuit. **[All India 2013]**



80. Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams. **[All India 2014]**

81. Differentiate between three segments of a transistor on the basis of their size and level of doping. **[Delhi 2014]**

82. Which property of a p–n junction is used in rectification of a.c. voltages?

83. What is the difference between half wave rectifier and full wave rectifier?

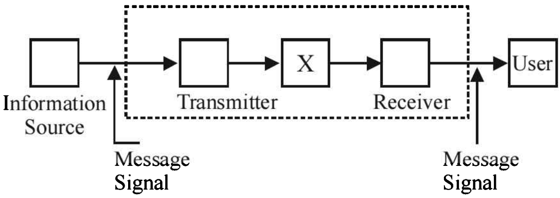
84. Distinguish between 'sky waves' and 'space waves' modes of propagation in communication system.
[All India 2009, Delhi 2009C, 2013]

85. Which mode of propagation is used by short wave broadcast services having frequency range from a few MHz upto 30 MHz?
[All India 2010]

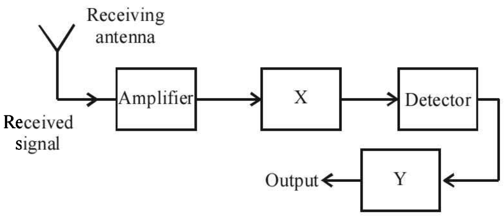
86. Differentiate between an analog and digital signal.

87. What is the difference among amplitude, frequency and phase modulation.

88. The figure given below shows the block diagram of a generalized communication system. Identify the element labelled 'X'.
[Foreign 2011, Delhi 2014]

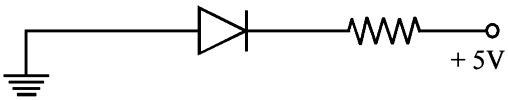


89. Block diagram of a receiver is shown in the figure. Identify 'X' and 'Y'
[All India 2012, Delhi 2013]



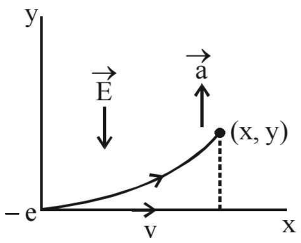
90. Distinguish between 'intrinsic' and 'extrinsic' semiconductors.
[Delhi 2015]

91. In the following diagram, is the junction diode forward biased or reverse biased? **[All India 2017]**



SOLUTIONS

1. Dielectrics are non-conductor and does not have free electrons at all. While conductor has free electrons in its any volume which makes it able to pass the electricity through it.
2. When a solid conducting sphere is placed in a uniform electric field $\vec{E}$, free electrons move in a direction opposite to $\vec{E}$. Electric lines of force starts from right part (i.e., negative region) and ends on left part (i.e., positive region). So path 4 is correct.
3. If an electron, moving with a finite velocity v in the +x direction, enters a transverse electric field $\vec{E}$ in the – y direction, as shown, it has no acceleration in the x direction but an acceleration $\vec{a}$ in the + y direction.



The displacements in the time t in the x and y directions are

$$x = vt$$

$$y = \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{eE}{m}\right)t^2 = \left(\frac{eE}{2mv^2}\right)x^2$$

which means that the path of electron is parabolic.

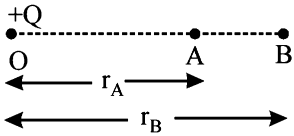
4. Spherical.
5. Electric potential at a point is the amount of workdone in moving a unit positive charge from infinity to that point.
   Potential energy is the amount of workdone in carrying the total charge from infinity to that point against the electrostatic forces.
6. Since we know that a negative charge always experiences a force in the direction opposite to that of the electric field present i.e., the negative charge will experience the force away from the centre. This will cause its motion to retard while moving from B to A. Hence, its kinetic energy will decrease in going from B to A.

7. When a conductor is placed in an external electric field, the free charges present inside the conductor redistribute themselves in such a manner that the electric field due to induced charges opposes the external field within the conductor. This happens until a static situation is achieved i.e. when the two field cancel with each other and net electrostatic field in the conductor becomes zero.

8. The direction of an electric field for positive charge density is in outward direction and perpendicular to the plane infinite sheet. And for the negative charge density the direction of the field is in inward direction and perpendicular to the sheet.

9. Electric potential at a distance r from the point charge

$$V(r) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$



Potential at point A, $V(r_A) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r_A}$

Similarly, potential at point B, $V(r_B) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r_B}$

$\because \; r_A < r_B \Rightarrow V_A > V_B \qquad \therefore \; V_A - V_B > 0$

10. As we know, $R = \rho\frac{l}{A}$ or, $\rho \propto A$

Also we know that copper is better conductor than manganin therefore copper will have less resistivity.

That means manganin wire will be thicker than that of copper.

11. $\because$ R series > R parallel and slope of V-I graph gives R.

Here $(\text{slope})_B > (\text{slope})_A$

$\therefore$ B denotes series combination and A denotes parallel combination.

12. Slope of I–V graph $= \frac{1}{R}$ and $R \propto T$

Here, slope of T_2 < slope of T_1

$$\frac{1}{R_2} < \frac{1}{R_1} \Rightarrow R_2 > R_1$$

The temperature of T_2 is higher.

13.

Emf	Terminal voltage
It is the maximum potential difference that can be delivered by a cell when no current flows through the circuit.	It is the potential difference across the terminals of the load when current flows through the circuit.
It is represented by E and remains constant for a cell.	It is represented by V and depends on the internal resistance of the cell.

14. (i) In region DE of the graph semiconductor has a negative resistance.

(ii) Ohm's law is obeyed when $V \propto I$

15. Nichrome wire is heated more.

Heat dissipated in a wire is given by Joule's heating law

$$H = I^2Rt = I^2 \frac{\rho \ell}{A} t$$

$H \propto \rho$ ($\because$ I, ℓ and A remains same)

As $\rho_{nichrome} > \rho_{copper} \therefore H_{nichrome} > H_{copper}$

16. Solenoid is a hollow circular ring having large number of turns of insulated copper wire on it.

There we can assume that toroid is a bent solenoid to close on itself.

17. As we know, $v = \dfrac{Bq}{2\pi m}$

$q_\alpha = 2\,q_\beta$ and $m_\alpha = 4m_\beta$

$$\frac{v_\alpha}{v_\beta} = \frac{2}{4} = \frac{1}{2}$$

$$\therefore \quad v_\alpha = \frac{v_\beta}{2}$$

$\therefore$ α-particle will have minimum frequency of revolution.

18. Difference between voltmeter and ammeter :

(i) Voltmeter has high resistance whereas ammeter has low resistance.

(ii) Voltmeter is connected in parallel, ammeter is connected in series in a circuit.

19. The magnetic material is a diamagnetic substance because for diamagnetic $\mu_r < 1$.

20. Negative susceptibility represents diamagnetic substance.
21. Ferromagnetic substances have very high magnetic permeability.
22. Diamagnetic materials have negative susceptibility.
23. Bi and Cu
24. At magnetic poles.
25. Al and Ca
26.

Diamagnetic	Paramagnetic	Ferromagnetic
$-1 \leq \chi < 0$ $0 \leq \mu_r < 1$ $\mu < \mu_0$	$0 < \chi < \varepsilon$ $\mu_r < 1+\varepsilon$ $\mu > \mu_c$	$\chi >> 1$ $\mu_r >> 1$ $\mu >> \mu_0$

27. Ferromagnetic materials e.g., steel is used to make permanent magnets.

28. Gauss's law for magnetism states that net magnetic flux ϕ_B through any closed surface is zero.

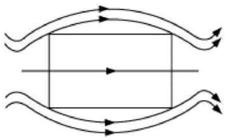
$$\phi_B = \oint \vec{B}.\vec{ds} = 0$$

On the other hand, Gauss's law for electrostatics states that electric flux through a closed surface S is given by

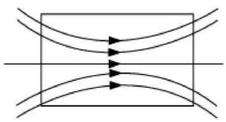
$$\phi_E = \oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$$

So, if an electric dipole is enclosed by surface, electric flux will be zero. But in magnetism there is no counterpart of isolated charge as in electricity. So, we can say that isolated magnetic poles or monopoles do not exist.

29. When a diamagnetic material is placed in an external magnetic field, the field lines are repelled or expelled and the field inside the material is reduced.



Diamagnetic material in external magnetic field.



Paramagnetic material in external magneitc field

Whereas when a paramagnetic material is placed in an external magnetic field, the field lines are attracted towards it. Thus the field lines get concentrated inside the material and the field inside is enhanced.

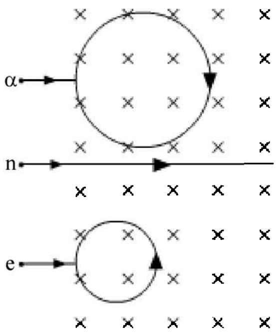
30. We know that a charged particle will experience a force when it enters a magnetic field. This force is balanced by centripetel force. The magnetic field will move the charged particle in a circular path, as the force is perpendicular to the velocity of particle. The radius of the circular path will be given by

$$\frac{mv^2}{r} = Bqv$$

As B and v are constant, we can write

$$r \propto \frac{m}{q}$$

The neutron will move along the straight line since neutron has no charge.



The electron will inscribe a circle of radius smaller than that of the α particle becayse the mass to charge ratio of the α particle is more than that of the electron.

So, the α particle will move in the clockwise direction and the electron will move in anticlockwise direction according to the right-hand rule.

31. **Self induction:** It is the property of a coil due to which the coil opposes any change in the strength of current flowing through it by inducing an e.m.f. in itself.

Mutual induction: It is the property of two coils due to which each opposes any change in the strength of current flowing through the other by developing an induced e.m.f.

32. Slip ring arrangement in an a.c generator is replaced by split ring arrangement in the d.c generator.

33. The phase difference is 180°.

34. X-ray has shortest wavelength.

35. γ-rays have highest penetrating power.

36. Ultraviolet rays.

37. Microwaves

38. γ-ray. Frequency range = 10^{18} to 10^{20} Hz.

39. X-rays

40. Infrared rays.

41. (a) Microwaves are used in RADAR system for aircraft navigation. These are Produced by special vacuum tubes, namely Klystrons, magnetrons.

(b) Infrared waves are used to treat muscular strain. These are produced by hot bodies and molecules.

(c) X rays are used as a diagnostic tool in medicine. These rays are produced when high energy electrons are stopped suddenly on a metal of high atomic mass.

42. (a) Microwaves (b) X-rays

43. If an iron rod is inserted in the inductor, then the value of inductance L increases. As such, the current through the bulb will decrease, thus, decreasing the brightness of the bulb.

44. Polarity of capacitor Plate A will be positive with respect to Plate B. According to Lenz law, Plate A of the capacitor is at a higher potential than Plate B.

45. (a) **X-rays:** Use-In medical diagnosis to detect fracture in bones, stones in kidney etc.
    (b) **Microwaves:** Use-In microwave oven.

46. (a) The device 'X' is a capacitor.
    (b) **Curve A:** Power consumed in the circuit
    Curve B : Voltage
    Curve C: Current
    This is because current leads voltage in a capacitive circuit.

47.

Characteristics		Telescope	Microscope
1.	Position of object	At infinity	Near objective at a distance lying between f_o and $2f_o$
2.	Position of image	Focal plane of objective	Beyond $2f_o$ where f_o is the focal length of objective.

48. **Primary rainbow:-** It is formed due to two refractions and one total internal reflection of the light incident on the droplet. Sunlight is first refracted as it enters a raindrop which cause different colours of light to separate. Different colours of light are bent through different angles. These components of light strike the inner surface of the water drop and get internally reflected.
The reflected light is refracted again as it comes out of the drop. Thus the observer sees a rainbow with red colour on the top and violet on the bottom.
Secondary rainbow:- It is formed due to two refractions and two total internal reflection of light incident on the water droplet. It is four - step process. The intensity of light is reduced at the second reflection and hence the secondary rainbow is fainter than the primary rainbow.

49. The virtual image formed by a concave mirror is magnified while that formed by a convex mirror is diminished.

50. A wavefront is defined as a surface of constant phase.
A ray is perpendicular to the wavefront. The energy of the wave travels in a direction perpendicular to the wavefront i.e. along rays of light.

51.

Characteristics	Interference	Diffraction
Fringe width	All bright and dark fringes are of equal width	The central bright fringe have got double width to that of width of secondary maxima or minima.
Intensity of bright fringes	All bright fringes are of same intensity	Central fringe is the brightest and intensity of secondary maxima, decreases with the increase of order of secondary maxima on either side of control maxima.

52. When two narrow slits are illuminated by a single monochromatic source, the pattern obtained on the screen is interference pattern which consists of alternate bright and dark fringes.
When one of the slits is covered, there is a diffraction pattern on the screen.

53. The pairs of curves (1 and 3) and (2 and 4) represent different materials because stopping potential is different for different materials.

54. Platinum has highest work function = 5.65 eV

55. Yes, velocity of light waves in vacuum is constant but velocity of matter waves depends on its wavelength.

56. As the rays converging towards a point P so, the lens is convex in nature.

57. (i) Number of photons per unit per second in both the beams is same as they have the same intensity.

(ii) The maximum kinetic energy of photoelectrons is given by $E = hc/\lambda - \phi$

We know that the wavelength of blue beam is less than that of red beam. So, we can say that the maximum kinetic energy of the photoelectrons of the blue beam will be more.

58. In photon picture of light, the intensity of light is determined by the number of photons.

59. On comparing the interference pattern observed in Young's double slit experiment (interference) with single-slit diffraction pattern (diffraction), we can have three distinguishing features:

1. In the interference pattern, all the bright fringes have the same intensity. In a diffraction pattern, all the bright fringes are not of the same intensity.
2. In the interference pattern, the dark fringe has zero or very small intensity so that the bright and dark fringes can easily be

distinguished. In diffraction pattern, all the dark fringes are not of zero intensity.

3. In the interference pattern, the widths of all the fringes are almost the same, whereas in diffraction pattern, the fringes are of different widths.

60. Difference between interference pattern and diffraction pattern.

Interference	**Diffraction**
It is due to the superposition of two waves coming from two coherent sources.	It is due to the superposition of secondary wavelets originating from different parts of the same wavefront.
Width of the interference bands is equal.	Width of diffraction bands is not the same.

61. (b) Lens L_1 – Objective; Lens L_2 – Eye-piece
Lens L_1 has higher aperture of 8 cm. So, it can gather more light and will have high resolving power. Hence, L_1 should be used as the objective lens. Lens L_3 has high power of 10 D. So, it will give higher magnification. Hence, lens L_3 should be used as an eye-piece.

62. Photoelectric effect shows the quantum nature of electromagnetic radiation.

63. **Spectral series** when the transition of the electron takes place from
$n_i = 4$ to $n_f = 3 \rightarrow$ Paschen series
$n_i = 4$ to $n_f = 2 \rightarrow$ Balmer series
$n_i = 4$ to $n_f = 1 \rightarrow$ Lyman series

64. According to Rutherford's model, the electrons revolve around the nucleus in any orbit and radiate waves of all frequencies, so the spectrum is continuous.
On the other hand in Bohr's model, the electrons revolve around the nucleus in some definite orbits and emit only waves of some definite frequencies and so they give line spectrum.

65. Alpha particle

66. They are same. An electron of nuclear orgin is called β –particle.

67.

Nuclear Fission	**Nuclear Fusion**
1. Heavy nucleus get split up into two smaller nucleus of comparable mass.	1. Two lighter nuclei fuse together to form a heavier nucleus.
2. The physical conditions viz. high temperature and pressure are not essential for fission.	2. The conditions of high pressure and temperature are essential for nuclear fusion.

68. An intrinsic semiconductor is a pure semiconductor in which the number of free electrons is equal to the number of holes.

i.e., $n_e = n_h = n_i$

P-type semiconductor is an extrinsic semiconductor doped with trivalent impurity like Indium. The number of holes is greater than the number of electrons, i.e. $n_h >> n_e$.

A pure Si or Ge crystal is electrically neutral.

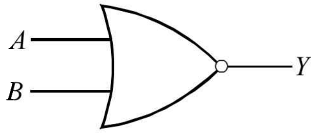
69. In the given combination of gates,

P – NAND gate.

Q – OR gate.

70. Logic gate is NOR gate.

Logic Symbol



71. P : NOT gate and Q : OR gate.

72. Zener diode is a semiconductor divice which operates under the reverse bias in the breakdown region.

73.

S. N.	Forward bias	Reverse bias
1.	Positive terminal of battery is connected to p-type and negative terminal to n-type semiconductor.	Positive terminal of battery is connected to n-type and negative terminal to p-type semiconductor.
2.	Depletion layer is very thin.	Depletion layer is thick.
3.	p-n junction offers very low resistance.	p-n junction offers very high resistance.
4.	An ideal diode have zero resistance.	An ideal diode have infinite resistance.

74. X : AND gate

Y : NOR gate i.e. A combination of OR and NOT gate.

75. The four valence electrons of carbon are present in second orbit while that of silicon in third orbit. So, energy required to extricate an electron from silicon is much smaller than carbon. Therefore, the number of free electrons for conduction in silicon is significant on contrary of carbon. This makes silicon conductivity much higher than carbon. This is the main distinguishable property.

76. Device, *D* is a Zener diode.

77. (i) In *n*-type semiconductor, the semiconductor is doped with pentavalent impurity. In it, the electrons are majority carriers and holes are minority carriers or $n_e >> n_h$ (n_e = number density of electrons, n_h = number density of holes)

(ii) In *p*-type semiconductor, the semiconductor is doped with trivalent impurity. In this semiconductor, the holes are the majority carriers and electrons are the minority carriers, i.e., $n_h >> n_e$.

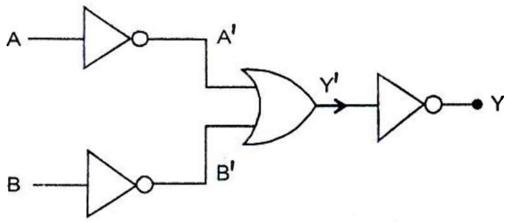
78. The given circuit is a combination of three NAND gates. The first two gates for the inputs A and B are NOT gates and third gates serves as a NAND gate for the inputes $\overline{A}$ and $\overline{B}$.

$\therefore \quad Y = \overline{\overline{A}.\overline{B}} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$

Hence, the three gates together form 'OR' gate.
The **truth table** of the 'OR' gate is :

A	B	$Y = A + B$
0	0	0
0	1	1
1	0	1
1	1	1

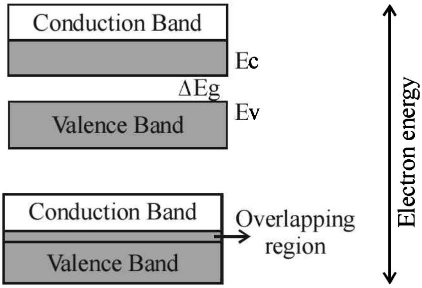
79. The inputs A and B are negated by the NOT gates. The outputs A' and B' are the inputs for the OR gate whose output has been negated to give Y.



i.e., the equivalent gate of the circuit is an AND gate. Its truth table is as follows :

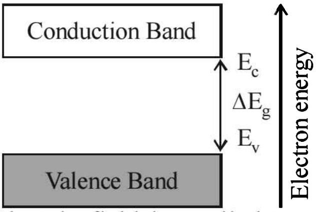
A	B	A'	B'	Y' = A'+B'	$Y = \overline{Y'}$
0	0	1	1	1	0
0	1	1	0	1	0
1	0	0	1	1	0
1	1	0	0	0	1

80. **Conductors:** (i) In conductors, the valence band is completely filled and the conduction band is either partially filled with an extremely small energy gap between the valence and conduction bands or empty, with the two bands overlapping each other.



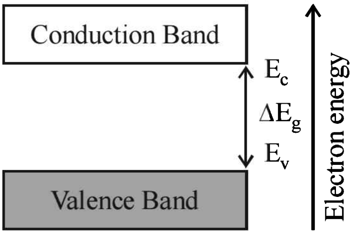
(ii) On applying an even small electric field, conductors can conduct electricity.

Semiconductors: (i) In semiconductors the energy band structure is similar to that of insulators, but in this case, the size of forbidden energy gap is much smaller than that of the insulators, as shown.



(ii) When an electric field is applied to a semiconductor, the electrons in the valence band find it comparatively easier to shift to the conduction band. So, the conductivity of semiconductors lies between the conductivity of conductors and insulators.

Insulators: (i) In insulators, the energy gap between the conduction and valence band is very large. Also, the conduction band is practically empty.



(ii) When an electric field is applied across such a solid, the electrons find it difficult to acquire such a large amount of energy to reach the conduction band. Thus, the conduction band continues to be empty. That is why no current flows through insulators.

81. Emitter (E) - It is the left hand side thick layer of the transistor, which is heavily doped.

Base (B) - It is the central thin layer of the transistor, which is lightly doped.

Collector (C) - It is the right hand side thick layer of the transistor, which is moderately doped.

Structure: (i) Emitter (E), (ii) Base (B), (iii) Collector (C)

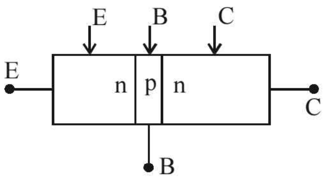
Emitter size > base

Collector size > emitter

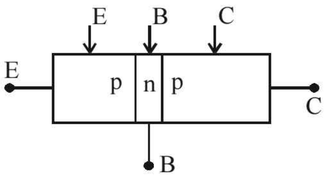
$\therefore$ C > E > B (size wise)

Doping wise E > C > B.

Representation:



n-p-n type



p-n-p type

82. The forward bias resistance is low as compared to reverse bias resistance. This property is used in rectification.

83. **Half wave rectifier:** Junction diode allows current to pass through only if it is forward biased, hence a pulsating voltage will appear across the load only during positive half cycles when diode is forward bias.

Full wave rectifier: The circuit uses two diodes connected to the ends of a centre tapped transformer. The voltage rectified by the two diodes is half of the secondary voltage i.e., each diode conducts for half cycle of input but alternately so that net output across load comes as half sinusoids with positive values only.

84. (i) In the **sky wave propagation**, the waves transmitted from the transmiting antenna are received by the receiving antenna after reflection from the ionosphere of the atmosphere.

In the **space wave propagation** mode, the electromagnetic waves are directly intercepted by the receiving antenna.

(ii) The sky wave mode of propagation is limited to 40 MHz. This is because the waves of this and higher frequencies are not reflected by the atmosphere but are transmitted. The critical frequency for sky wave mode of propagation is 40 MHz.

85. Sky wave propagation is used to short wave broadcast services having frequency range from a few MHz upto 30 MHz.

86. **Analog signals** are continuous variations of voltage or current. They are essentially single valued functions of time e.g., *sine* wave, sound and picture signals.

Digital signals are those which can take only discrete stepwise values. They follow binary system of coding (0 → low voltage 1 → high voltage) e.g., Computer signals.

87. **Amplitude modulation :** In this mode of modulation, the amptitude of the carrier wave signal varies in according with the modulating signal (message or indormation signal).

Frequency modulation : In this mode of modulation, frequency of the carrier signal varies in accordance with the modulating signal.

Phase modulation : Here the phase angle ϕ of the carrier signal varies in accordance with the modulating voltage.

88. The element labelled 'X' is called 'channel'.

89. **(a)** X is an I.F. stage and Y is an amplifier.

90.

S.no	Intrinsic Semiconductor	Extrinsic Semiconductor
1	It is pure semiconducting material and no impurity atoms are added to it.	It is prepared by doping a small quantity of impurity atoms to the pure semiconducting material.
2	Examples are crystalline forms of pure silicon and germanium.	Examples are silicon and germanium crystals with impurity atoms of arsenic, antimony, phosphorous etc. or indium, boron, aluminium etc.
3	The number of free electrons in conduction band and the number of holes in valence band is exactly equal and very small indeed.	The number of free electrons and holes is never equal. There is excess of electrons in n-type semiconductors and excess of holes in p-type semiconductors.
4	Its electrical conductivity is low.	Its electrical conductivity is high.
5	Its electrical conductivity is a function of temperature alone.	Its electrical conductivity depends upon the temperature as well as on the quantity of impurity atoms doped in the structure.

91. Reverse biased as P-crystal of the diode is earthed i.e., at lower potential and N-crystal is at higher potential (5V)

□□□

CHAPTER 3

Why does the following phenomenon happen (reason).....?

(A) Electrostatics

1. Can two equipotential surfaces intersect each other ? Give reason. **[Delhi 2009]**

2. A parallel plate capacitor is charged to a potential difference, V by a DC source. The capacitor is then disconnected from the source. If the distance between the plates is doubled, state with reason how the following will change?

(i) Electric field between the plates.

(ii) Capacitance.

(iii) Energy stored in the capacitor. **[Delhi 2010]**

3. The electric field due to a charged parallel plate capacitor affected when a dielectric slab is inserted between the plates fully occupying the intervening region. Why? **[Foreign 2010]**

4. Why most electrostatic field be normal to the surface at every point of a charged conductor? **[Delhi 2012]**

5. Why there is no work done in moving a charge from one point to another on an equipotential surface? **[Foreign 2012]**

6. Equipotential surfaces are perpendicular to field lines. Why?

7. Why is the potential inside a hollow spherical charged conductor is constant and has the same value as on its surface? **[Foreign 2012]**

8. Why do the electrostatic field lines not form closed loops? **[Delhi 2012, All India 2014]**

9. An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why ?

10. Why do the electric field lines never cross each other? **[All India 2014]**

11. When a glass rod is rubbed with a silk cloth, charges appear on both. A similar phenomenon is observed with many other pairs of bodies. Explain how this observation is consistent with the law of conservation of charge.

12. Two spherical conductors A and B of radii r_A and r_B ($r_A > r_B$) are given equal amounts of charge. In which direction will the charge flow when these spheres are brought in contact?

Give reason for your answer.

13. "The outward electric flux due to charge + Q is independent of the shape and size of the surface which encloses it." Give two reasons to justify this statement. **[All India 2015]**

14. Why the equipotential surfaces about a single charge are not equidistant ?

15. Can electric field exist tangential to an equipotential surface ? Give reason. **[All India 2016]**

(B) Current Electricity

16. The emf of a cell is always greater than its terminal voltage. Why? **[All India 2013C, Delhi 2013]**

17. Why are the connections between the resistors in a meter bridge made of thick copper strips? **[All India 2014]**

18. Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire? **[All India 2014]**

19. Which material is used for the meter bridge wire and why? **[All India 2014]**.

20. Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why? **[Delhi 2014]**

21. Why is a potentiometer preferred over a voltmeter for measurirg the emf of a cell? **[All India 2015]**

22. Why alloys like constantan and manganin are used for making standard resistors? **[Delhi 2016]**

(C) Magnetism

23. Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity. Explain, giving reason. **[All India 2009, 2014]**

24. Magnetic field lines can be entirely confined within the core of a toroid, but not within a straight solenoid. Why ? **[Delhi 2009]**

25. Write two reasons why a galvanometer cannot be used as such to measure the current in a given circuit. **[Delhi 2010]**

26. An α-particle and a proton are released from the centre of the cyclotron and made to accelerate.

(i) Can both be accelerated at the same cyclotron frequency? Give reason to justify your answer.

(ii) When they are accelerated in turn, which of the two will have higher velocity at the exit slit of the dees?

[Delhi 2012, All India 2013]

27. Is the steady electric current the only source of magnetic field? Justify your answer. **[Delhi 2013C]**

28. No force is experienced by a stationary charge in a magnetic field. Why?

29. For converting a galvanometer into an ammeter, a shunt resistance of small value is used in parallel, whereas in the case of a voltmeter a resistance of large value is used in series. Explain why?

[Delhi 2013C]

30. Explain why two straight parallel current carrying conductors carrying current in same direction attract and carrying current in opposite direction repel each other.

31. A light metal disc on the top of an electromagnet is thrown up as the current is switched on. Why? Give reason. **[All India 2013]**

32. Why is core of an electromagnet made of ferromagnetic materials?

33. Whe do magnetic lines of force prefer to pass through ferromagnetic substances than through air?

34. A vertical metallic pole falls down through the plane of the magnetic meridian. Will any e.m.f. be produced between its ends? Give reason for your answer.

35. A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends? Justify your answer. **[Delhi 2013]**

36. No two magnetic lines of force intersect each other. Explain.

37. The motion of copper plate is damped when it is allowed to oscillate between the two poles of a magnet. What is the cause of this damping? **[All India 2013]**

38. A bar magnet falls from a height 'h' through a metal ring. Will its acceleration be equal to g? Give reason for your answer.

39. Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer? **[All India 2014]**

(D) EMI, Alternating Current and EM Waves

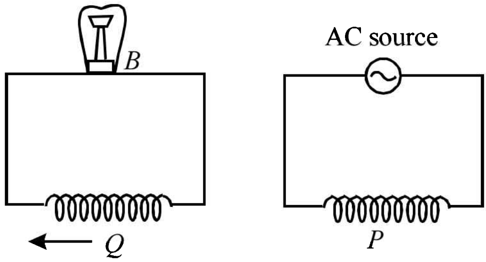
40. Why should the quality factor have high value receiving circuits ? **[Delhi 2009]**

41. A coil, Q is connected to low voltage bulb B and placed near another coil, P as shown in the figure. Give reasons to explain the following observations.

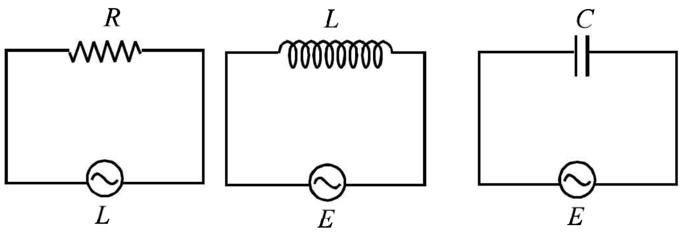
(i) The bulb, B lights.

(ii) Bulb gets dimmer if the coil, Q is moved towards left.

[Delhi 2010]



42. Three electrical circuits having AC sources of variable frequency are shown in the figures. Initially, the current flowing in each of these is same. If the frequency of the applied AC source is increased, how will the current flowing in these circuits be affected? Give the reason for your answer. **[Delhi 2011C]**



43. Why is the core of transformer laminated? **[Delhi 2013C]**

44. In electric power transmission circuit, a low power factor results in large power loss in transmission. Give the reason.

45. Why is the use of A.C. voltage preferred over D.C. voltage ? Give two reasons. **[All India 2014]**

46. Why cannot we have resonance in a RL or RC circuit?

47. Why is choke coil needed in the use of fluorescent tubes with ac mains? **[Delhi 2014]**

48. Why are infrared waves often called as heat waves? **[Delhi 2014]**

49. Why is the amount of the momentum transferred by the em waves incident on the surface so small ? **[Delhi 2014]**

50. An em wave exerts pressure on the surface on which it is incident. Justify. **[Delhi 2014]**

51. An inductor L of inductance X_L is connected in series with a bulb B and an ac source. How would brightness of the bulb change when (i) number of turn in the inductor is reduced, (ii) an iron rod is inserted in the inductor and (iii) a capacitor of reactance $X_C = X_L$ is inserted in series in the circuit. Justify your answer in each case. **[Delhi 2015]**

52. Why are microwaves considered suitable for radar systems used in aircraft navigation? **[Delhi 2016]**

(E) Optics

53. Why must both the objective and the eyepiece of a compound microscope have short focal lengths? **[Delhi 2009, All India 2010]**

54. Why does the sky appear blue? **[Foreign 2010]**

55. Out of blue and red light which is deviated more by a prism? Give reason. **[Delhi 2010]**

56. When monochromatic light travels form a rarer to a denser medium, explain the following, giving reasons : **[Delhi 2013]**

(i) Is the frequency of reflected and refracted light same as the frequency of incident light?

(ii) Does the decrease in speed imply a reduction in the energy carried by light wave?

57. Vehicles moving in foggy weather use yellow - colour head light. Why?

58. When a monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency. Explain why? **[Delhi 2013C]**

59. Why does light usually appear to travel in a straight line inspite of its wave nature?

60. A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason. **[All India 2014]**

61. Welders wear special glass goggles while working. Why? Explain. **[Delhi 2014]**

62. State the reasons, why two independent sources of light cannot be considered as coherent sources? **[Delhi 2008]**

63. In a single slit diffraction experiment, when a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. why ? **[Delhi 2009, All India 2010, 2013C]**

64. Explain the following giving reason for each.

(i) How does a polaroid work to produce a linearly polarized light from an unpolarized beam of light?

(ii) Why does the light waves can be polarized but sound wave cannot be?

(iii) Why are sun goggles made of polaroids preferred over those using coloured glasses? **[Delhi 2011C]**

65. In what way is diffraction from each slit related to the interference pattern in a double slit experiment? **[Delhi 2013, All India 2013C]**

66. Which of the following waves can be polarized (i) Heat waves; (ii) Sound waves? Give reason to support your answer. **[Delhi 2013]**

67. Why is the intensity maximum at the central maximum on the diffraction pattern?

68. 'Two independent monochromatic sources of light cannot produce a sustained interference pattern'. Give reason. **[Delhi 2014]**

69. An electron and a proton are accelerated through the same potential. Which one of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less momentum? Justify your answer.

70. Two monochromatic radiations, blue and violet, of the same intensity, are incident on a photosensitive surface and cause photoelectric emission. Would (i) the number of electrons emitted per second and (ii) the maximum kinetic energy of the electrons, be equal in the two cases? **[Delhi 2010]**

71. Explain briefly the reasons why wave theory of light is not able to explain the observed features in photoelectric effect? **[Foreign 2010]**

72. Why is minimum or threshold frequency different for different materials? **[Delhi 2011C]**

73. An electron and a proton have the same kinetic energy. Which of the two will have larger de-Broglie wavelength? Give reason. **[All India 2011C, 2012]**

74. Why photoelectric effect cannot be explain on the basis of wave nature of light? Give reasons. **[Delhi 2013]**

75. An increase in intensity of incident light doesn't change the maximum velocity of the emitted photo electron. Why?

76. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has **[Delhi 2014]**

(a) greater value of de-Broglie wavelength associated with it, and

(b) less momentum?

Give reasons to justify your answer.

77. Give two reasons to explain why reflecting telescopes are preferred over refracting type. **[All India 2015]**

78. Why does an unpolarised light incident on a polaroid get linearly polarised ? **[All India 2015]**

79. Explain why the maxima at $\theta = \left(n + \frac{1}{2}\right)\frac{\lambda}{a}$ become weaker and weaker with increasing n? **[Delhi 2015**

80. Why does sun appear red at sunrise and sunset ? **[All India 2016]**

81. When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency. Why? **[All India 2016]**

82. The value of Brewster angle for a transparent medium is different for light of different colours. Give reason. **[Delhi 2016]**

83. Using mirror formula, explain why does a convex mirror always produce a virtual image. **[Delhi 2016]**

84. How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced by red light? Give reason. **[All India 2017]**

(F) Atoms and Nuclei

85. Explain, in brief, why Rutherford's model cannot account for the stability of an atom? **[Delhi 2010C]**

86. Why does mass of nucleus does not enter the formula of impact parameter but charge does?

87. In heavy nuclei, number of neutrons is more than number of protons, why?

88. Answer the following, giving reasons

(i) Why is the binding energy per nucleon found to be constant for nuclei in the range of mass number (A) lying between 30 and 170?

(ii) In β-decay the experimental detection of neutrinos (or antineutrinos) is found to be exactly difficult. Why?

[Foreign 2012]

89. Why is energy variations of the electron emitted in β–decay continuous?

90. For scattering of α-particles we don't take into account electrons. Why?

91. Why is it found experimentally difficult to detect neutrinos in nuclear-decay? **[All India 2014]**

(G) Electronics and Communication Systems

92. Give reason, why, a P-type semiconductor crystal is electrically neutral, although $n_h >> n_e$? **[Delhi 2008]**

93. Why are Si and GaAs preferred materials for solar cells?

[All India 2011C]

94. Why is the current under reverse bias almost independent of the applied potential up to a critical voltage? **[All India 2012C]**

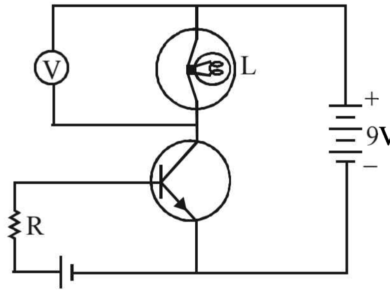
95. The current in the forward bias is known to be more $(\sim mA)$ than the current in the reverse bias $(\sim \mu A)$. What is the reason, to operate the photodiode in reverse bias? **[Delhi 2012]**

96. Why does the reverse current show a sudden increase at the critical voltage? **[Delhi 2012]**

97. Why is photodiode used in reverse biased? **[All India 2013C]**

98. Why current is high in forward bias of p–n junction?

99. In the given circuit diagram, a voltmeter 'V' is connected across a lamp 'L'. How would (i) the brightness of the lamp and (ii) voltmeter reading 'V' be affected, if the value of resistance 'R' is decreased? Justify your answer. **[Delhi 2013]**



100. Why do we say that an intrinsic semiconductor is like an insulator at 0 K?

101. Why is the base region of a transistor thin and lightly doped? **[Delhi 2013C]**

102. Why are high frequency carrier waves used for transmission? **[Delhi 2009]**

103. Why is transmission of signals using ground waves restricted to frequencies less than 1500 kHz.?

104. State the main reasons explaining the need of modulation for transmission of audio signals. **[All India 2010]**

105. Why is there an upper limit to frequency of waves used in sky wave mode? **[All India 2010]**

106. Why is sky wave mode of propagation restricted to the frequencies only upto few MHz? **[All India 2011, Delhi 2013]**

107. Give reasons for the following.

(i) For ground wave transmission, size of antenna (l) should be comparable to wavelength (λ) of signal, i.e., $l = \lambda / 4$.

(ii) Audio signals, converted into an electromagnetic wave, are not directly transmitted.

(iii) The amplitude of a modulating signal is kept less than the amplitude of carrier wave. **[Delhi 2011C]**

108. Why is slight shaking of a picture of a T.V. screen noticed when a low flying aircraft passes overhead?

109. Thin ozone layer on top of stratosphere is crucial for human survival. Why ? **[Delhi 2014]**

110. With what considerations in view, a photodiode is fabricated? Eventhough the current in the forward bias is known to be more than in the reverse bias, yet the photodiode works in reverse bias. What is the reason? **[Delhi 2015]**

SOLUTIONS

1. No, two equipotential surfaces cannot intersect each other because at the point of intersection there would be two directions of electric field, which is not possible.
2. After disconnection from battery and doubling the separation between two plates.

   (i) Charge on capacitor remains same.

   $Q = Q'$

   i.e., $CV = C'V' \Rightarrow CV = \left(\frac{C}{2}\right)V' \Rightarrow V' = 2V$

   ∴ Electric field between the plates

   $$E' = \frac{V'}{d'} = \frac{2V}{2d} \; ; \; E' = \frac{V}{d} = E$$

   Therefore, Electric field between the two plates remains same.

   (ii) Capacitance reduces to half of original value as

   $$C \propto \frac{1}{d} \quad \Rightarrow \quad C' = \frac{\varepsilon_0 A}{2d} = \frac{C}{2}$$

   (iii) Now, energy stored in capacitor after disconnection from battery

   $$U_2 = \frac{q^2}{2(C')} = \frac{q^2}{2 \times \left(\frac{C}{2}\right)} = \frac{q^2}{C}$$

   $$\Rightarrow \quad U_2 = 2\left(\frac{q^2}{2C}\right) = 2U_1 \qquad \left[\because U = \frac{q^2}{2C}\right]$$

   Energy stored in capacitor gets doubled to its initial value.
3. The total charge of the capacitor remain conserved and the capacitance of capacitor increases to K times of original values on introduction of dielectric slab.

   ∴ $CV = C'V'$

   $$CV = (KC)V', \; V' = \frac{V}{K}$$

   ∴ New electric field

$$E' = \frac{V'}{d} = \left(\frac{V/K}{d}\right) = \left(\frac{V}{d}\right)\frac{1}{K}$$

$$E' = \frac{E}{K}$$

4. The electric lines of force exert lateral pressure on each other, leads to repulsion between like charges. Thus in order to stable spacing, the lines are normal to the surface.

5. On an equipotential surface, the potential remains constant and thus potential difference (ΔV) is zero. The work done on a charge q is given as, $W = q\Delta V$

Now, $W = 0 \quad [\because \Delta V = 0]$

6. On an equipotential surface, no work is done in moving a charge from one point to another. Therefore, the component of electric field intensity along the equipotential surface is zero. So equipotential surfaces are perpendicular to field lines.

7. Electric field inside the shell is zero. So, no work is done in moving a charge inside the shell. This implies that potential is constant and therefore equal to its value at the surface i.e.,

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

8. It electrostatic field lines form a closed loop, then work done by electric force should be zero in closed loop but we do not find any zero value. Hence, electric field lines do not form any closed loop.

9. They start from a positive charge and end at a negative charge. They are continuous, because force is continuous. They do not have sudden breaks, otherwise a moving test charge will have to take jumps.

10. If the electric field lines do not cross each other, the tangent to a line of electric field at any point gives the direction of the electric field at that point. If any two lines of electric field cross each other, then at the intersection point, there would be two tangents and hence two directions for electric field, which is not possible.

11. Charge is neither created nor destroyed. It is merely transferred from one body to another. Electrons are transferred from glass to silk, so glass has positive charge and silk has negative charge.

12. As $r_A > r_B \Rightarrow V_A < V_B$ $\left[\because \quad V = \frac{kq}{r}\right]$

$\therefore$ Charge will flow from B to A. Charges flow from higher potential to lower potential.

13. The outward electric flux due to charge +Q is independent of the shape and size of the surface, which encloses it because :

(i) Number of electric field lines coming out from a closed surface enclosing the charge depends on the charge enclosed by the surface,

(ii) Number of electric field lines coming out from a closed surface enclosing the charge is independent of the position of the charge inside the closed surface.

14. As electric field due to a single change is not constant so equipotential surfaces about a single charge are not equidistant

15. No, if the electric field exists along tangential to an equipotential surface, a charged particle will experience a force along the tangential line and can move along it. As a charged particle can move only due to the potential difference (along the direction of change of potential), this contradicts the concept of an equipotential surface.

16. Every cell has a characteristic emf E and some internal resistance. When the cell is in a closed circuit, a current flows through the cell. As a result some potential drop takes place inside the cell. The terminal voltage $V = E - ir$, clearly, $V < E$.

17. The resistivity of a copper wire is very low, and when the connections are thick, so that the area is quite large and hence the resistance of the wires is almost negligible.

18. To improve the sensitivity of the meter bridge, the balance point is obtain in the middle of the meter bridge.

19. Constantan is used for meter bridge wire because the temperature coefficient of constantan is almost negligible due to which the resistance of the wire does not change with increase in temperature of the wire due to flow of current.

20. Glass bob is non-conducting in nature. Due to the non-conducting nature of the glass bob, it will only experience the Earth's gravitational pull. So, the glass bob will reach the ground earlier.

While a metallic bob is conducting in nature. So, eddy current is induced in the metallic bob as it falls through the magnetic field of the Earth. By Lenz's law, the current induced is such that it opposes the motion of the metallic bob. So, the metallic bob will experience a force in the upward direction. This will slow down the metallic bob by some extent. Hence, it will reach the Earth after the glass bob.

21. Potentiometer is preferred over voltmeter because it measures accurate emf of the cell. It uses null method, so no current is drawn by the galvanometer from the cell in balanced condition of potentiometer and a voltmeter measures the voltage across the terminals of a cell when the cell is in closed circuit. This voltage is called terminal voltage of a cell not emf.

22. Alloys like constantan and manganin are used for making standard resistors because

(a) they have high value of resistivity and low value of conductivity

(b) temperature coefficient of resistance is less.

23. On increasing the current sensitivity, voltage sensitivity may or may not increase because of similar changes in the resistance of the coil, which may also increase due to increase in temperature.

The current sensitivity of a moving coil galvanometer is given by $nBAk$,

where n is the number of turns , A is the area of the coil , B is the magnetic field strength of the poles and k is the spring's constant of the suspension wire.

Similarly, voltage sensitivity is given by $\frac{nBAk}{R}$,

where R is the resistance of the wire.

From the above two expressions, we get:

Voltage sensitivity = Current sensitivity/R

24. There exists a weak magnetic fields outside a straight solenoid. A toroid is in the form of a circular ring and magnetic fields induction outside the toroid is zero.

25. The galvanometer cannot be used to measure the current because,

(i) all the currents to be measured passes through coil and it gets damaged easily as hair line spring.

(ii) its coil has considerable resistance because of length and it may affect original current.

26. (i) No, the time for which a charged particle remains inside a 'dee' for continuous acceleration is given by

$$t = \frac{m\pi}{BQ},$$

For t be the same, the ratio of $\frac{m}{Q}$ must be the same.

For proton, $\frac{m}{Q} = \frac{m_p}{e}$

For α particle, $\frac{m}{Q} = \frac{4m_p}{2e} = \frac{2m_p}{e}$

i.e., $\frac{m}{Q}$ is not same for both α-particle and proton, hence they cannot be accelerated by the same cyclotron frequency.

(ii) As, $v = \frac{BQ}{m}r$ $\quad \therefore \quad v \propto \frac{Q}{m}$

and $\frac{Q}{m}$ is more for the proton, therefore, proton will have higher velocity at the exit slit of the dees.

27. No, it is also produced by alternating current.

28. We have force $F = q\,(v \times B) = qvB \sin\theta$.

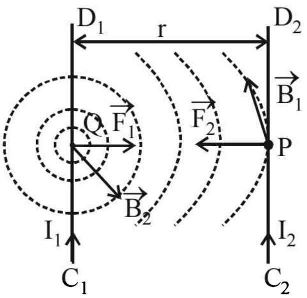
Since the charge is stationary, $v = 0$

$\therefore \quad F = 0.$

29. An ammeter is an instrument for measuring current therefore, its resistance has to be kept low as it is connected in series. Hence shunt of low resistance is joined in parallel to convert a galvanometer into an ammeter.

A voltmeter is a high resistance device. It is connected in parallel. Therefore its resistance is kept high such that the current in the main circuit is not affected. Hence a high resistance is joined in parallel to convert a galvanometer into a voltmeter.

30.



Magnetic field at P in C_2D_2 due to current I_1 through conductor

$C_1D_1 = B_1 = \frac{\mu_0}{4\pi}.\frac{2I_1}{r}$

∴ Force experienced by unit length of C_2D_2 due to magnetic field

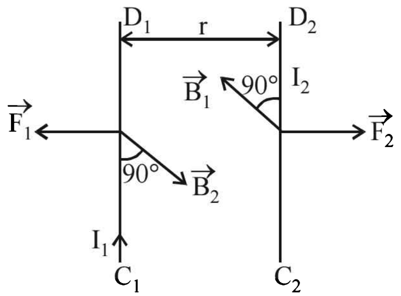
$$\vec{B_1} = F_2 = B_1I_2 \times 1 = B_1I_2 = \frac{\mu_0}{4\pi}.\frac{2I_1I_2}{r}$$

Similarly C_1D_1 will also experience a force F_1 due to magnetic field $\vec{B_2}$ of C_2D_2

$\vec{F_2}$ is directed towards C_1D_1 and F_1 is directed towards C_2D_2 and both act in the plane of the paper.

So C_1D_1 and C_2D_2 attract each other.

∴ Two linear conductors carrying current in same direction attract each other.



If current is in opposite direction, magnitude of F_1 and F_2 remains same but they are in opposite direction.

∴ They repel each other.

31. As the current is switched on the electromagnet is magnetised. It attracts the metal disc. Soon a change of flux takes place and an induced emf is produced which according to Lenz's law opposes the cause which produced it. Hence metal disc thrown up.

32. Core of an electromagnet made of ferromagnetic material, because of its

(a) low coercevity

(b) low hysterisis loss

33. The permeability of ferromagnetic substances is greater than that of air so lines of force prefer to pass through them.

34. No e.m.f. will be produced between the ends of a metallic pole falling vertically through the plane of magnetic meridian as the falling pole does not cut any magnetic lines of force.

35. Yes, emf will be induced in the metallic rod because there will be a change of magnetic flux. The metallic rod will cut the magnetic lines of the earth's magnetic field.

36. The tangent at any point at a magnetic line of force gives the direction of magnetic field at that point. If two magnetic lines of force intersect then at the point of intersectrion there will be two different tangents and two directions of magnetic field which is not possible.

37. The cause of damping is the inducted emf (e) produced in the copper plate due to change in magnetic flux ($d\phi$).

38. When the magnet falls, the magnetic flux linked through the metal ring changes, so current is induced in the ring will be in such a direction according to Lenz's law that it opposes the motion of the magnet, so its acceleration will be less than g.

39. When cylindrical soft iron core, is placed inside the coil of a galvanometer, it makes the magnetic field stronger and radial in the space between it and pole pieces, such that whatever the position of the rotation of the coil is the magnetic field is always parallel to its plane. Thus it isnecessary to introduce a cylindrical soft iron core inside the coil of a galvanometer.

40. Q-factor of the circuit is defined as the ratio of inductive reactance at resonance to the resistance R in the circuit

$$\text{i.e.,} \quad Q = \frac{L\omega_0}{R} = \frac{1}{C\omega_0 R} \quad \text{i.e.,} \quad Q \propto \frac{1}{R}$$

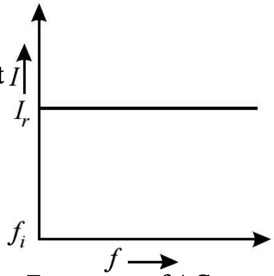
The Q-factor of an LCR circuit is a measure of the sharpness of the resonance. Larger the value of Q-factor sharper is the resonance curve.

41. (i) Due to varying current in *P*, the flux linked with P changes and hence with *Q* also changes, which in turn induces the emf in *Q* and bulb B lights.

(ii) When *Q* is moved towards left. This decrease the rate of change of magnetic flux linked with *Q* and hence lesser induced emf and bulb *B* gets dimmer.

42. Let initially I_r current is flowing in all the three circuits. If frequency of applied *AC* source is increased then, the change in current will occur in following manner:

Circuit containing resistance R only. There will not be any effect in the current, on changing the frequency of *AC* source.



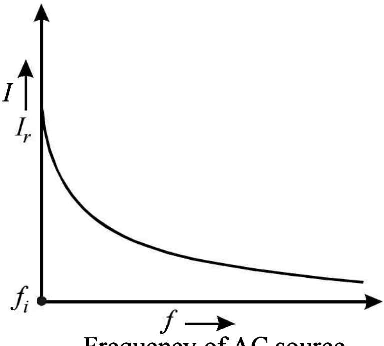
Frequency of AC source

where, f_i = initial frequency of AC source.
There is no effect on current with the increase in frequency.

Circuit containing inductance L only. With the increase of frequency of AC source, inductive reactance increases as

$$I = \frac{V_{rms}}{X_L} = \frac{V_{rms}}{2\pi f L}$$

For given circuit, $I \propto \frac{1}{f}$



Frequency of AC source

Current decreases with the increase of frequency.

Circuits containing capacitor C only

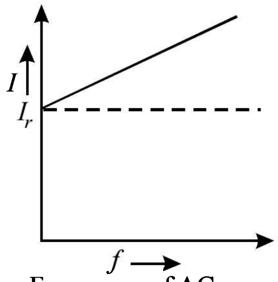
$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

Current, $I = \frac{V_{rms}}{X_C} = \frac{V_{rms}}{\left(\frac{1}{2\pi f C}\right)}$

$$I = 2\pi f C V_{rms}$$

For given circuit, $I \propto f$

Current increases with the increase of frequency.



Frequency of AC source

43. To reduce the effects of eddy currents.

44. The power loss in transmission is I^2R. As $P = VI\cos\phi$ where $\cos\phi$ is the power factor. If $\cos\phi$ is small, the current has to be increased accordingly in order to supply a given power at a given voltage therefore the power loss I^2R is large.

45. The reasons of using A.C. voltage over D.C. voltage are,

(i) By using a transformer A.C. voltage can be stepped up and stepped down as per the requirement

(ii) A.C. voltage can be transmitted over long distances without loss of energy as compared to D.C. voltage.

46. The resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. Only then do the voltages across L and C cancel each other as both being out of phase.

47. A choke coil is an electrical appliance used for controlling current in an a.c. circuit. Therefore, if we use a resistance R for the same purpose, a lot of energy would be wasted in the form of heat.

48. Infrared waves induce resonance in molecules and increase internal energy in a substance. Hence infrared waves are called heat waves.

49. Momentum transferred $= \dfrac{\text{Energy}}{\text{Speed of light}}$

$$= \frac{hv}{c} \approx 10^{-22} \text{ (for } v \sim 10^{20} \text{ Hz)}$$

Thus, the amount of the momentum transferred by the em waves incident on the surface is very small.

50. The linear momentum carried by a portion of wave having energy U is given by, $P = \dfrac{U}{C}$

Thus, if the wave incident on a material surface is completely absorbed, it delivers energy U and momentum $P = \frac{U}{C}$ to the surface.

If the wave is totally reflected, the momentum delivered $P = \frac{2U}{C}$ is because the momentum of the wave changes from p to $-p$. Therefore, it follows that an em waves incident on a surface exert a force and hence a pressure on the surface.

51. (i) When the number of turns in the inductor is reduced, the self inductance of coil decreases; so impedance of circuit reduces and so current increases. Thus the brightness of the bulb increases.

(ii) If soft iron rod is inserted in the inductor, then the inductance L increases. Therefore, the current through the bulb will decrease, decreasing the brightness of the bulb.

(iii) When capacitor of reactance $X_C = X_L$ is introduced the net reactance of circuit becomes zero, so impedance of circuit decreases. Therefore $Z = R$, so current in the circuit increases, hence brightness of bulb increases. Thus brightness of bulb increases in both cases.

52. Microwaves are considered suitable for radar systems used in aircraft navigation because they have a short wavelength range (10^{-3} m–0.3 m), which makes them suitable for long-distance communication.

53. The focal length of objective and eyepiece f_o and f_e of compound microscope must be small so as to have large magnification

$$m = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

54. Due to large scattering of visible light of smaller wavelength (blue colour) as intensity of scattered light $\propto \frac{1}{\lambda^4}$ sky appears blue.

55. Blue light suffers more deviation by a prism than red light.
This happens due to high value of refractive index of material of prism for blue light because of its smaller wavelength in visible spectrum.

56. (i) Yes, when monochromatic light suffers reflection or refraction, there is no change in frequency although the velocity of light changes. The velocity of light decreases as light travels from rarer to denser medium.

(ii) No, because the energy of the wave do not depend on speed however it depends upon its frequency which remains the same.

57. The yellow colour has small scattering and optimum sensitivity.

58. Incident ray of light is reflected and refracted when, it interacts with the atomic constituents of matter. Atoms may be viewed as oscillators, which gain frequency of light emitted by a charged oscillator equals its frequency of oscillation. Thus the frequency of reflected and refracted light is same as that of incident light frequency.

59. Due to its very small wavelength its diffraction is not easily observed.

60. The biconvex lens will behave as a converging lens, because refractive index of water (1.33) is more than the refractive index of the material of the lens (1.25).

On the other hand it acts as a diverging lens in air because the refractive index of air is less than that of the material of the lens.

61. It is very necessary to wear special glass goggles to welders while working so that they can protect their eyes from harmful electromagnetic radiation.

62. Two independent sources of light cannot be considered as coherent sources because the phase difference changes randomly with time.

63. Waves are from different edges of the circular obstacle and constructive interference takes place. As a result a bright spot is seen at the centre of the shadow of the obstacle.

64. (i) When an unpolarized light beam is incident on a polaroid then only those vibration electric vector which are parallel to crystallographic axis of polaroid are transmitted through polaroid and other vibrations are being absorbed by it. This selective absorption of electric field vector which are not parallel to axis, is termed as dichroism and hence plane polarized light is produced by polaroid.

(ii) Because light wave is transverse and sound waves are longitudinal. The longitudinal waves can't be polarized, therefore, sound wave can't be polarized.

(iii) Because it reduces the glare to half of that of incident unpolarised light on the sun goggles.

65. The intensity of interference fringes in a double slit experiment is modulated by the diffraction pattern of each slit.

66. Heat waves can be polarized as they are electromagnetic, transverse in nature.

67. In the region of central maximum, the intensity is maximum because the path difference between the waves arising from all parts of the slit is zero.

68. Two independent sources of light cannot be coherent and hence cannot produce interference pattern.

Two sources are monochromatic if they have the same frequency and wavelength. Since they are independent, i.e. they have different phases with irregular difference, they are not coherent sources.

69. (i) The de-Broglie wavelength associated with same potential V

$$\lambda = \frac{h}{\sqrt{2meV}} \qquad \lambda \propto \frac{1}{\sqrt{m}}$$

Since the mass of proton is larger than electron

$\therefore \quad \lambda_{electron} > \lambda_{proton}$

(ii) Since $\lambda = \frac{h}{mV} \quad \Rightarrow \quad mV = \frac{h}{\lambda} \Rightarrow \quad P = \frac{h}{\lambda}$

$\therefore \quad P \propto \frac{1}{\lambda}$ Since $\lambda_{electron} > \lambda_{proton}$

$\therefore$ Momentum of electron (P_e) < momentum of proton (P_p)

70. The intensities for both the monochromatic radiation are same but their frequencies are different. Therefore

(i) The number of electrons ejected in two cases are same because it depends on number of incident photons.

(ii) As, $KE_{max} = h\nu - \phi_0$

The KE_{max} of violet radiation will be more.

71. The wave theory of light is not able to explain the observed features of photoelectric effect because of following reasons.

(i) The greater energy incident per unit time per unit area increases with the increase of intensity which should facilitate liberation of photoelectron of greater kinetic energy which is in contradiction of observed feature of photoelectric effect.

(ii) Wave theory states that energy carried by wave is independent of frequency of light wave and hence wave of high intensity and low frequency (less than threshold frequency) should stimulate photoelectric emission but practically, it does not happen.

72. Threshold frequency is different for different material as each material responds differently to light. Some metals like selenium are more sensitive than zinc or copper. The same photosensitive substance gives different response to light of different wavelengths. eg: UV light gives photoelectric effect in copper but not red or green light.

73. Wavelength, $\lambda = \frac{h}{\sqrt{2mk}}$ here k = kinetic energy of electron.

Therefore, it is clear that KE of electron is more than that of proton.

74. When light wave is incident on photoelectric material, the photoelectrons should be emitted (after a long time) if work function is large. But no photoelectron is emitted by incident radiations if the frequency is less than the threshold frequency. The energy of the ejected electrons also has no relevance with the intensity of incident light, although according to the wave nature, it should be there. If the light is incident for a longer interval of light, the energy should also have increased. That is why photoelectric effect is not explained on the basis of wave nature of light.

75. The speed of photo electron emitted depends on energy of incident photon i.e., $h\nu$ or hc/λ hence only frequency and wavelength affect velocity of photo electron. Intensity is no. of photons/area/time which does not affect velocity of ejected electron but only increases no of e^- ejected /sec.

76. (a) de-Broglie wavelength of a charged particle is given by,

$$\lambda \propto \frac{1}{\sqrt{mq}}$$

If m_p and e are mass and charge of a proton respectively,
and, m_D and e are mass and charge of a deutron respectively, then

$$\frac{\lambda_p}{\lambda_o} = \sqrt{\frac{m_D q_D}{m_p q_p}} = \sqrt{\frac{(2m_p)(e)}{(m_p)(e)}} = \sqrt{2}$$

$$\lambda_p = \sqrt{2}\lambda_D$$

Thus, de-broglie wavelength associated with proton is $\sqrt{2}$ times of the de-broglie wavelength of deutron and hence it is more.

(b) Momentum, is given by, $P = \frac{h}{\lambda}$ or, $p \propto \frac{1}{\lambda}$

where, h = plank's constant
Since the wavelength of a proton is more than that of deutron

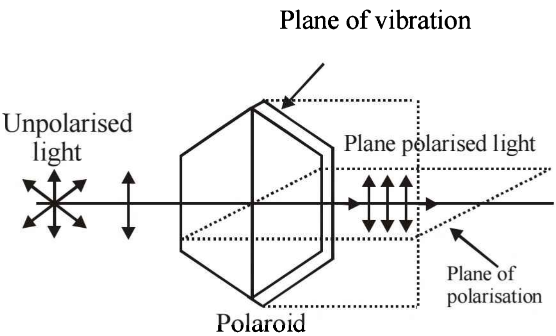
thus, the momentum of a proton is lesser than that of deutron. Hence, the momentum of proton is less.

77. The reflecting telescopes are preferred over refracting type because of the following reasons:

(i) There is no chromatic aberration in case of reflecting telescopes as the objective is a mirror.

(ii) Spherical aberration is reduced in case of reflecting telescopes by using mirror objective in the form of a paraboloid.

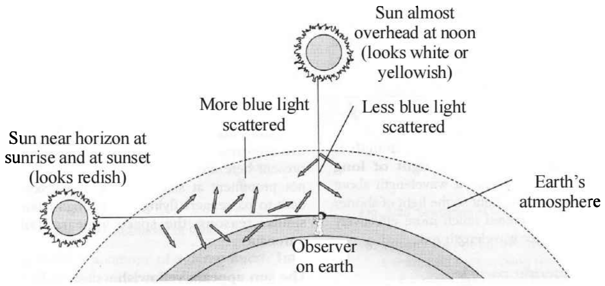
78. When unpolarised light is passed through a polaroid, only those vibrations of light pass through the crystal that are parallel to the axis of the crystal. All other vibrations will be absorbed by the crystal. In this way, the unpolarised light gets linearly polarised.



79. On increasing the value of n, the part of slit contributing to the maximum decreases. Hence, the maxima becomes weaker.

80. At the time of sunset or sunrise, the Sun and its surroundings appear red because of the scattering of light.

$$\text{Scattering} \propto \frac{1}{\lambda^4}$$



At noon, the light of sun travels relatively shorter distance through earth's atmosphere thus appears white as only a little of blue and violet colours are scattered. Near the horizon , most of the blue light and shorter wavelengths are scattered and appears red.

81. Frequency (ν) and wavelength (λ) of light are related as $\nu = \frac{v}{\lambda}$ where v is the velocity of light. As the wave travels from one medium to another, the wavelength of light changes changing the speed of light with it. The frequency remains constant.

82. For a medium, the light of different wavelength will have different values of refractive indices. So these light waves have different values of Brewster's angles.

83. For a convex mirror,

Focal length, $f > 0$

Position of object, $u < 0$

From mirror formula, we have

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{f} - \frac{1}{u} = \frac{1}{v}$$

So, $\frac{1}{v} > 0$ or, $v > 0$ or, v + ve

This means the image formed by a convex mirror is always behind the mirror and hence, virtual.

84. The angle of minimum deviation of a glass prism decreases, if the incident violet light is replaced with red light.

As we know $\mu = \dfrac{\sin\left(\dfrac{A + \delta_m}{2}\right)}{\sin\dfrac{A}{2}}$ and from cauchy's equation,

$$\mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \ldots$$

$\lambda_{Red} > \lambda_{violet}$ so $\mu_{Red} < \mu_{violet}$ and therefore, angle of minimum deviation $\delta_{m\ Red} < \delta_{m\ violet}$.

85. The following are the drawbacks of Rutherford's model

(i) Rutherford suggested that "on revolving in the orbits, electron radiates energy and strinks consequently towards the nucleus. The radius followed by the electrons, gradually decreases based on it, electron should fall into nucleus and atom should be destroyed.

(ii) According to it we should obtain radiation of all possible wavelength but in actual practice atomic spectrum is line spectrum.

86. This is because scattering of α-particle is due to electrostatic force and not gravitational force.

87. If number of protons is large, coulomb's repulsion would be large hence nucleus would split. To hold the nucleons inside the nucleus no. of neutrons is large to increase nuclear force which is a short range force and acts between neighbours only.

88. (i) The BE per nucleon for nucleus of range, $30 < A < 170$ is close to its maximum value. So, the nucleus belongs to this region is highly stable and does not shows radioactivity.

(ii) In β-decay, the detection of neutrino is found to be difficult. A neutrino hits a proton in H-atom and collision occurred may be as of the three kinds. Neutrino do not have any change which implies that they are unaffected in the region of electromagnetic forces.

89. β–decay see conversion of neutron into p^+ ,e^- and $\bar{\nu}$ Since energy available is shared by e^- and $\bar{\nu}$ in all possible ratios hence energy variations of β–decay are continuous.

90. Electron being very light, cannot scatter α-particles (heavy) at very large angles hence they are not considered.

91. Neutrinos are uncharged particles with almost no mass and they interact very weakly ith matter, so they are very difficult to detect.

92. An intrinsic semiconductor is a pure semiconductor in which the number of free electrons is equal to the number of holes.

$n_e = n_h = n_i$

P-type semiconductor is an extrinsic semiconductor doped with trivalent impurity. The number of holes is greater than the number of electrons, i.e. $n_h >> n_e$.

A pure Si or Ge crystal is electrically neutral. A P-type semiconductor is obtained by doping with trivalent impurity atoms (Al, B, In) which are also electrically neutral, hence a P-type semiconductor crystal is electrically neutral.

93. The energy for the maximum intensity of the solar radiation is nearly 1.5 eV. In order to have photoexcitation the energy of radiation ($h\nu$) must be greater than energy band gap (E_g). Therefore, the semiconductor with energy band gap about 1.5 eV or lower than it and with higher absorption coefficient is likely to give better solar conversion efficiency. The energy band gap for Si is about 1.1 eV while for GaAs, it is about 1.53 eV. The GaAs is better inspite of its higher band gap than Si because it absorbs relatively more energy from the incident solar radiations being of relatively higher absorption coefficient.

94. Under the reverse bias condition, the holes of *p*-side are attracted towards, the negative terminal of the battery and the electrons of the *n*-side are attracted towards the positive terminal of the battery. This increases the depletion layer and the potential barrier. However the minority charge carriers are drifted across the junction producing a small current. At any temperature, the number of minority carriers is constant so there is the small current at any applied potential. This is the reason for the current under reverse bias to be almost independent of applied potential. At the critical voltage, avalanche breakdown takes place which results in a sudden flow of large current.

95. When photodiode is illuminated with light due to breaking of covalent bonds, equal number of additional electrons and holes comes into existence whereas fractional change in minority charge carrier is much higher than fractional change in majority charge carrier. Since, the fractional change of minority carrier current is measurable significantly in reverse bias than that of forward bias. Therefore, photodiode are connected in reverse bias.

96. At the critical voltage, the holes in the n-side and conduction electrons in the p-side are accelerated due to the reverse-bias voltage.These minority carriers acquire sufficient kinetic energy from the electric field and collide with a valence electron. Thus the bond is finally broken and the valence electrosn move into the conduction band resulting in enormous flow of electrons and thus formation of hole-electron pairs. Thus there is a sudden increase in the current at the critical voltage.

97. Photodiode is used in reverse bias as it is easier to observe the change in the current with change in the light intensity.

98. A p–n junction is forward biased when positive terminal is connected to p–side and negative to n–side of external voltage V_0. This makes holes from p–side go to n–side and vice-versa. This increases minority carrier concentration at junction boundary from where the injected electrons on p–side diffuse to other end of p–side and holes from n–side junction to end of n–side. This gives rise to current. The total diode current is sum of hole diffusion current and conventional current due to electrons hence is high (few mA).

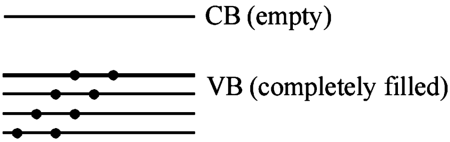
99. If the value of resistance R decreases, the input circuit will become more forward biased, decreasing the base current I_B, increasing emitter current I_E hence increases collector current I_C as

$I_E = I_B + I_C$

(i) as I_C increases which passes through the lamp so brightness of the lamp increases.

(ii) the reading of voltmeter will also increase.

100. An intrinsic semiconductor at 0 K is like an insulator because all its electrons are in the valence band in form of bound electrons and hence not free to conduct current. At T > 0 K, some of these electrons pick up thermal energy and move to conduction band.



At T = 0 K, intrinsic semiconductor does not have free charges

101. A thin and light doped base region of a transistor contains a smaller number of majority charge carriers. This reduces the recombination rate of electrons and holes at the base-emitter junction. Most of the majority charge carriers coming from emitter into base immediately get collected by the collector. This reduces base current and increases both collector current and current gain of the transistor.

102. The power radiated by an antenna is proportional to $(l/\lambda)^2$. Thus, for the same antenna length, the power radiated increases with decreasing wavelength (λ) i.e. increasing frequency.

For a good transmission we need high powers and hence high frequency carrier waves are used.

103. Because radio waves of higher frequency do not follow the curvature of the earth.

104. The need for modulation for transmission of a signal are given below.

(i) The transmission of low frequency signal needs antenna of height 4-5 km which is impossible to construct. So, there is need to modulate the wave in order to reduce the height of antenna to a resonable height.

(ii) Effective power radiated by antenna for low wavelength or high frequency wave as

$$P \propto \frac{1}{\lambda^2}$$

So, for effective radiation by antenna, there is need to modulate the wave.

105. In general, 30 MHz > f_C > 5 MHz, when frequency is greater than f_C then it crosses the ionosphere and never reflects back on the surface of the earth. The ranges of critical frequency upto few MHz sets an upper limit to frequency of waves used in sky wave mode.

106. The radiowave of frequencies upto 30 MHz cannot penetrate the ionosphere and they get reflected back to earth whereas higher frequencies (> 40 MHz) bends slightly but not reflected back to earth.

107. (i) To radiate the signals with high efficiency.

(ii) Because they are of large wavelength and power radiated by antenna is very small as $P \propto \frac{1}{\lambda^4}$.

(iii) It is so to avoid making overmodulated carrier wave. In that situation, the negative half cycle of the modulating signal is dipped and distortion occurs in reception.

108. The aircraft intercepts the waves reaching the antenna so it causes slight shaking of the picture.

109. The thin ozone layer on top of stratosphere absorbs most of the harmful ultraviolet rays coming from the Sun towards the Earth. They include UVA, UVB and UVC radiations, which can destroy the life system on the Earth. Hence, this layer is crucial for human survival.

110. The diode is fabricated such that the generation of e-h pairs takes place in or near the depletion region.

Photodiode is used in reverse bias as it is easier to observe the change in the current with change in the light intensity.

Photodiode is used in reverse bias as it is easier to observe the change in the current with change in the light intensity.

□□□

CHAPTER 4

How will you draw graph / diagram of ......?

(A) Electrostatics

1. Draw the field lines when the charge density of the sphere is (i) positive (ii) negative. **[Delhi 2008]**

2. Draw the equipotential surfaces due to an electric dipole. Locate the points where the potential due to the dipole is zero. **[All India 2009C, 2011C, 2013]**

3. Sketch the lines of force due to two equal positive point charges placed near each other.

4. Draw a graph of electric fields $E(r)$ with distance r from the centre of the shell for $0 \leq r \leq \infty$. **[Delhi 2009]**

5. Draw lines of force to represent a uniform electric field.

6. Plot a graph comparing the variation of potential V and electric field E due to a point charge q as a function of distance r from the point charge. **[Foreign 2010, Delhi 2012]**

7. Draw an equipotential surface in a uniform electric field.

8. Two charges of 5μC and –5μC are placed at points A and B 2 cm apart. Depict an equipotential surface of the system. **[Delhi 2013C]**

9. Draw a labelled schematic diagram of a Van-de-Graff generator. **[Delhi 2013C, All India 2014]**

10. Draw equipotential surfaces :

(i) in case of a single point charge and

(ii) in a constant electric field in Z-direction. **[All India 2016]**

11. Draw a graph of E versus r for r >> a. **[All India 2017]**

(B) Current Electricity

12. Plot a graph showing the variation of resistivity with temperature for a metallic conductor. **[Delhi 2008]**

13. Draw the circuit diagram of a potentiometer which can be used to determine the internal resistance r of a given cell of emf E. **[Delhi 2008C, 2010]**

14. Plot a graph showing temperature dependence of resistivity for a typical semiconductor. How is this behaviour explained? **[Delhi 2011, 2012, 2014]**
15. Sketch a graph to show the charge Q acquired if a capacitor of capacitane 'C' varies with increase in potential difference between its plates.
16. Draw a graph showing the variation of resistivity with temperature for nichrome. **[All India 2013C]**
17. A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I. **[Delhi 2015]**

(C) Magnetism

18. Draw a schematic sketch of a cyclotron. **[Delhi 2008, 2011C, 2012, All India 2013, 2014]**
19. Draw a labelled diagram of a moving coil galvanometer. **[Foreign 2012, All India 2014]**
20. Sketch the magnetic field lines for a finite solenoid. **[Foreign 2010]**
21. Draw magnetic field lines when a (i) diamagnetic, (ii) paramagnetic substance is placed in an external magnetic field. **[Delhi 2010]**
22. Draw the magnetic field lines due to a current carrying loop. **[Foreign 2010, Delhi 2013C]**
23. Draw magnetic field lines due to U-shaped magnet.
24. Three identical specimens of a magnetic materials, nickel, antimony, aluminium are kept in a non-uniform magnetic field. Draw the modification in the filed lines in each case. **[Delhi 2011]**
25. Plot graph of inverse magnetic susceptibility $\frac{1}{\chi}$ versus temperature T of an antiferromagnetic sample.
26. The current flowing through an inductor of self inductance L is continuously increasing. Plot a graph showing the variation of
    (i) Magnetic flux versus the current
    (ii) Induced emf versus dI/dt
    (iii) Magnetic potential energy stored versus the current. **[Delhi 2014]**
27. Draw the magnetic field lines due to a circular wire carrying current *I*. **[All India 2016]**

(D) EMI, Alternating Current and EM waves

28. Draw a schematic diagram of a step-up transformer. **[All India 2010, Delhi 2011C]**
29. Sketch a schematic diagram depicting electric and magnetic fields for an electromagnetic wave propagating along the *Z*-direction. **[Delhi 2009]**

30. An em wave is travelling in a medium with a velocity $\vec{v} = v\hat{i}$. Draw a sketch showing the propagation of the em wave, indicating the direction of the oscillating electric and magnetic fields. **[Delhi 2013]**

31. Draw a graph to show variation of capacitive-reactance with frequency in an a.c. circuit. **[All India 2015]**

32. A series LCR circuit is connected across an a.c. source of variable angular frequency 'ω'. Plot a graph showing variation of current 'i' as a function of 'ω' for two resistances R_1 and R_2 ($R_1 > R_2$).

33. Draw a schematic sketch of the electromagnetic waves propagating along the + x–axis. Indicate the directions of the electric and magnetic fields. **[All India 2015]**

34. Draw a labelled diagram of a step-down transformer. **[All India 2016]**

35. Draw a labelled diagram of an ac generator. **[All India 2017]**

(E) Optics

36. Draw a neat labelled ray diagram of an astronomical telescope in normal adjustment. **[Delhi 2008, All India 2010, 2016, 2017]**

37. Draw a schematic ray diagram of reflecting telescope showing how ray coming from a distant object are received at the eye-piece. **[Delhi 2008, 2016, Foreign 2010]**

38. Draw a neat labelled ray diagram of a compound microscope. **[Foreign 2008, All India 2010, Delhi 2008, 2009, 2010, 2014]**

39. Draw a ray diagram, showing the passage of a ray of light through a prism when the angle of incidence is 52°. **[Delhi 2010C]**

40. Draw a ray diagram to show the formation of the image in a far-sighted (Hypermetropic) eye. **[Foreign 2010]**

41. Draw a ray diagram to show the image formation by a concave mirror when the object is kept between its focus and the pole. **[Delhi 2011]**

42. A ray of monochromatic light is incident on one of the faces of an equilateral triangular prism of refracting angle A. Trace the path of ray passing through the prism. **[Foreign 2011]**

43. Three light rays red (R), green (G) and blue (B) are incident on the right angled prism ABC at face AB. The refractive indices of the materials of the prism for red, green and blue wavelengths are respectively 1.39, 1.44 and 1.47. Trace the paths of these rays reasoning out the difference in their behaviour. **[Foreign 2011]**

44. An equiconvex lens of refractive index μ_1 focal length 'f' and radius of curvature 'R' is immersed in a liquid of refractive indux μ_2. For (i) $\mu_2 > \mu_1$, and (ii) $\mu_2 < \mu_1$, draw the ray diagrams in the two cases when a beam of light coming parallel to the principal axis is incident on the lens. **[All India 2013C]**

45. Draw a labelled ray diagram of a refracting telescope.

[All India 2013, Delhi 2013C]

46. Using Huygens' construction draw a figure showing the propagation of a plane wave reflecting at the interface of the two media.

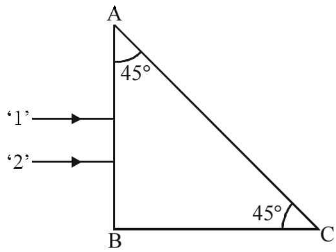
[Delhi 2008]

47. Draw the shape of a plane wavefront after refraction through a concave lens?

48. Draw a diagram to show refraction of a plane wavefront incident on a convex lens and hence draw the refracted wavefront. **[Delhi 2009]**

49. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering the prism.

[All India 2014]



50. Plot a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials having work function W_1 and W_2 ($W_1 > W_2$). **[Delhi 2010]**

51. Show the variation of photocurrent with collector plate potential for different intensities but same frequency of incident radiation.

[Foreign 2011]

52. Draw graph of variation of photoelectric current with collector plate potential for different frequencies of incident radiation.

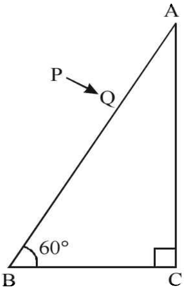
53. Draw a graph between the frequency of incident radiation (n) and the maximum kinetic energy of the electrons emitted from the surface of a photosensitive material. **[Foreign 2012, Delhi 2014]**

54. Show on a plot the nature of variation of photoelectric current with the intensity of radiation incident on a photosensitive surface.

[Delhi 2013C, 2014]

55. In Young's double slit experiment, plot a graph showing the variation of fringe width versus the distance of the screen from the plane of the slits keeping other parameters same. **[All India 2015]**

56. A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism. **[All India 2016]**



57. Sketch the graphs showing variation of stopping potential with frequency of incident radiations for two photosensitive materials A and B having threshold frequencies $\nu_A > \nu_B$.

(i) In which case is the stopping potential more and why ?

(ii) Does the slope of the graph depend on the nature of the material used ? Explain. **[All India 2016]**

58. Draw a graph showing the variation of intensity (I) of polarised light transmitted by an analyser with angle (θ) between polariser and analyser. **[All India 2016]**

59. Draw a proper diagram to show how the incident wavefront traverses through the lens and after refraction focusses on the focal point of the lens, giving the shape of the emergent wavefront. **[All India 2016]**

60. Plot a graph showing variation of de-Broglie wavelength λ versus $\frac{1}{\sqrt{V}}$, where V is accelerating potential for two particles A and B carrying same charge but of masses $m_1, m_2 (m_1 > m_2)$. **[Delhi 2016]**

61. Draw a graph showing variation of intensity in the interference pattern against position 'x' on the screen. **[Delhi 2016]**

62. Plot a graph to show variation of the angle of deviation as a function of angle of incidence for light passing through a prism. **[Delhi 2016]**

63. Draw the intensity pattern for single slit diffraction and double slit interference. **[All India 2017]**

64. Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. **[All India 2017]**

(F) Atoms and Nuclei

65. Draw a schematic arrangement of the Geiger-Marsden experiment for studying α-particle scattering by a thin foil of gold. **[All India 2009, Foreign 2010]**

66. Draw the energy level diagram showing how the transitions between energy level result in the appearance of Lyman series. **[Delhi 2013]**

67. Draw the energy level diagram showing how the line spectra corresponding to Paschen series occur due to transition between energy levels. **[Delhi 2013]**

68. Draw the graph scattering particle v/s scattering angle.

69. Draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels. **[Delhi 2013]**

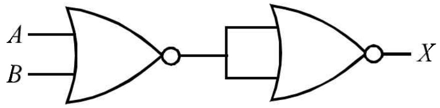
70. Draw a plot of the binding energy per nucleon as a function of mass number for a large number of nuclei $20 > A > 240$.
[Foreign 2008, All India 2009C, 2010, 2013]

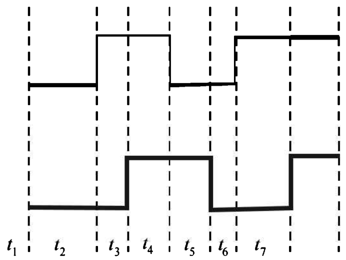
71. Draw a plot of potential energy between a pair of nucleons as a function of their separation. Mark the regions where potential energy is (i) positive and (ii) negative. **[Delhi 2013]**

(G) Electronics and Communication systems

72. Draw the circuit diagram for studying the characteristics of an *n-p-n* transistor in common emitter configuration. Sketch the typical (i) input and (ii) output characteristics in CE configuration
[All India 2008, 2014, Delhi 2009, 2009C, 2010C, 2013C, Foreign 2012]

73. Draw the output waveform at X, using the given inputs, A and B for the logic circuit shown below. **[Delhi 2008, 2011]**





74. Draw a simple circuit of a CE transistor amplifier. **[Foreign 2008, Delhi 2012]**

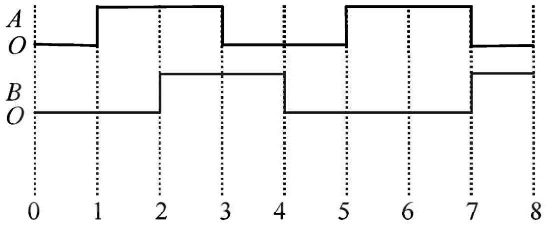
75. Draw V-I characteristics of a *p-n* junction diode.
[All India 2009, 2011, 2013]

76. Draw the logic circuit of a NAND gate.
[All India 2009, Foreign 2011]

77. Draw the logic circuit of AND gate. **[All India 2009, Foreign 2011]**

78. Draw I-V characteristics of zener diode **[Delhi 2009]**

79. Sketch the output waveform from an AND gate for the inputs *A* and *B* shown in the figure. **[Delhi 2009]**



80. Draw the transfer characteristic curve of a base biased transistor in *CE* configuration. **[All India 2010C, Delhi 2011, 2011C, Foreign 2012]**

81. Draw the circuit diagram showing how a *p-n* junction diode is (i) forward biased, (ii) reverse biased **[All India 2010, 2011C]**

82. Draw the circuit diagram of an illuminated photodiode in reverse bias. **[Delhi 2010]**

83. Draw the circuit diagram of a base-biased n-p-n transistor in CE configuration. **[Foreign 2010]**

84. Draw the logic circuit of a NOT gate **[Foreign 2011]**

85. Draw transfer characteristics of a common emitter n-p-n transistor. **[Foreign 2011, All India 2013C]**

86. Show how intensity of current varies with illumination intensity in a photodiode.

87. Plot a graph showing variation of current versus voltage for the material GaAs. **[Delhi 2014]**

88. Draw the diagram of a Zener diode.

89. Draw a labelled block diagram of a simple modulator for obtaining an AM signal. **[All India 2008, Delhi 2008C, 2009, Foreign 2010]**

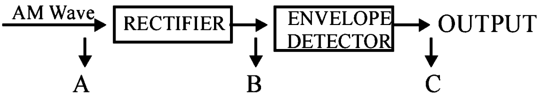
90. Draw a plot of the variation of amplitude versus ω for an amplitude modulated wave. **[Delhi 2008]**

91. Draw block diagram of a detector for AM waves? **[Delhi 2008C, 2013C]**

92. Draw a schematic diagram showing the (i) ground wave (ii) sky wave and (iii) space wave propagation modes for em waves. **[All India 2011C, Delhi 2012]**

93. Draw diagram for following :
(a) Carrier wave (b) Modulating wave
(c) AM wave (d) FM wave
(e) PM wave

94. Figure shows the block diagram of a detector for AM signal. Draw the waveforms for the (i) input AM wave at A (ii) output B at the rectifier and (iii) output signal at C.



[All India 2013C]

95. Draw a schematic sketch showing how amplitude modulated signal is obtained by superposing a modulating signal over a sinusoidal carrier wave. **[All India 2014, Delhi 2013]**

96. Draw the necessary energy band diagrams to distinguish between conductors, semiconductors and insulators. How does the change in temperature affect the behaviour of these materials ? Explain briefly. **[All India 2015]**

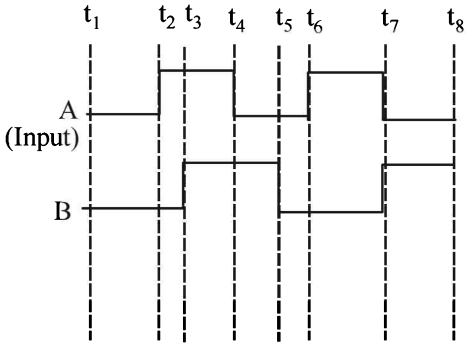
97. Draw a circuit diagram of a transistor amplifier in CE configuration. **[Delhi 2015]**

98. Draw the circuit diagram of a half wave rectifier. **[All India 2013C, 2016]**

99. Draw the circuit diagram for studying the input and output characteristics of n-p-n transistor in common emitter configuration. **[Delhi 2016]**

100. Draw the circuit diagram of a full wave rectifier **[All India 2017]**

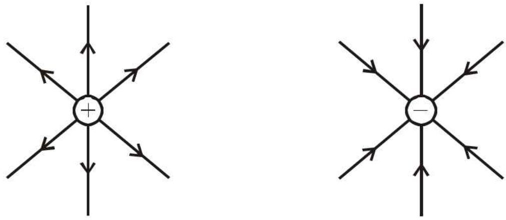
101. The figure shows the input waveforms A and B for 'AND' gate. Draw the output waveform. **[All India 2017]**



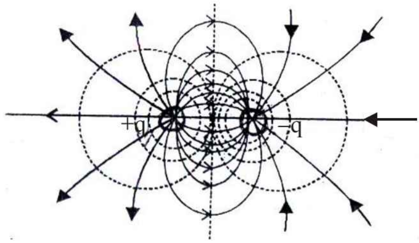
102. Draw a block diagram of a generalized communication system. **[All India 2017]**

[redacted]

1. Electric field lines when the charged density of the sphere,
(i) Positive (ii) Negative

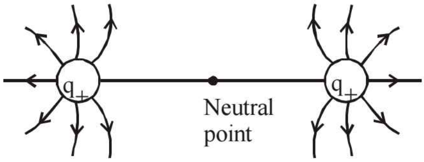


2. Equipotential surfaces due to an electric dipole.

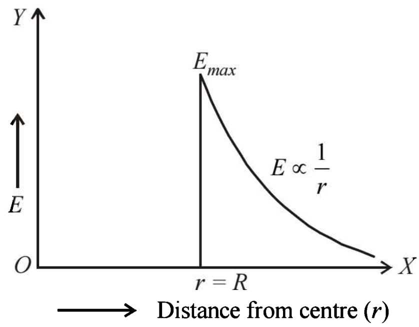


Potential due to the dipole is zero at the line bisecting the dipole length.

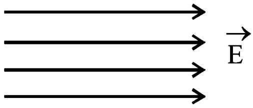
3. Lines of force due to two equal positive point charge.



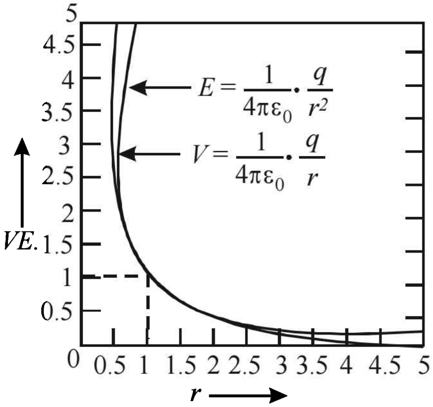
4. Graph of variation of electric field intensity E(r) with distance r from the centre for shell $0 \leq r < \infty$ is shown below.



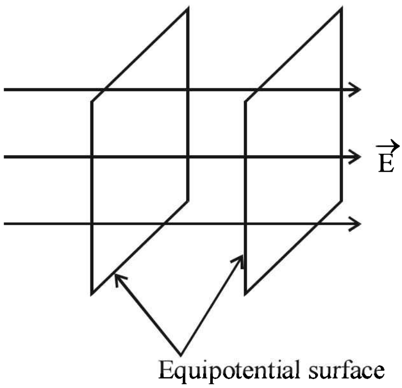
5. Lines of force representing uniform electric field.



6. The graph showing variation of potential V and field E with r for a point charge q.

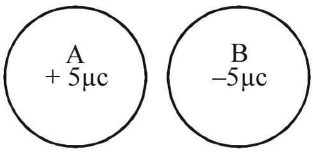


7. Equipotential surface in a uniform electric field.

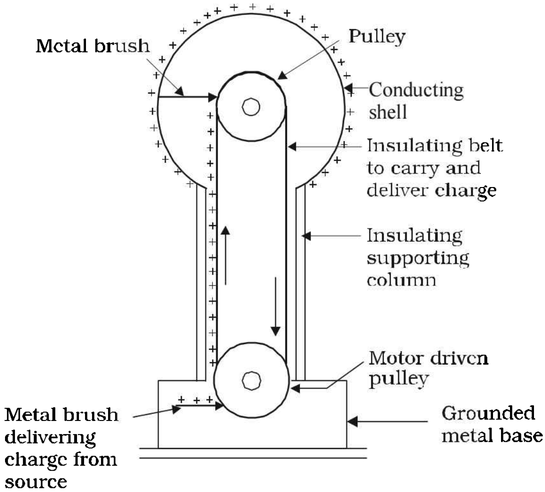


It is a plane surface perpendicular to the electric field.

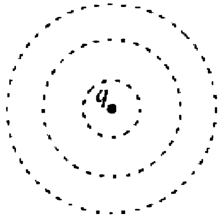
8. The equipotential surface of the system is as shown :



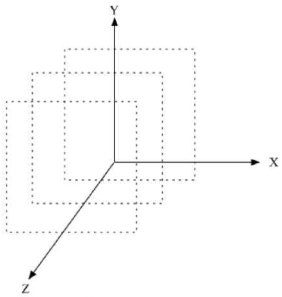
9. A labelled Schematic diagram of a Van de-Graff generator



10. (i) Equipotential surface in case of single point charge.



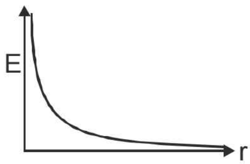
(ii) Equipotential surface in a constant electric field in z-direction.



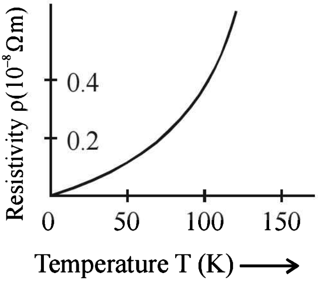
11. (b) Graph of E versus r for r >> a

$$\because E = \frac{p}{4\pi\varepsilon_0}\frac{2r}{r^4} = \frac{2p}{4\pi\varepsilon_0 r^3}$$

$$\therefore E \propto \frac{1}{r^3}$$



12. Resistivity of a conductor is defined as the resistance offerered by unit length and unit area of cross – section of material of the conductor.

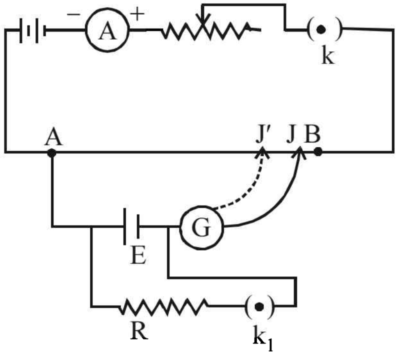


The temperature dependence of resistivity of a metal can be obtained from, $r = r_0 [1 + \alpha(T - T_0)]$

where r and r_0 are the resistivity at temperature T and T_0 respectively and α is called temperature coefficient of resistivity.

The value of α is positive, shows that resistivity increases with increases in temperature.

13. Circuit diagram of a potentiometer to determine internal resistance *r* of a given cell.



When the key k_1 is off, the cell of e.m.f E is in open circuit. Let the null point in that case be J and AJ = ℓ_1

$\therefore \quad E = k\ell_1$

When the key is closed, the new null point is at J' and let AJ' = ℓ_2 Then the potential difference between two poles of the cell $= V = k\ell_2$

$$\therefore \quad \frac{E}{V} = \frac{\ell_1}{\ell_2}$$

∴ Internal resistance of the cell

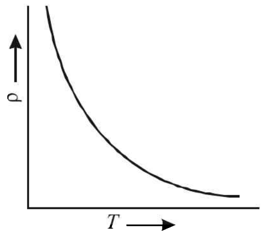
$$r = \left(\frac{E}{V} - 1\right)R \Rightarrow r = \left(\frac{\ell_1}{\ell_2} - 1\right)R$$

knowing R and measuring ℓ_1 and ℓ_2, r can be calculated.

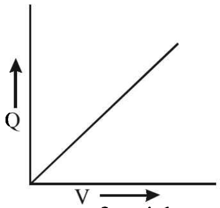
14. Resistivity of material of conductor (ρ) is given by

$$\rho = \frac{m}{ne^2\tau}$$

With the rise of temperature of semiconductor, number density of free electrons increases hence resistivity decreases.

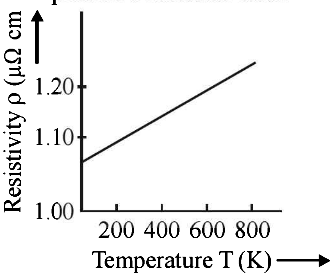


15. As $Q \propto V \Rightarrow C = \frac{Q}{V}$

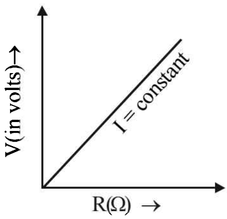


16. Graph of variation of resistivity with temperature for nichrome.

Property of nichrome used to make standard resistance coils : Its low temperature coefficient of resistance.

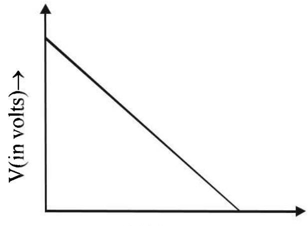


17. (i) Graph between terminal voltage V and resistance (R)

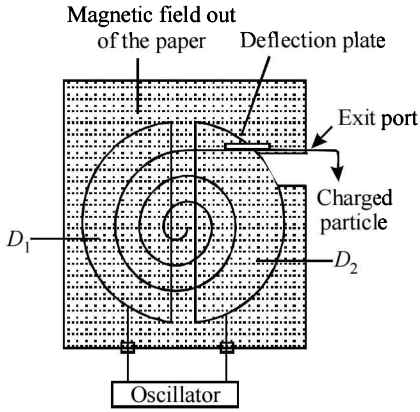


In the situation when no current is drawn from the cell then $V = E$ $(\because V = E - Ir \text{ and } I = 0)$

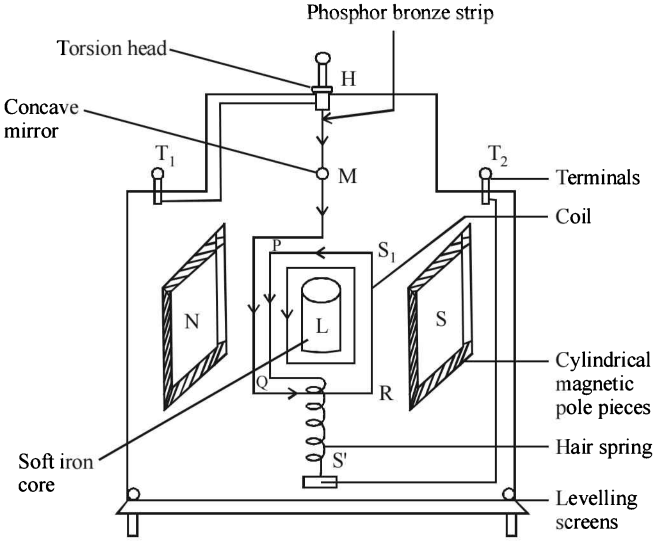
(ii) Graph between terminal voltage (V) and current (I)



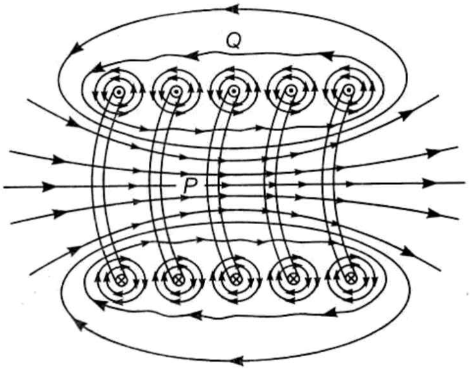
18. **Schematic sketch of a Cyclotron.**



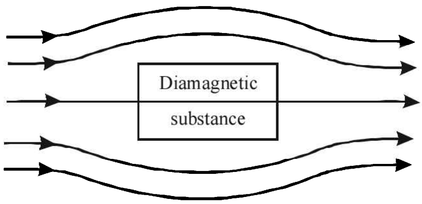
19. **Moving coil Galvanometer.**



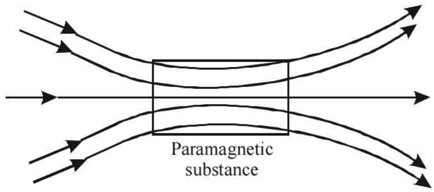
20. Magnetic field lines due to a finite solenoid has been shown below.



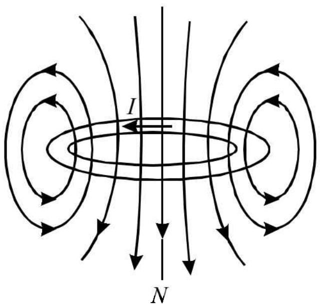
21. (i) Behaviour of magnetic field lines when diamagnetic substance is placed in an external field.



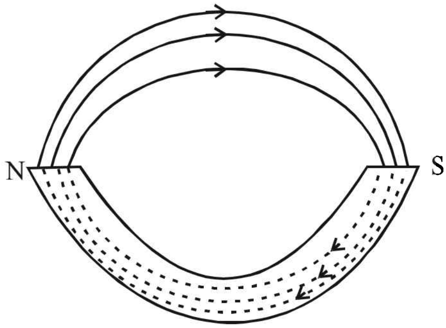
(ii) Behaviour of magnetic field lines when paramagnetic substance is placed in a external field.



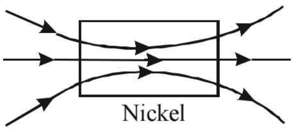
22. Magnetic lines of force due to current carrying coil have been shown in the diagram given below.



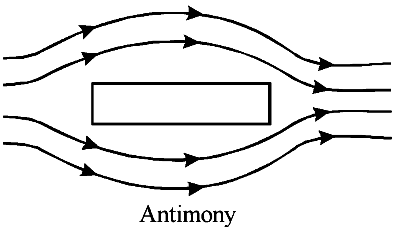
23. Magnetic field lines due to the U-shaped magnet.



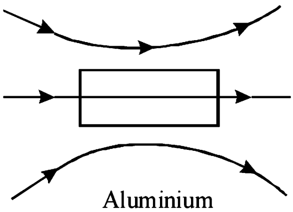
24. Nickel is a ferromagnetic substance so field lines are



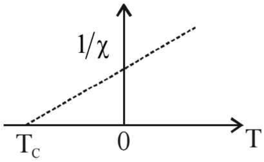
Antimony is a diamagnetic substance so field lines are



Aluminium is a paramagnetic substance so field lines are



25. The graph of inverse magnetic susceptibility $\frac{1}{\chi}$ versus temperature T of an antiferromagnetic sample.

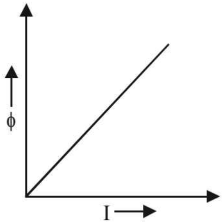


26. (i) Since

where, I = Strength of current through the coil at any time

= Amount of magnetic flux linked with all turns of the coil at that time

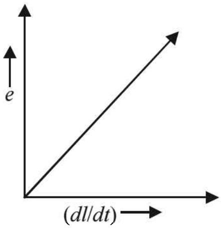
and, ϕ = Constant of proportionality called coefficient of self induction



(ii) Induced emf,

$$e = \frac{-d\phi}{dt} = \frac{-d}{dt}(LI)$$

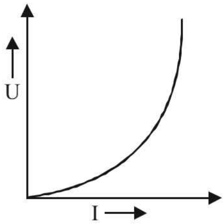
i.e., $e = -L\frac{dI}{dt}$



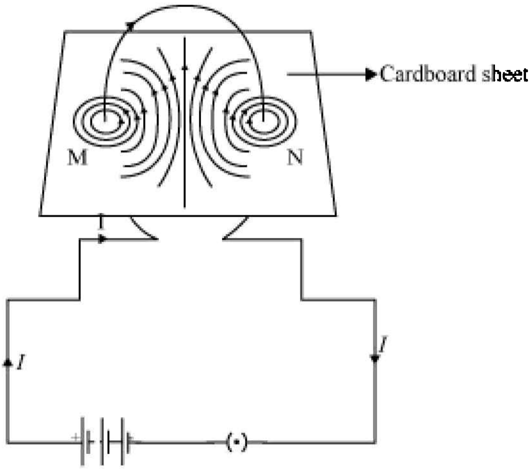
[The graph is drawn considering only magnitude of *e*]

(iii) Since magnetic potential energy is given by,

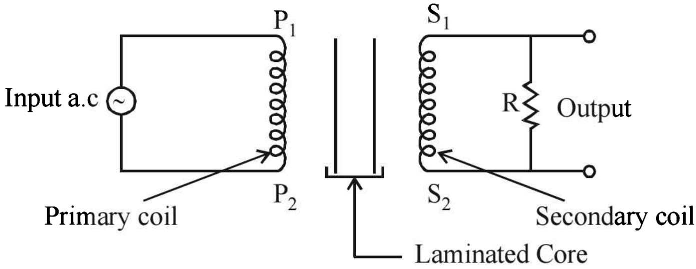
$$U = \frac{1}{2}LI^2$$



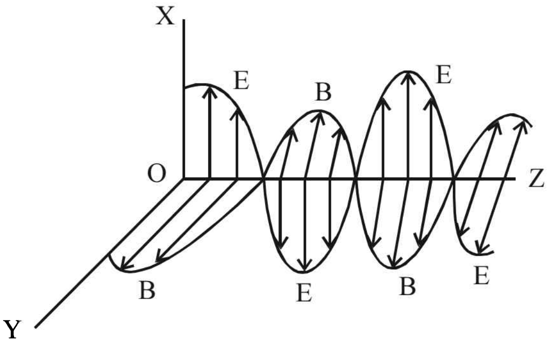
27.



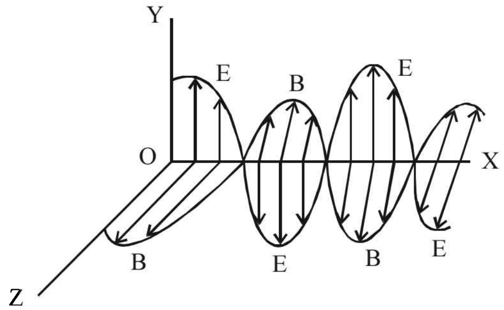
28. Schematic diagram of a step-up transformer.



29. A charge q oscillating at certain frequency produces an oscillating electric field in space, which produces an oscillating magnetic field. The oscillating electric and magnetic fields thus regenerate each other and produce electromagnetic wave. The frequency of the electromagnetic wave equals the frequency of oscillation of the charge.



30. From $\vec{V} = V\hat{i}$, it is clear that the wave is propagating along the x-axis. The direction of electric field is along the y-axis and that of the magnetic field along the z-axis as shown below.



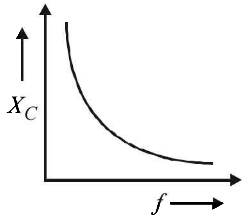
Direction of propagation →

31. As capacitive reactance

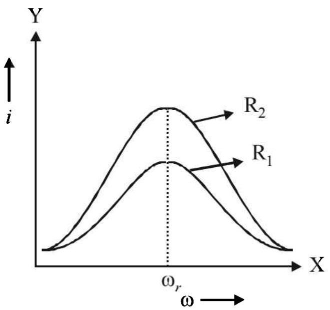
$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

Hence, it is inversely proportional to frequency f.

Graph: X_C versus f



32. The variation of current with angular frequency for the two resistances R_1 and R_2 shown in the graph below.



Here,

ω_r= Resonance frequency

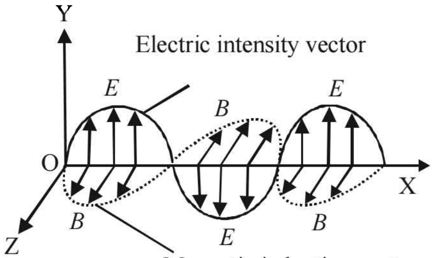
(a) From the graph, we can see that resonance for the resistance R_2 is sharper than for R_1 because resistance R_2 is less than resistance R_1 Therefore, at resonance, the value of peak current will rise more abruptly for a lower value of resistance.

(b) Power associated with the resistance is given by

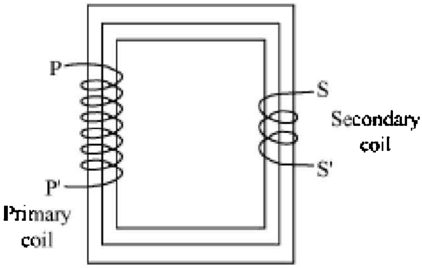
$P = E_v I_v$

From the graph, we can say that the current in case of R_2 is more than the current in case of R_1. Hence, the power dissipation in case of the circuit with R_2 is more than that with R_1

33. Schematic sketch of the electromagnetic waves:



34. A labelled diagram of a Step-down transformer



35. (a) **AC Generator:** It is used to convert mechanical energy into electrical energy.

Principle : It works on the principle of electromagnetic induction.

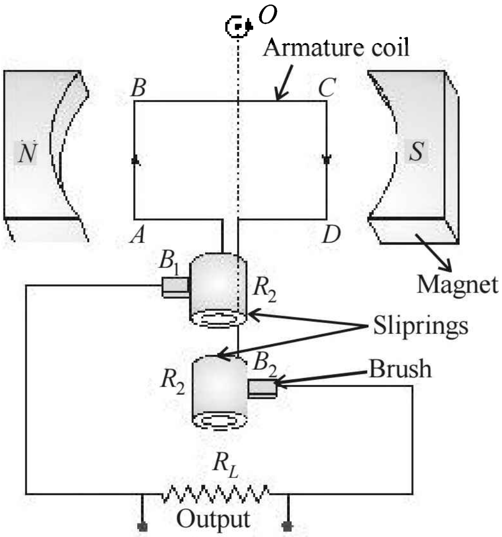
Construction : The main components of ac generator are :

(i) **Armature coil :** It consist of large number of turns of insulated copper wire wound over iron core.

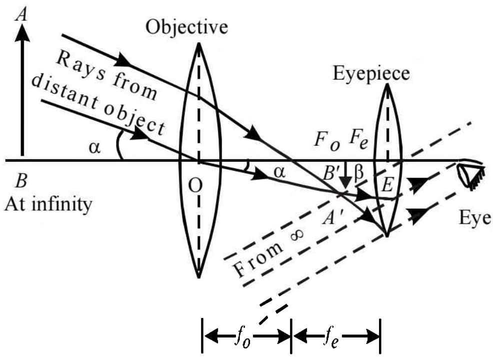
(ii) Magnet : Strong permanent magnet (for small generator) or an electromagnet (for large generator) with cylindrical poles in shape.

(iii) Slip rings : The two ends of the armature coil are connected to two brass rings R_1 and R_2. These rings rotate along with the armature coil.

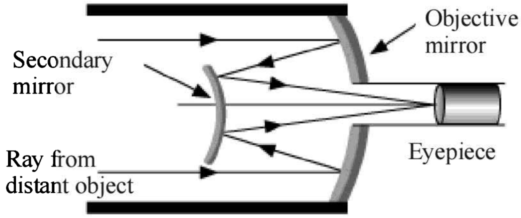
(iv) Brushes : Two carbon brushes (B_1 and B_2), are pressed against the slip rings. These brushes are connected to the load through which the output is obtained.



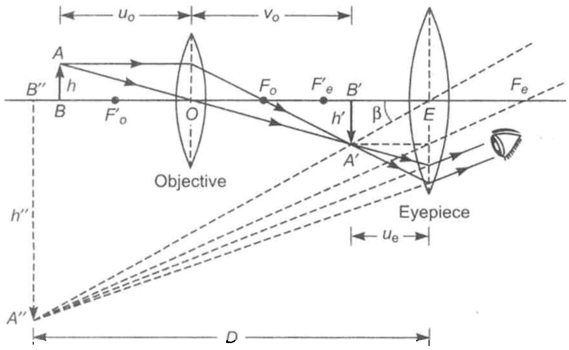
36. Ray diagram of an astronomical telescope in normal adjustment.



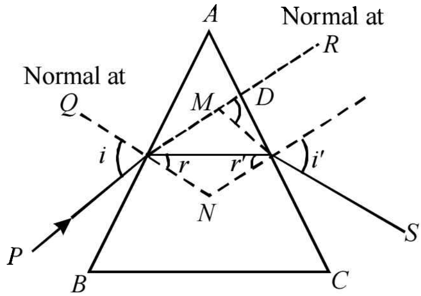
37. The ray diagram of reflecting telescope showing how ray coming from distant object are received at the eye-piece is shown in figure.



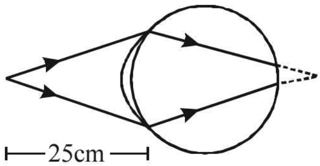
38. Ray diagram of a compound microscope :



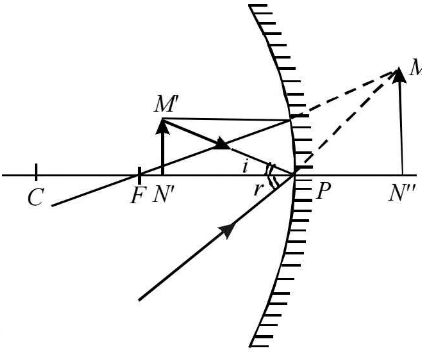
39. The ray diagram in the condition of minimum deviation is shown below. Angle of incidence $\angle i = 52°$.



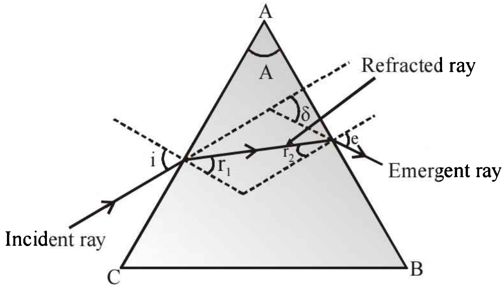
40. Ray diagram showing the formation of image in a far-sighted eye.



41. Formation of image by a concave mirror when the object is placed between the pole and the focus.



42. Ray passing through a prism.



43. By geometry, angle of incidence (i) of all three rays is 45°. Light suffer total internal reflection for which this angle of incidence is greater than critical angle.

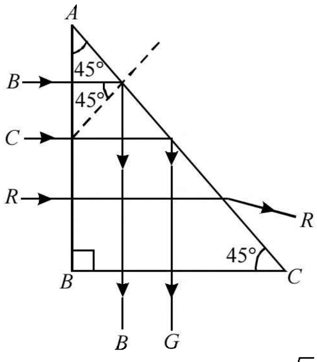
$$i > i_c$$

$\Rightarrow \quad \sin i > \sin i_c$

or $\quad \sin 45° > \sin i_c$

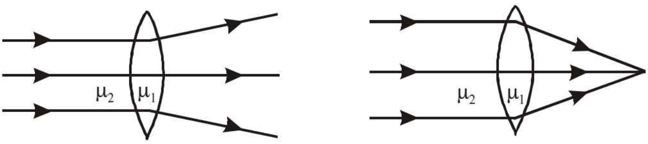
or $\quad \dfrac{1}{\sin 45°} < \dfrac{1}{\sin i_c}$

$$\sqrt{2} < \mu$$

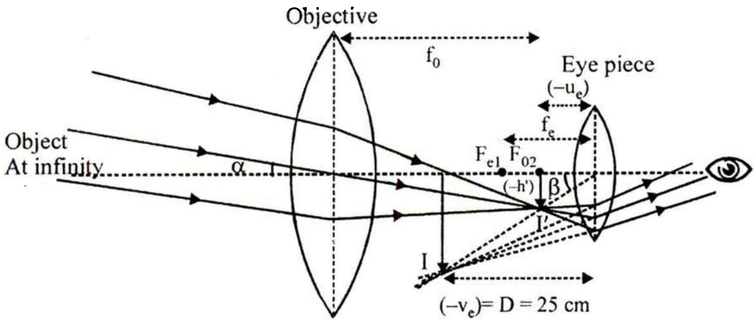


Total internal reflection takes place on AC for rays with $\mu > \sqrt{2} = 1.414$ i.e., green and blue colour whereas red undergoes refraction.

44. (i) Ray diagram : for $\mu_2 > \mu_1$ (ii) Ray diagram : for $\mu_2 < \mu_1$



45. Ray diagram of a refracting type telescope.



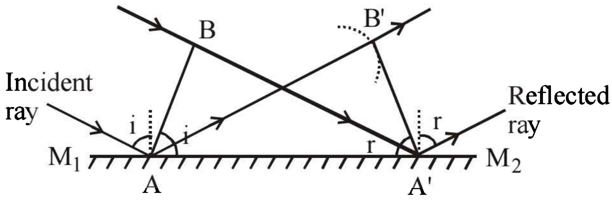
46. A wavefront is defined as the continuous locus of all the particles of a medium, which are vibrating in the same phase or it is a surface of constant phase.

Huygen's principle:

(1) Every points on the given wavefront (called primary wavefront) acts as a fresh source of new disturbance (secondary wavelets), which travel in all directions with the velocity of light in the medium.

(2) A surface touching these secondary wavelets, tangentially in the forward direction at any instant gives the new wavefront at that instant. This is called secondary wavefront.

Reflection by Huygen's principle:



AB is a plane wavefront incident on a plane mirror M_1M_2 at $\angle BAA' = \angle i$. Let the secondary wavelet from B strike M_1M_2 at A' in t seconds.

$\therefore$ $BA' = c \times t$ where c is the velocity of light in the medium.

The secondary wavelets from A will travel the same distance $c \times t$ in the same time, meet at B'. So that

$AB' = c \times t$

A'B' represents the secondary wavefront (reflected wavefront) after t seconds.

In figure,

angle of incidence, $i = \angle BAA'$.

and angle of reflection, $r = \angle B'A'A$.

In triangle AA'B and AA'B', AA' is common.

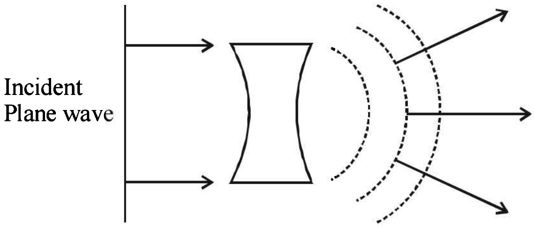
$BA' = AB' = ct$ and $\angle B = \angle B' = 90°$.

So, the triangles are congruent.

$\therefore$ $\angle BAA' = \angle B'A'A$.

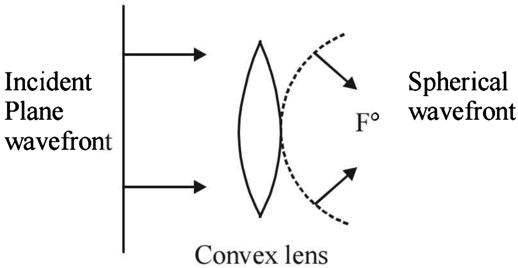
i.e., $\angle i = \angle r$ which is the first law of reflection.

47. Refraction of a plane wave by a concave lens:



Thus, the shape of a plane wavefront after refraction through a concave lens is spherical.

48. Diagram showing refraction of a plane wavefront



49. Critical angle of ray 1:

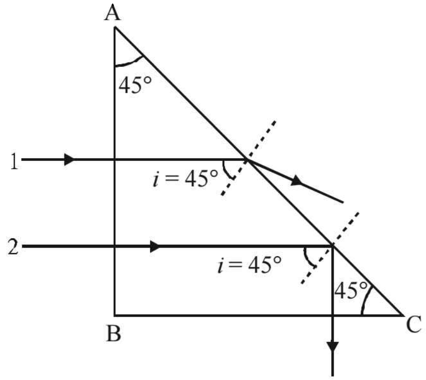
$\sin(c_1) = 1/\mu_1 = 1/1.35$

$\Rightarrow c_1 = \sin{-1}(1/1.35) = 47.73°$

Similarly, critical angle of ray 2:

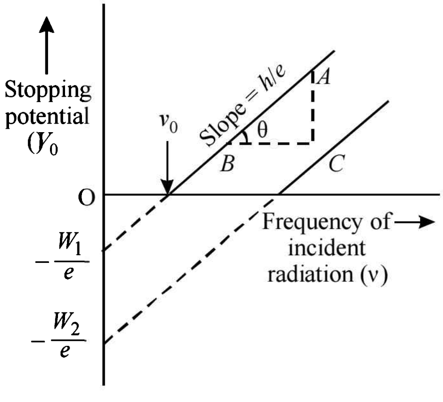
$\sin(c_2) = 1/\mu_2 = 1/1.45 \Rightarrow c_2 = \sin{-1}(1/1.45) = 43.6°$

Both the rays will fall on the side AC with angle of incidence (i) equal to 45°.

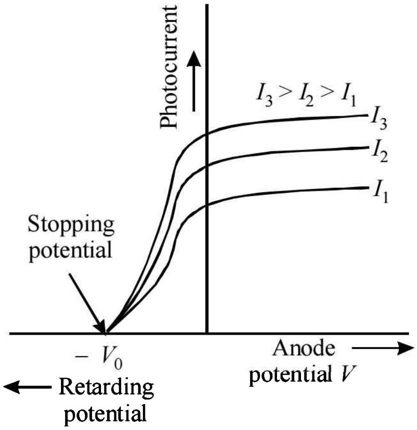


Critical angle of ray 1 is greater than that of i. Hence, it will emerge from the prism, as shown in the figure. Critical angle of ray 2 is less than that of i. Hence, it will be internally reflected.

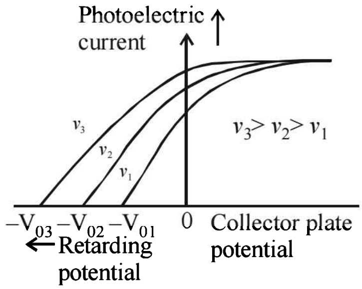
50. The variation of stopping potential with frequency of incident radiation is shown below.



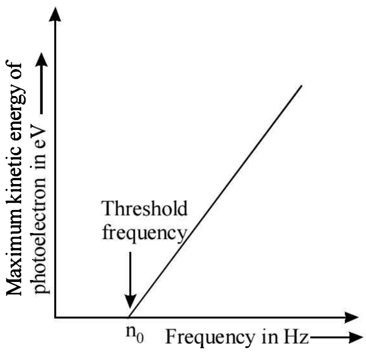
51. The variation of photocurrent for different intensities at constant frequency is shown below.



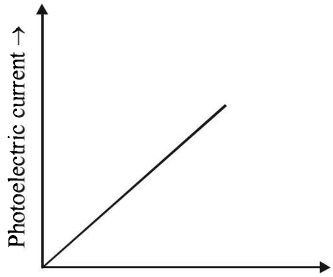
52. Graph of variation of photoelectric current with collector plate potential.



53. Graph between the frequency of incident radiation and the maximum kinetic energy of the electrons emitted.



54. Graph of photoelectric current versus intensity of light



55. The fringe width in Young's double slit experiment is given by

$$\beta = \frac{\lambda D}{d}$$

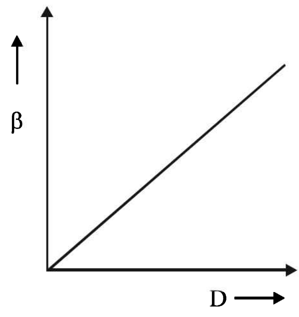
where λ = wavelength of source

D = distance between the slits and screen

d = distance between the slits

$\Rightarrow \beta \propto D$

The variation of fringe width with distance of screen from the slits is given by the graph shown below:

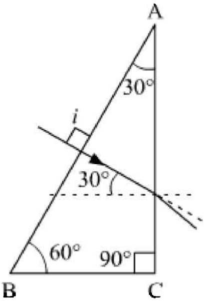


It is a linear graph with slope equal to λ/d, So. for the fringe width to vary linearly with distance of screen from the slits, the ratio of wavelength to distance between the slits should remain constant. Therefore, it is advised to take wavelengths of incident light nearly equal to the width of the slit.

56. Here, refractive index of the material of prism, $\mu = 1.5$

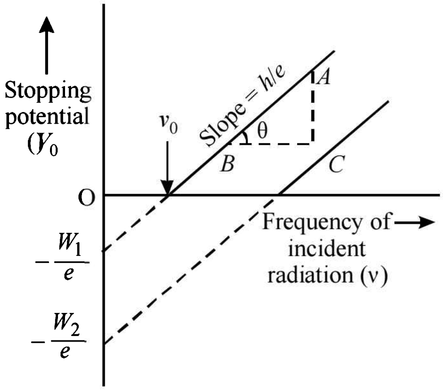
As we know, $\mu = \frac{1}{\sin i_c}$

$\Rightarrow \sin i_c = \frac{1}{\mu} = \frac{1}{1.5} = 0.66$



And we know, $\sin 30° = 0.5$
i.e., $i_c > 30°$
Thus, here light will emerge out from face AC.

57. The variation of stopping potential with frequency of incident radiation for two photosensitive materials A and B having threshold frequencies $v_A > v_B$ is shown below.



From the graph, it is very clear that

(i) the stopping potential is inversely proportional to the threshold frequency, hence the stopping potential is higher for metal B.

(ii) the slope of the graph does not depend on the nature of the material used

As we know, from Einsteins photoelectric equation,

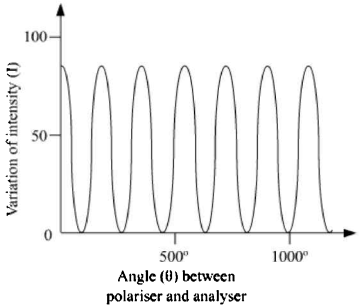
$$K_{max} = hv - \phi_0 = eV_0$$

Dividing the whole equation by e, we get

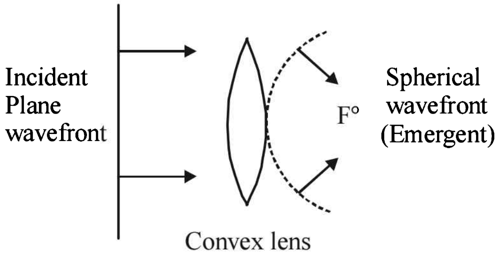
$$\frac{hv}{e} - \frac{\phi_0}{e} = V_0$$

From the above equation, the slope of the graph is $\frac{h}{e}$ (on comparing with the straight line equation). Thus, we see that the slope is independent of the nature of the photoelectric material.

58. (ii)



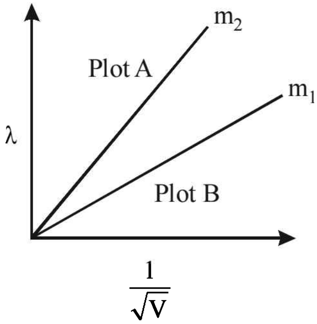
59. Diagram showing how the incident wavefront traverses through the lens.



60. The de Brogile wavelength is given by

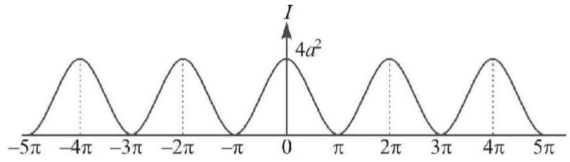
$\lambda = \dfrac{h}{\sqrt{2mqV}}$ Where h - Planck's constant

The slope of the graph λ versus $\dfrac{1}{\sqrt{V}}$ is $\dfrac{h}{\sqrt{2mq}}$



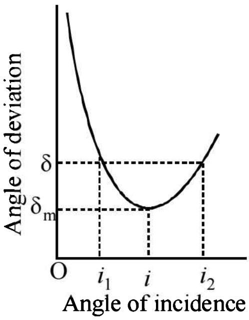
The slope of the smaller mass (m_2) is larger; therefore, plot A in the above graph is for mass m_2

61. Graph of intensity distribution in Young's double-slit experiment



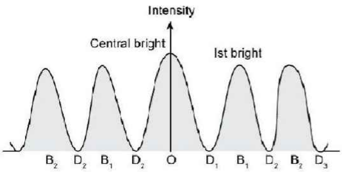
Variation of I with ϕ.

62. (i) If the angle of incidence is increased gradually, then the angle of deviation first decreases, attains a minimum value (δ_m) and then again starts increasing.

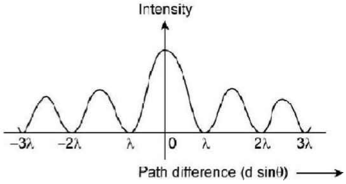


63.

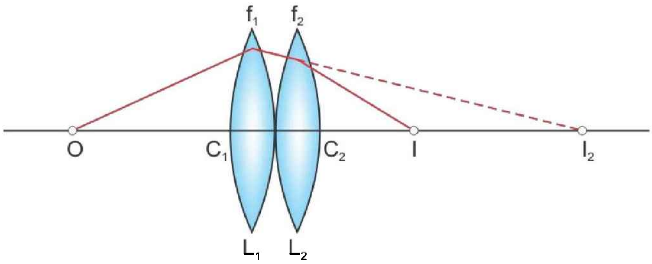
Intensity pattern for single slit diffraction



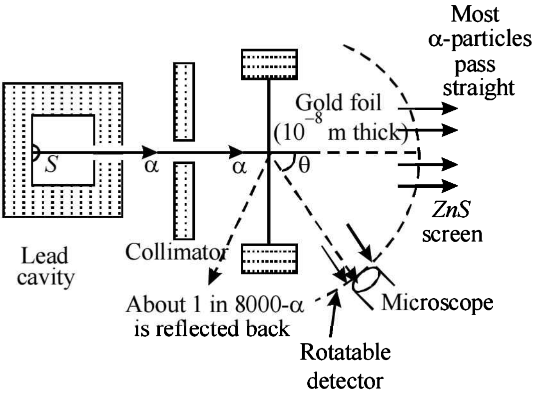
Intensity pattern for double slit diffraction



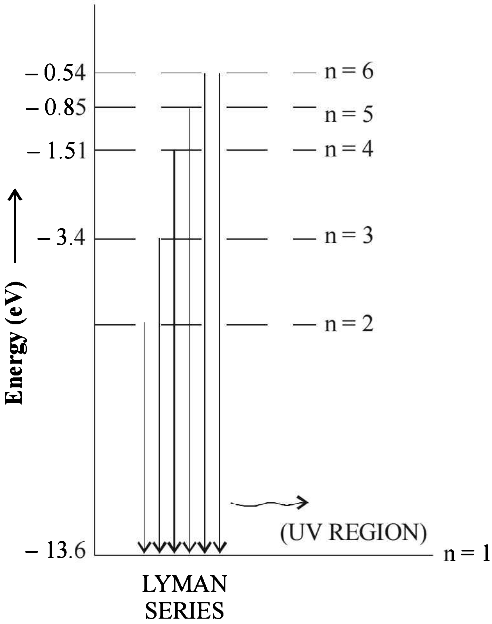
64. (a) **Ray diagram to show the image formation by a combination of two thin convex lenses in contact:**



65. Given figure shows a schematic diagram of Geiger-Marsden experiment.

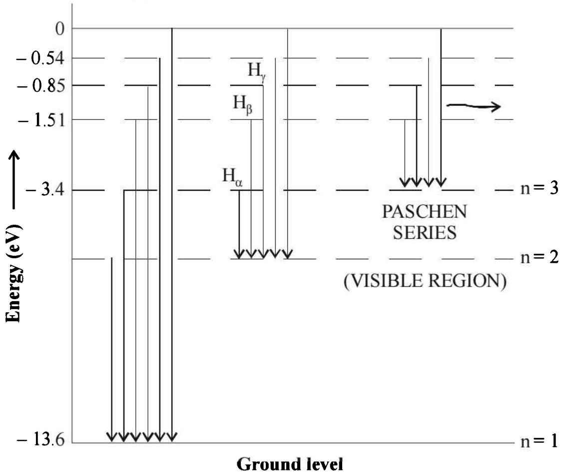


66. Energy level diagram for the Lymann series :



The Lymann series of the hydrogen atom is produced when transitions take place from higher orbits to the first orbit $n_1 = 1$

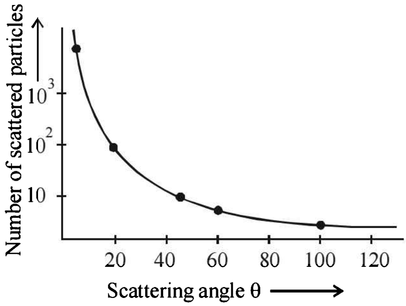
67. Energy level diagram for the Paschen series



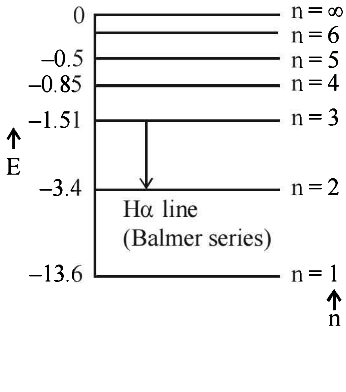
The Paschen series of the hydrogen atom is produced when transitions take place from higher orbits to the third orbit.

i.e., $n_1 = 3$ and $n_2 = 4, 5, 6,$ .... so on.

68.

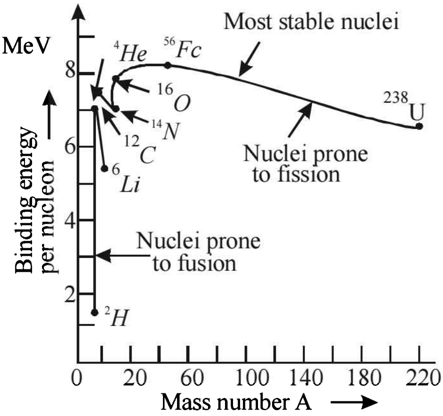


69. **Energy level diagram :** The Balmer series is produced when transition take place from higher orbits to n = 2 as shown in the figure.

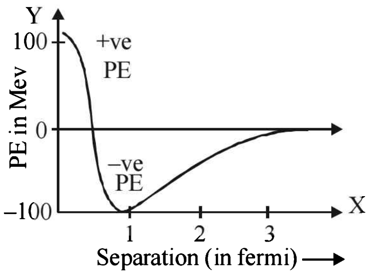


GP_3166

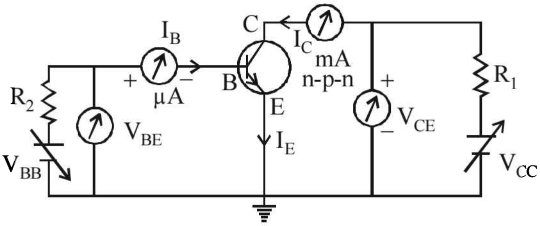
70. The binding energy per nucleon curve is shown below.



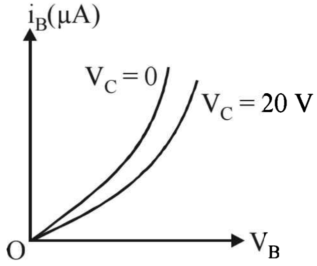
71. Plot of potential energy between a pair of nucleons as a function of their separation :



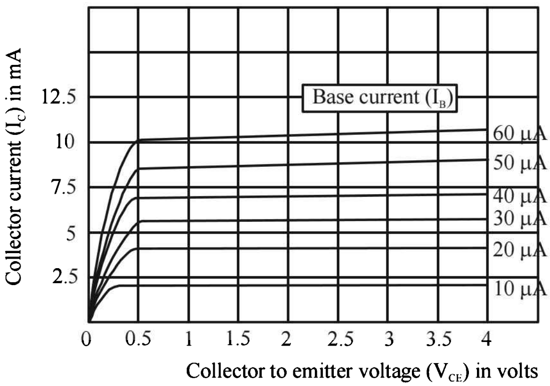
72. The circuit diagram of n-p-n transistor in CE configuration is as shown below



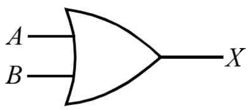
(i) **Input characteristics :** It is a graph between base voltage V_B and the base current I_B for a constant value of collector voltage V_C.



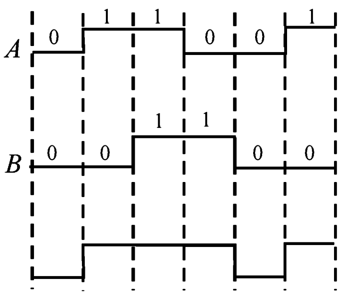
(ii) Output characteristics : It is a graph between collector voltage V_{CE} and collector current Ic for a constant value of base current I_B.



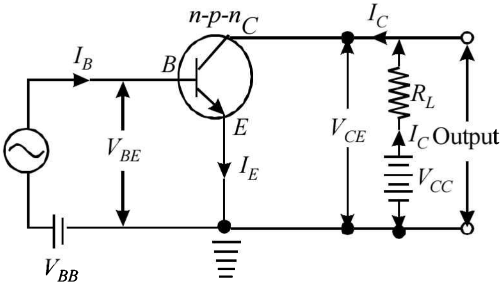
73. Equivalent gate is OR gate.
Logic symbol of OR gate and the output waveform is shown below.
Symbol of OR gate.



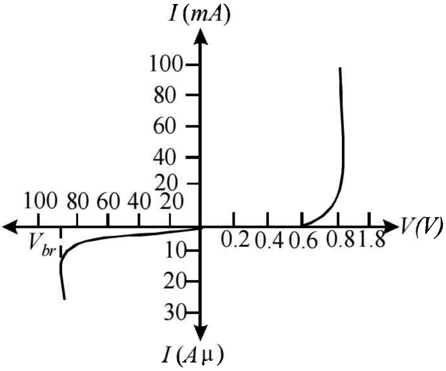
Output wave front



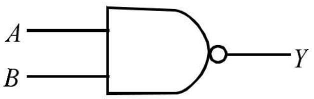
74. Circuit diagram of a common emitter transitor amplifier



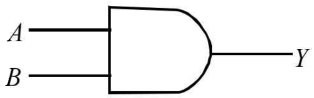
75. *V-I* characteristic of a *p-n* junction diode



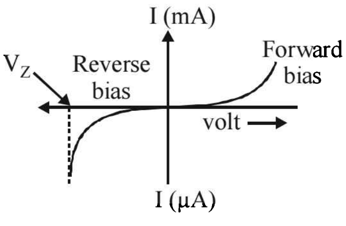
76. Logic circuit of NAND gate.



77. Logic circuit of a AND gate

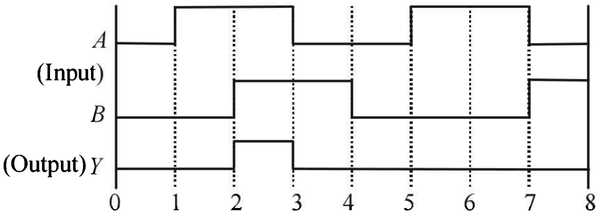


78. Zener diode is operated in the reverse breakdown region. The voltage across it remains constant.
V-I characteristic of a zener diode

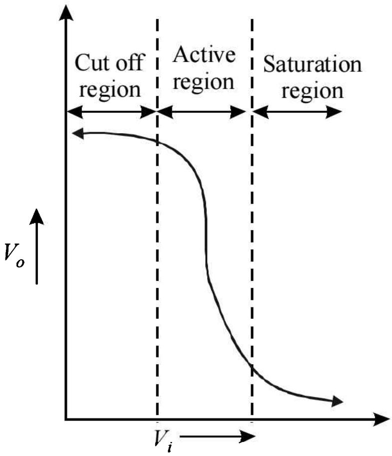


79. The output for an AND gates is given as

For 0 to 1, $A=0$, $B=0$, hence, $y=0$
For 1 to 2, $A=1$, $B=0$, hence, $y=0$
For 2 to 3, $A=1$, $B=1$, hence, $y=1$
For 3 to 4, $A=0$, $B=1$, hence, $y=0$
For 4 to 5, $A=0$, $B=0$, hence, $y=0$
For 5 to 6, $A=1$, $B=0$, hence, $y=0$
For 6 to 7, $A=1$, $B=0$, hence, $y=0$
For 7 to 8, $A=0$, $B=1$, hence, $y=0$



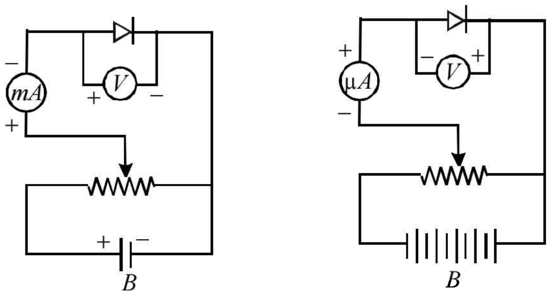
80. The transfer characteristic curve of base biased transistor of CE configuration are shown below.



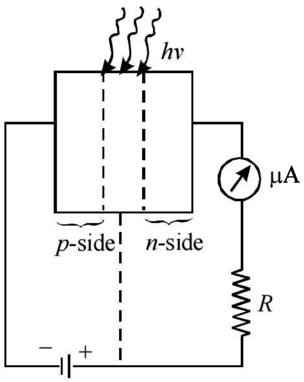
81. Circuit diagram of (i) forward biased and (ii) reverse biased *p-n* junction diode is shown below.

(i) Circuit diagram of forward biased p-n junction diode.

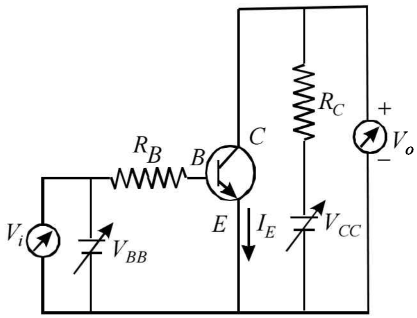
(ii) Circuit diagram of reverse biased p-n junction diode



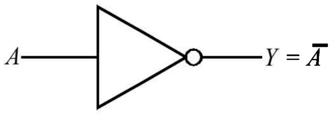
82. Circuit diagram of illuminated photodiode in reverse bias is shown below.



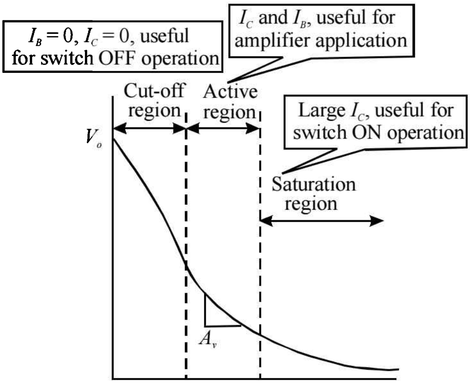
83. Circuit diagram of a base biased transistor in CE configuration are shown below.



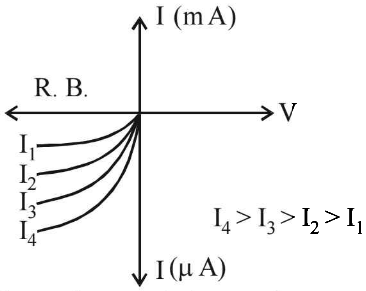
84. Logic circuit of a NOT gate.



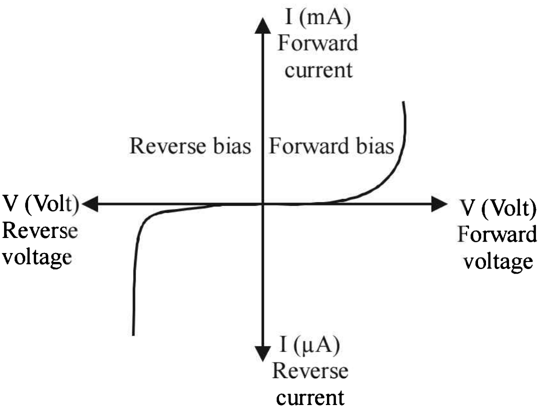
85. Transfer characteristics of a common emitter n-p-n transistor.



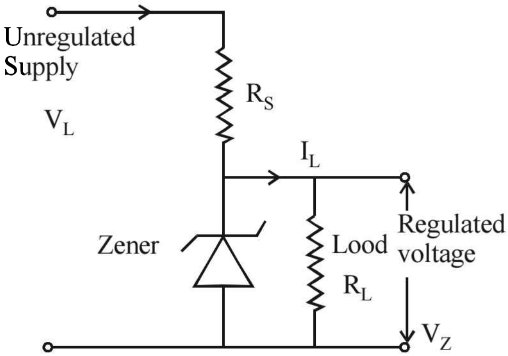
86. Graph showing variation of intensity of current with illumination intensity.



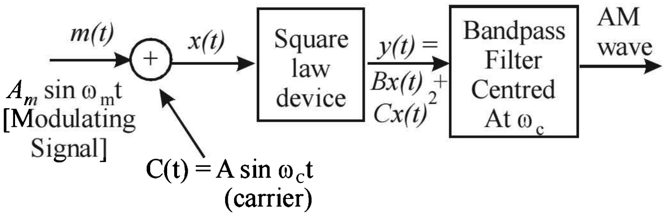
87. Current – Voltage characteristics graph for GaAs:



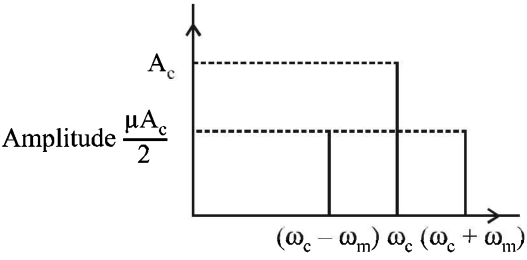
88. Zener diode as voltage regulator:



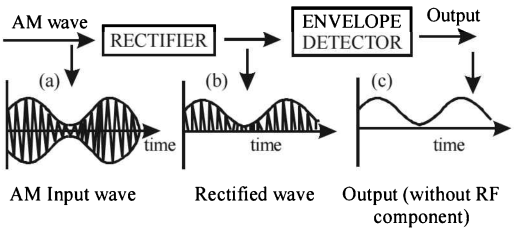
89. Block diagram of a simple modulator



90. A plot of amplitude versus ω for an amplitude modulated wave.

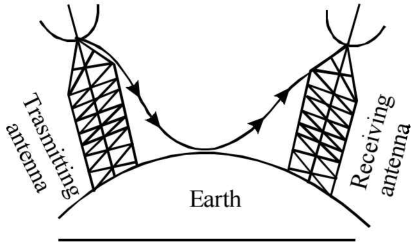


91. The block diagram is as shown below :

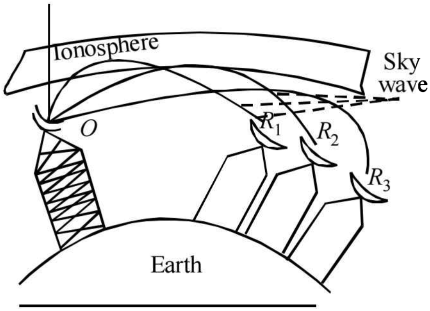


92. Schematic diagram of showing propagation of

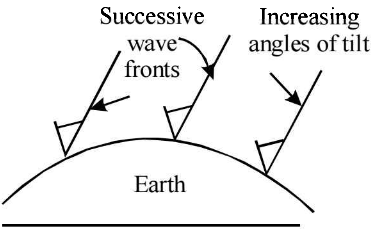
(i) Ground wave



(ii) Sky wave



(iii) Space wave



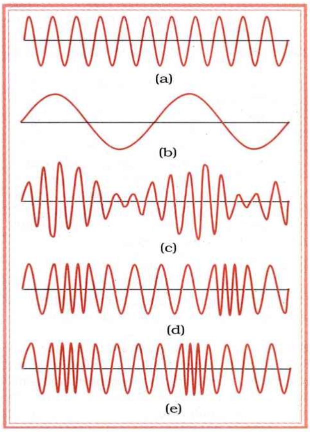
93. (a) Carrier wave

(b) Modulating wave

(c) AM wave

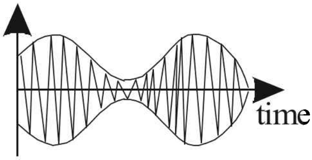
(d) FM wave

(e) PM wave

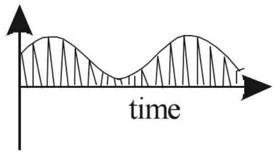


94. Wave forms for the :

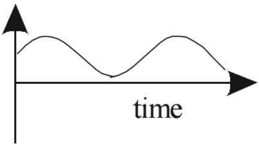
(i) Input AM wave at A



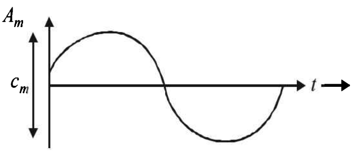
(ii) Output B at the rectifier



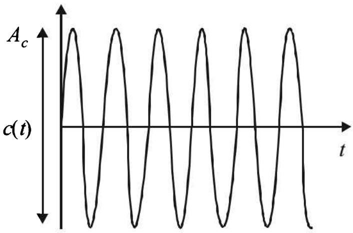
(iii) Output signal at C



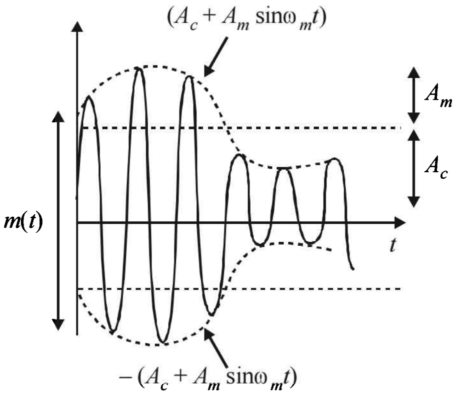
95. Amplitude modulated signal is obtained by superposing a modulating signal over a sinusoidal carrier wave is shown in the figure given below



Modulating Signal



Carrier Wave

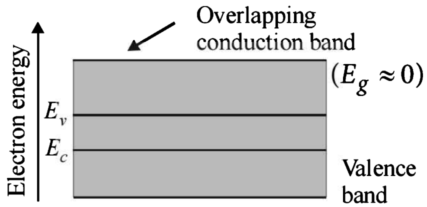


Amplitude Modulated Wave

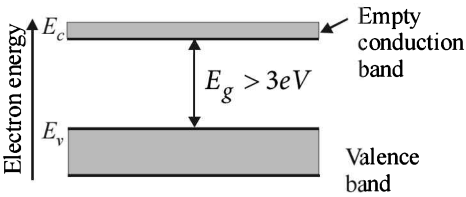
96. In **conductors**, the conduction and the valence band overlap each other.

As the temperature increase, the conductivity of the conductors decreases due to increase in the thermal motion of the free electrons.

Energy band diagram for a conductor

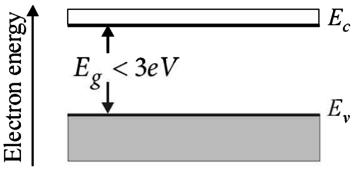


Energy band diagram for an insulator



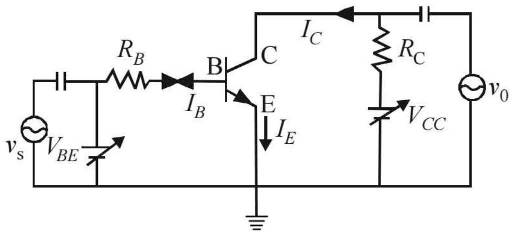
Here, the valence band is completely filled and the conduction band is empty. The energy band gap of the insulator is quite large. So, on increasing the temperature, the electrons of the valence band are not able to reach the conduction band. Therefore, electrical conduction in these materials is almost impossible.

Energy band diagram for a semiconductor

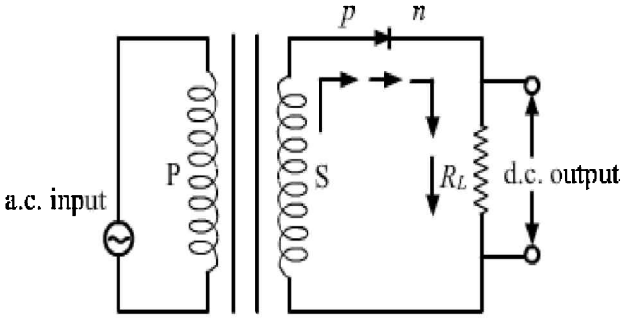


In **semiconductors,** the valence band is totally filled and the conduction band is empty but the energy gap between conduction band and valence band is quite small. At 0 K, electrons are not able to cross even this small energy gap and, hence, the conduction band remains totally empty. At room temperature, some electrons in the valence band acquire thermal energy greater than energy band gap, which is less than 3 eV and jump over to the conduction band where they are free to move under the influence of even a small change in the temperature. As the temperature increases more and more electrons crosses the band gap and hence conductivity increases.

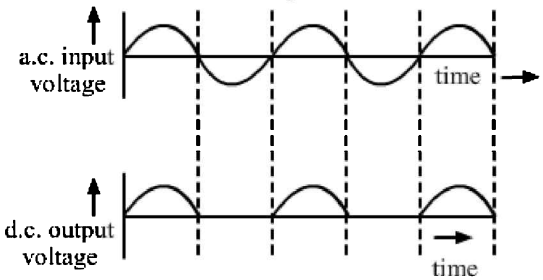
97. The circuit diagram of an n-p-n transistor amplifier in CE configuration is given below:



98. The circuit diagram for a half wave rectifier is shown below :

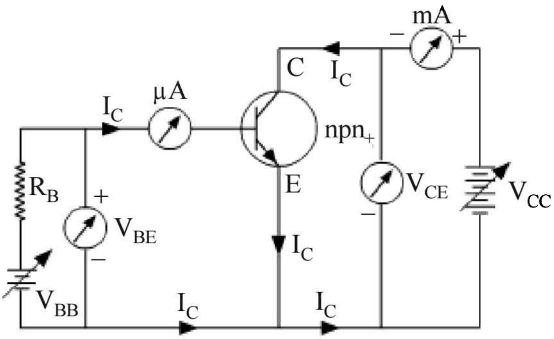


Working : During the positive half cycle of the input a.c., the p-n junction is forward biased i.e., the forward current flows from p to n and the diode offers a low resistance path to the current. Thus, we get output across-load i.e. a.c input will be obtained as d.c output.



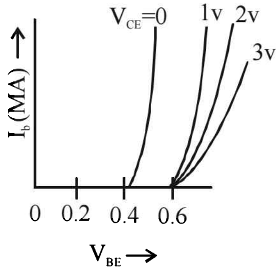
During the negative half cycle of the input a.c., the p-n junction is reversed biased i.e, the reverse current flows from n to p, the diode offers a high resistance path to the current. Thus, we get no output across-load.

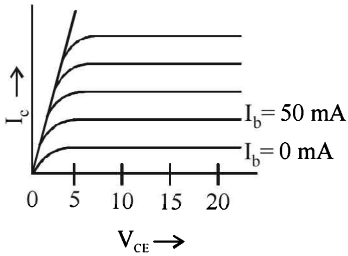
99. (ii) Circuit diagram for studying the input and output characteristics



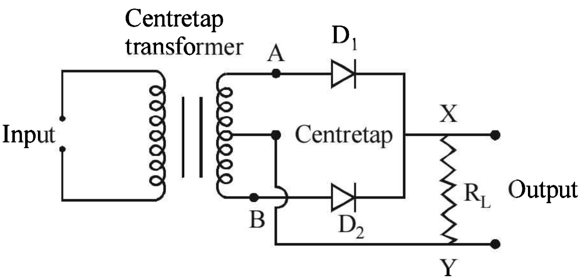
Input characteristics. Curve is drawn between base current I_b and emitter base voltage V_{EB} at constant collector emitter voltage V_{CE}

Output characteristics. Variation of collector current I_C with V_{CE} can be noticed for V_{CE} between 0 to 1 volt only.



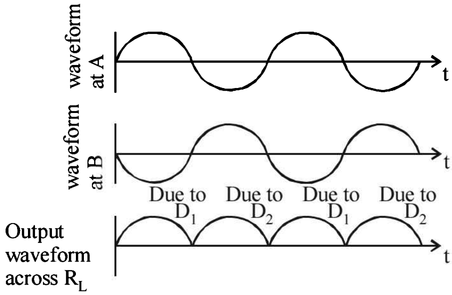


100. (b) **P-N junction diode as a full wave rectifier :** The circuit uses two diodes connected to the ends of a centre tapped transformer. The voltage rectified by the two diodes is half of the secondary voltage i.e., each diode conducts for half cycle of input but alternately so that net output across load comes as half sinusoids with positive values only.

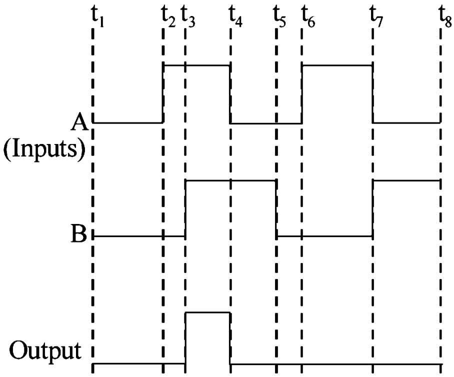


For positive cycle diode D_1 conducts (FB) but D_2 is being out of phase is reverse biased and does not conduct. Thus output across R_L is due to D_1 only. In negative cycle of input D_1 is R.B.

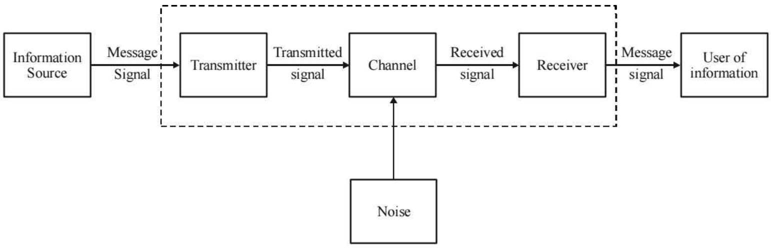
but D_2 is F.B. and conducts as with respect to centretap point A is negative but B is positive. Hence output across R_L is due to D_2.



101. The corresponding output waveform of the input waveforms A and B for 'AND' gate.



102. Block diagram of a generalised communication system:



□□□

CHAPTER 5

What is the law/rule/principle of ......?

(A) Electrostatics

1. What is Gauss's law ? **[Delhi 2008, 2009, All India 2011C, Foreign 2012]**

2. State Coulomb's law.

(B) Current Electricity

3. State Kirchhoff's rules. **[Foreign 2009, All India 2010, Delhi 2013, 2014]**

4. What is wheatstone bridge ?

5. What is Ohm's law ? Using the concept of drift velocity deduce it.

6. State the principle of working of a potentiometer. **[Foreign 2011, Delhi 2013, 2013C, 2016, All India 2015]**

7. Write the principle of working of a metre bridge. **[All India 2017]**

(C) Magnetism

8. State the underlying principle of a cyclotron. **[Delhi 2008, 2011C, 2014]**

9. State Biot-Savart law. **[All India 2006, Delhi 2007, 2009, 2011, 2013C]**

10. State Curie law in magnetism.

11. State Gauss's law in magnetism.

12. State the underlying principle of working of a moving coil galvanometer. **[All India 2010, Delhi 2010, 2015, 2016]**

13. State Coulomb's law for magnetic force.

14. State Ampere's circuital law.

[All India 2010C, Foreign 2010, Delhi 2014, 2015]

(D) EMI, Alternating Current and EM waves

15. State Lenz's law. **[All India 2009, 2011, Delhi 2013]**

16. State Faraday's laws of electromagnetic induction. Express it mathematically.

17. Explain working principle of a.c. generator.

18. State the underlying principle of a transformer.

[All India 2010, 2011, 2012, 2016, Delhi 2011, Foreign 2012]

(E) Optics

19. State Snell's law of refraction.

20. What is Rayleigh's law of scattering?

21. What is Brewster's law?

22. What is the superposition principle?

23. State de-Broglie hypothesis. **[Delhi 2012]**

24. State law of Malus. **[All India 2016]**

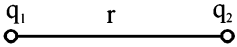
25. State Huygens' principle. **[All India 2016]**

SOLUTIONS

1. **Gauss's law :** The surface integral of electrostatic field $(\vec{E})$ produced by any source over any closed surface S in vacuum, or the total electric flux over the closed surface in vacuum is $\frac{1}{\varepsilon_0}$ times of the total charge (Q) contained inside S.

i.e., Electric flux $\phi_E = \oint \vec{E}.d\vec{S} = \frac{Q}{\varepsilon_0}$

2. **Coulomb's law :** The force of interaction between any two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.



Mathematically, $F \propto q_1 q_2$

and $F \propto \frac{1}{r^2}$ $\therefore$ $F \propto \frac{q_1 q_2}{r^2}$

or, $F = k\frac{q_1 q_2}{r^2}$

where, k = electrostatic force constant

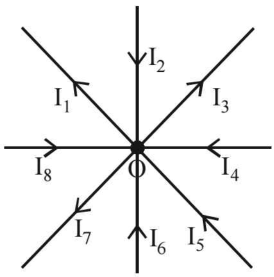
$= \frac{1}{4\pi\varepsilon_0}$ in free space and $k = \frac{1}{4\pi\varepsilon}$ in any medium

where, ε is the absolute electric permittivity of the medium and ε_0 is the absolute electric permittivity of free space or vacuum.

3. **Kirchhoff's 1st rule or Junction rule:** The algebraic sum of electric currents at any junction of electric circuit is equal to zero.

i.e., $\Sigma I = O$

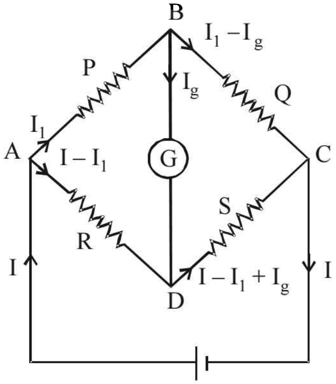
or, $I_1 + I_3 + I_7 - I_2 - I_4 - I_5 - I_6 - I_8 = 0$



Kirchhoff's IInd rule or voltage law : In any closed mesh of electric circuit, the algebraic sum of emfs of cells and the product of currents and resistances is always equal to zero.

i.e., $\Sigma\varepsilon + \Sigma IR = 0$

4. Wheatstone's bridge is an arrangement of four resistances used to measure one of them in terms of other three.



The currents in different branches are shown in the figure according to Kirchhoff's first law.

In the loop ABDA applying Kirchhoff's second law,

$$I_1P + I_gG - (I - I_1)R = 0 \quad \text{..........(1)}$$

[G = Galvanometer resistance]

In the loop BCDB, $(I_1 - I_g)Q - (I - I_1)S - I_gG = 0$ .... (2)

In the balanced condition of the bridge the value of R is so adjusted that the galvanometer shows no deflection, i.e. $I_g = 0$

$\therefore$ Putting $I_g = 0$ in (1) and (2)

$$I_1P - (I - I_1)R = 0 \Rightarrow I_1P = (I - I_1)R \quad \text{...........(3)}$$

$$I_1Q - (I - I_1)S = 0 \Rightarrow I_1Q = (I - I_1)S \quad \text{..........(4)}$$

Dividing (3) and (4) we get, $\dfrac{P}{Q} = \dfrac{R}{S}$

This is the condition of balanced wheatstone bridge.

5. $I \propto v_d$ and $v_d \propto E$ and $E \propto V$

$\therefore I \propto V$ or $V = RI$ which is Ohm's law.

$$v_d = -\frac{eE\tau}{m} \text{ and } E = -\frac{V}{\ell} \quad \therefore v_d = \frac{eV\tau}{m\ell} \text{ and } I = nAev_d$$

$$\therefore \quad I = neA\left(\frac{eV}{m\ell}\right)\tau = \left(\frac{ne^2A\tau}{m\ell}\right)V = \frac{1}{R}V$$

or $V = IR$ where $R = \dfrac{m\ell}{nAe^2\tau}$ is a constant for a particular conductor at a particular temperature and is called the resistance of the conductor.

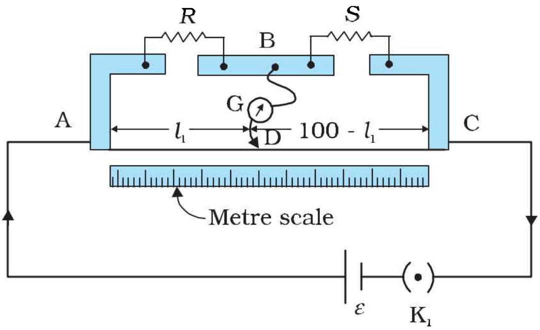
6. **Principle of working of a potentiometer:** When a steady current flows through the potentiometer wire then, the potential difference across the uniform wire is directly proportional to the length of the part across which the potential is measured.
   Potentiometer is a device used to measure emf of a given cell and to compare emf's of cells. It is also used to measure internal resistance of a given cell.

7. **Principle of working of a meter bridge:** Meter bridge works on the principle of Wheatstone bridge. According to the principle, the balancing condition
   for balancing length l_1,

$$\frac{R}{S} = \frac{P}{Q} = \frac{\sigma l_1}{\sigma(100 - l_1)}$$

$$\Rightarrow \quad \frac{R}{S} = \frac{l_1}{100 - l_1} \Rightarrow R = S\frac{l_1}{100 - l_1}$$

   where σ is the resistance per unit length of the wire and l_1 is the length of the wire from one end where null point is obtained. The bridge is most sensitive when null point is somewhere near the middle point of the wire. This is due to end resistances.

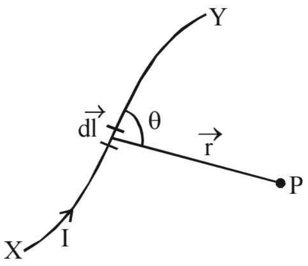


A meter bridge. Wire AC is 1 m long.

8. **Principle of cyclotron :** A positive ion can acquire sufficiently large energy with a comparatively smaller alternating potential difference by making them to cross the same electric field again and again by making use of a strong magnetic field.

9. **Biot-Savart's law:–** The strength of magnetic field or magnetic flux density at a point P (dB) due to current element dl depends on,

(i) $dB \propto I$
(ii) $dB \propto dl$
(iii) $dB \propto \sin\theta$
(iv) $dB \propto \dfrac{1}{r^2}$,



Combining,(i) to (iv) $dB \propto \dfrac{Idl\sin\theta}{r^2}$

$$\Rightarrow dB = k\frac{Idl\sin\theta}{r^2} \qquad [k = \text{Proportionality constant}]$$

In S.I. units, $k = \dfrac{\mu_0}{4\pi}$ where μ_0 is called permeability of free space.

$$\mu_0 = 4\pi \times 10^{-7}\ TA^{-1}m$$

$$\therefore \qquad dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

10. **According to Curie law,** intensity of magnetisation (I) of a magnetic material is directly proportional to magnetic induction (B) and inversely proportional to the temperature (T) of the material.

i.e., $I \propto \dfrac{B}{T}$ or $I \propto \dfrac{H}{T}$ (since $B \propto H$)

or $\dfrac{I}{H} \propto \dfrac{1}{T}$ i.e., $\chi_m \propto \dfrac{1}{T}$ or $\chi_n = \dfrac{C}{T}$.

where C is a constant known as Curie constant.

11. According to Gauss's law for magnetism, the net magnetic flux (ϕ_B) through any closed surface is always zero.

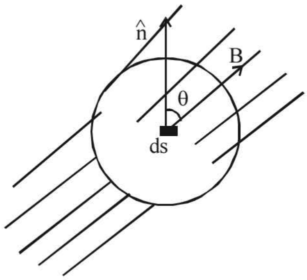
Suppose a closed surface S is held in a uniform magnetic field $\vec{B}$.

Consider a small element of area $\vec{ds}$ on this surface.

Magnetic flux through this element $d\phi_B = \vec{B}.\vec{ds}$.

If the area elements are really small, then the net magnetic flux through the surface is,

$$\phi_B = \int_S \vec{B}.\vec{ds} = 0.$$



12. **Principle of working of a moving coil galvanometer:** The current carrying coil placed in normal magnetic field experiences a torque which is given by

$$\tau = NIAB$$

where, N = number of turns
I = current
A = area of coil
B = magnetic field

13. The force of attraction or repulsion between two magnetic poles of strengths m_1 and m_2 separated by a distance r is directly proportional to the product of pole strengths and inversely proportional to the square of the distance between their centres.

i.e., $F \propto \frac{m_1 m_2}{r^2}$ or $F = K\frac{m_1 m_2}{r^2}$

where K is the magnetic force constant.

or $F = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^2}$

where μ_0 is called absolute magnetic permeability of free space.

14. The line integral of magnetic field $\vec{B}$ around any closed path in vacuum is μ_0 times the total current through the closed path.

Mathematically, $\oint \vec{B}.d\vec{\ell} = \mu_0 I$.

15. **Lenz's law :** Whenever the magnetic flux linked with a circuit changes, an induced emf is produced and the direction of the induced current is such that it opposes the cause which produces it.

16. **Faraday's laws of electromagnetic induction:**

First law: Wherever there is a change in magnetic flux associted with a coil, an e.m.f. is induced in the coil. It last so long as the change continues.

Second law: The induced e.m.f. is directly proportional to the rate of change of magnetic flux of the coil and has a direction opposite to that of the change of magnetic flux.
Mathematically,

$$e \propto -\frac{d\phi}{dt} \Rightarrow e = -k\frac{d\phi}{dt} \quad [k = 1 \text{ for all system of units}]$$

$$\therefore \quad e = -\frac{d\phi}{dt}$$

17. **Principle of a.c. generator:** A dynamo or generator is a device which converts mechanical energy into electrical energy. It is based on the principle of electromagnetic induction.
18. **Principle of transformer:** A transformer is based on the principle of mutual induction i.e., whenever the amount of magnetic flux linked with a coil changes, an emf is induced in the neighbouring coil.
19. The ratio of the sine of the angle of incidence to the sine of angle of refraction for a pair of media is constant. $\frac{\sin i}{\sin r} = n_{21}$
20. The amount of scattering of light is inversely proportional to the fourth power of wavelength $\left(\frac{1}{\lambda^4}\right)$.
21. **Brewester's laws:** $\mu = \tan i_p$ where i_p is the polarising angle and μ is the refractive index of the denser medium.
22. **Super position principle:** At a particular point in the medium, the resultant displacement produced by a number of waves is the vector sum of the displacements produced by each of the waves.
23. **De-Broglie hypothesis:** Material particles in motion should display wave like properties.
24. **Law of Malus :** It states that when a completely plane polarised light beam is incident on an analyser, the intensity of the emergent light varies as the square of the *cosine* of the angle between the plane of transmission of the analyser and the polariser. i.e., $I = I_0 \cos^2 \phi$
25. **Huygens' Principle** is based on the following assumptions:
    (i) Each point on the primary wavefront acts as a source of secondary wavelets, sending out disturbances in all directions in a similar manner as the original source of light does.
    (ii) The new position of the wavefront at any instant (called secondary wave front) is the envelope of the secondary wavelets at that instant.

□□□

CHAPTER 6

What are the properties/ functions/ uses/effects of ......?

(A) Electrostatics

1. A graph showing the variation of Coulomb's force (F) versus $1/r^2$, where r is the distance between the two charges of each pair of charges: (1μC, 2μC) and (1μC, – 3μC). Interpret the properties obtained. **[All India 2011C]**
2. What are the applications of Gauss's law
3. What are the uses of capacitor? **[Foreign 2012]**
4. State the effect of filling a dielectric in a capacitor with battery connected.
5. State the effect of filling a dielectric in a capacitor after disconnecting the battery.
6. How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased? **[Delhi 2016]**

(B) Current Electricity

7. Write any two factors effecting internal resistance of a cell. **[All India 2010]**
8. Write two characteristics of manganin which make it suitable for making standard resistances. **[Delhi 2011]**
9. State the condition in which terminal voltage across a secondary cell is equal to its e.m.f
10. Which property of nichrome is used to make standard resistance coils ? **[All India 2013C]**
11. Write two possible causes for one sided deflection in a potentiometer experiment. **[Delhi 2013]**

12. Write two factors by which current sensitivity of a potentiometer can be increased. **[All India 2015]**

(C) Magnetism

13. What is the function of radial magnetic field and the soft iron core used in moving coil Galvanometer? **[Delhi 2013C]**
14. Write two characteristics of a material used for making permanent magnets? **[Foreign 2007, Delhi 2009, 2010]**
15. What are the properties of permanent magnets.
16. Define the properties of diamagnetic, paramagnetic and ferromagnetic substance.
17. Write two properties of a material suitable for making (a) a permanent magnet, and (b) an electromagnet. **[All India 2017]**

(D) EMI, Alternating Current & EM Waves

18. What are the applications of eddy current ?
19. Name any four causes of energy loss in an actual transformer. **[All India 2009C, 2011, 2012, 2013C, Delhi 2009C, 2011]**
20. What is the function of a step-up transformer? **[All India 2011C, Delhi 2016]**
21. Mention the two characteristic properties of the material suitable for making core of a transformer. **[All India 2012]**
22. Write two uses of X-rays. **[Delhi 2010, Foreign 2010, 2011]**
23. Define the properties of electromagnetic waves.
24. Write two uses of infrared rays. **[Foreign 2010, 2011, All India 2011C]**
25. What are uses of electromagnetic waves.
26. Give one use of each of the following **[Delhi Board 2011C]**
    (i) Microwaves (ii) Ultraviolet rays
    (iii) Infrared rays (iv) Gamma rays

(E) Optics

27. State two drawbacks of astronomical type of telescope. **[Delhi 2008]**
28. Write two important advantages that the reflecting telescope has over a refracting type of telescope. **[Delhi 2008, 2010C, All India 2009, Foreign 2010]**
29. Write the properties of light.
30. Write two important limitations of a refracting type of telescope over a reflecting type of telescope. **[All India 2013]**
31. State the characteristics of image formed by plane mirror.

32. Write two main considerations required of an astronomical telescope. **[Delhi 2013C]**

33. What are the drawbacks of Huygens' wave theory?

34. State clearly, the three salient features observed in photoelectric effect, which can be explained on the basis of Einstein's photoelectric equation. **[All India 2010, Delhi 2012]**

35. Write two characteristic features observed in photoelectric effect which supports the photon pictures of electromagnetic radiation. **[Foreign 2012, Delhi 2012]**

36. Write two important observations of photoelectric effect which can be explained by Einstein's equation. **[All India 2013, 2013C]**

37. Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based. **[Delhi 2013]**

38. State three important properties of photons which describe the particle nature of electromagnetic radiation. **[Delhi 2013C]**

39. Write the necessary conditions to obtain sustained interference fringes. **All India 2015]**

40. What is the effect on the fringe width if the distance between the slits is reduced keeping other parameters same? **[All India 2015]**

(F) Atoms and Nuclei

41. State any two postulates of Bohr's theory of hydrogen atom. **[All India 2010C]**

42. What are the drawbacks of Rutherford's atomic model?

43. What are limitation of Bohr's model.

44. State the characteristics of nuclear force.

45. Write properties of α, β and γ-rays.

(G) Electronics and Communication systems

46. In a typical output characteristics of an n-p-n transistor in CE configuration. Show how these characteristics can be used to determine output resistance. **[All India 2008C, 2013]**

47. Give two applications of semiconductor devices?

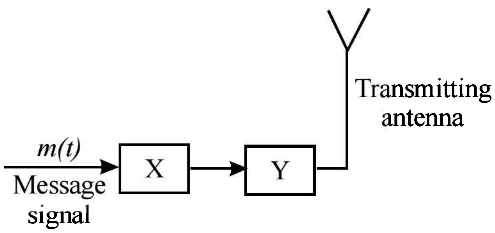
48. Give two advantages of LED's over the conventional incandescent lamps. **[All India 2010, 2011, Foreign 2012]**

49. Mention some uses of LEDs.

50. Mention few applications of logic gates.

51. Write the main use of the (i) photodiode (ii) Zener diode. **[All India 2010C]**

52. Mention a few advantages of semiconductor devices.
53. What is the function of a photodiode? **[All India 2013C]**
54. What are the important properties of material for selection of a solar cell material?
55. Under what condition does the transistor act as an amplifier? **[All India 2014]**
56. Write the function of each of the following used in communication system:
    (i) Transducer
    (ii) Repeater
    (iii) Transmitter **[All India 2009, 2012, 2014, Delhi 2010, 2012, 2013C, Foreign 2011]**
57. Give two examples of communication system which uses the space wave mode. **[Delhi 2010, 2013]**
58. Mention few disadvantages of using higher harmonics of a *sine* wave to form digital signal.
59. Write two uses of microwaves. **[Foreign 2011]**
60. Write the functions of the following in communication systems: **[Foreign 2011, Delhi 2012, All India 2014]**
    (i) Transmitter
    (ii) Modulator
61. What is the significance of modulation index?
62. Write three important factors which justify the need of modulating a message signal. **[All India 2011, Delhi 2012, 2013]**
63. Figure shows a block diagram of a transmitter identify the boxes *X* and *Y* and write their functions. **[Foreign 2012]**



64. Write the functions of the following in communication systems: **[All India 2014]**
    (i) Receiver
    (ii) Demodulator

65. What is the function of a 'Repeater' used in communication system? **[All India 2015]**

66. Write any three applications of the Internet used in communication systems. **[All India 2015]**

67. What is the role of a bandpass filter ? **[All India 2016]**

68. (a) Write the functions of the three segments of a transistor. **[Delhi 2016, All India 2017]**

69. Write the functions of each of the following: **[All India 2017]**

(a) Transmitter

(b) Channel

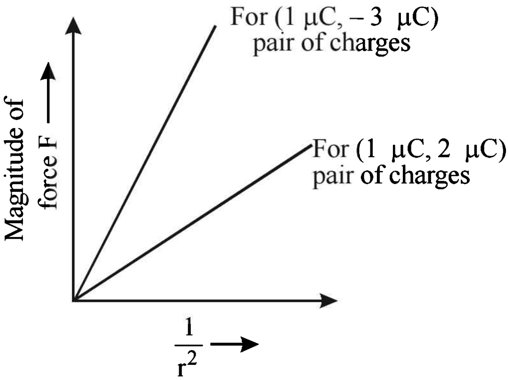
(c) Receiver

SOLUTIONS

1. According to Coulomb's law, magnitude of force acting between two stationary point charges is given by $F = \left(\frac{q_1 q_2}{4\pi\varepsilon_0}\right)\left(\frac{1}{r^2}\right)$

For given, $q_1 q_2$, $F \propto \left(\frac{1}{r^2}\right)$

Graph of Coulomb's force (F) versus $\frac{1}{r^2}$



Higher the magnitude of product of charges q_1q_2, higher the slope of the graph and hence higher the magnitude of force.

2. Applications of Gauss's Law :

(i) To determine electric field due to a point charge.

(ii) To determine electric field due to a cylindrically symmetric charge distribution.

3. Uses of capacitor :

- In LC oscillators
- As filter circuits
- Tuner circuit in radio etc.

4. Effect of filling dielectric with battery connected

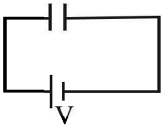
When there is no dielectric

Capacitance $C_0 = \frac{A\varepsilon_0}{d}$

Potential difference between the plates V

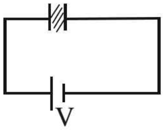
Charge on a plate Q = CV

Energy $E_0 = \frac{1}{2} C_0 V^2$



Electric field $E_0 = \frac{V}{d}$

When dielectric is inserted



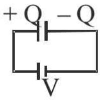
$C = \frac{KA\varepsilon_0}{d} = KC_0$

$Q = K C_0 V = KQ_0$

$U = \frac{1}{2} KC_0 V^2 = KE_0$

$E = \frac{V}{d} = E_0$

5. Effect of filling a dielectric in a capacitor after disconnection of battery

	When no dielectric 	When dielectric is inserted 
Capacitance	C_0	$C = K C_0$
Charge	Q_0	$Q = Q_0$
Potential difference	$V_0 = \frac{Q_0}{C_0}$	$V = \frac{Q_0}{C} = \frac{V_0}{K}$
Potential energy	$U_0 = \frac{1}{2} C_0 V_0^2$	$U = \frac{1}{2} KC_0 \left(\frac{V_0}{K}\right)^2 = \frac{U_0}{K}$

6. As we know from Gauss's law, flux through a closed surface is given by $\phi_E = \oint \vec{E}.ds = q/\varepsilon_0$

Here, q is the charge enclosed by the Gaussian surface.

Since, q/ε_0 is independent of radius of surface, charge through the spherical Gaussian surface will not be affected when its radius is increased.

7. Factors effecting internal resistance of a cell are

(i) the concentration of electrolyte

(ii) distance between the two electrodes.

8. Two properties of manganin are:
(i) Low temperature coefficient of resistance
(ii) High value of resistivity

9. Since, $V = E - Ir$, therefore, if $r = 0$ i.e the internal resistance of the cell is zero then the terminal voltage across a secondary cell is equal to its e.m.f.

10. Property of nichrome used to make standard resistance coils : Its low temperature coefficient of resistance.

11. Two possible causes for one sided deflection in a potentiometer experiment.
(i) Positive ends of all the cells are not connected to the same end of the wire.
(ii) The emf of the cell connected to the main is less than the emf's of cells whose emf's have to be compared.

12. Current sensitivity can be increased by
(i) increasing the length of the wire
(ii) decreasing the current in the wire using a rheostat

13. Function of radial magnetic field : It ensures that the plane of the coil remains parallel to the magnetic field.
Function of soft iron core : It ensures that the magnetic field is strong and remains on the coil.

14. Two characteristics of a material for making permanent magnets are :
(i) High coercivity, (ii) High retentivity

15. Substances which at room temperature retain their ferromagnetic property for a long period of time are called permanent magnets. The materials used for making permanent magnets should have high retentivity, high coercivity and high permeability. Steel, alnico, cobalt-steel and ticonal are the suitable materials for permanent magnets.

16. The properties of diamagnetic substances are :
(a) They are feebly repelled by a strong magnet
(b) Their susceptibility is negative (i.e. $\chi < 0$)
(c) Their relative permeability is less than 1. (i.e. $\mu_r < 1$)
(d) Their susceptibility is independent of magnetising field and temperature (except for Bismuth at low temperature)

The properties of paramagnetic substances are
(a) They are attracted by a strong magnet
(b) Their susceptibility is positive but very small ($\chi > 0$)
(c) Their relative permeability is slightly greater than unity. ($\mu > 1$)
(d) Their susceptibility and permeability do not change with the variation of magnetising field.

(e) Their susceptibility is inversely proportional to temperature, $\left(\text{i.e. } \chi \alpha \frac{1}{T}\right)$.

(f) They are found in those material which have atoms containing odd number of electrons

The properties of ferromagnetic substances are

(a) They are attracted even by a weak magnet.

(b) The susceptibility is very large and positive. $(\chi >> 0)$

(c) The relative permeability is very high (of the order of hundreds and thousands). $(\mu >> 1)$

(d) The intensity of magnetisation is proportional to the magnetising field H for smaller values, varies rapidly for moderate values and attains a constant value for larger values of H.

(e) The susceptibility of a ferromagnetic substance is inversely proportional to temperature i.e., $\chi \propto 1/T \Rightarrow \chi = \frac{C}{T}$;

C = curie constant .

This is called **Curie law**. *At a temperature called* **curie temperature**, *ferromagnetic substance becomes paramagnetic.* The curie temperatures for Ni, Fe and Co are 360°C, 740°C and 1100°C respectively.

(f) They are found in those material which have domains and can be converted into strong magnets

17. (a) Two properties of material suitable for making permanent magnets are
(i) high coercivity
(ii) high retentivity

(b) Two properties of material suitable for making electromagnets are
(i) low coercivity
(ii) low retentivity.

18. Applications of eddy current

(1) Dead beat galvanometer.
(2) Energy meter.
(3) Speedometer.
(4) Electric brakes.
(5) Single phase AC motor.
(6) Induction furnace.
(7) Diathermy

19. Four causes of energy loss in actual transformer are :
(i) Copper loss (ii) Iron loss
(iii) Flux loss (iv) Hysteresis loss

20. Step-up transformer converts low alternating voltage into high alternating voltage and high alternating current into low alternating current.

21. (i) Low retentivity or coercivity.
(ii) Low hysterisis loss.

22. Uses of X-rays
(i) In medical diagnosis as they pass through the muscles not through the bones.
(ii) In detecting faults, cracks etc. in metal products.

23. Properties of electromagnetic waves
(i) The direction of oscillations of E and B fields are perpendicular to each other as well as to the direction of propagation. Electromagnetic waves are transverse in nature.
(ii) The electric and magnetic field oscillate in same phase.
(iii) The electromagnetic waves travel through vacuum with the same speed of light

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_o}} = 3 \times 10^8 \text{ ms}^{-1}$$

(iv) The energy density of electric field is $\frac{1}{2}\varepsilon_o E^2$ and that of magnetic field is $\frac{1}{2}\frac{B^2}{\mu_0}$, so the energy density of the electromagnetic wave is $u = \frac{1}{2}\left[\varepsilon_o E^2 + \frac{B^2}{\mu_0}\right]$
where E and B are the instantaneous values of the electric and magnetic field vectors.
(v) The ratio $\frac{E}{B} = c = \frac{1}{\sqrt{\mu_0 \varepsilon_o}}$.

24. Uses of infrared rays
(i) In knowing the molecular structure
(ii) In remote control of TV, VCR etc.

25. Uses of electromagnetic waves
The following are some of the uses of electromagnetic waves
(i) **Radio waves** are used in radio and T.V. communication systems.
(ii) **Microwaves** are used in microwave oven.
(iii) **Infrared radiations** are used (a) in revealing the secret writings on the ancient walls (b) in green houses to keep the plants warm (c) in warfare, for looking through haze, fog or mist as these radiations can pass through them.

(iv) **Ultraviolet radiations** are used in the detection of invisible writing, forged documents, finger prints in forensic laboratory and to preserve the food stuffs.

(v) The **study of infrared, visible and ultraviolet radiations** help us to know through spectra, the structure of the molecules and arrangement of electrons in the external shells.

(vi) **X-rays** can pass through flesh and blood but not through bones. This property of X-rays is used in medical diagnosis, after X-rays photographs are made.
The study of X-rays has revealed the atomic structure and crystal structure.

(vii) The study of **γ-rays** provides us valueable information about the structure of the atomic nuclei

(viii) **Super high frequency electromagnetic waves** (3000 to 30,000 MHz) are used in radar and satellite communication.

(ix) **Electromagnetic waves (frequency 50 to 60 Hz)** are ued for lighting. These are weak waves having wavelength 5×10^6 to 6×10^6 m and can be produced from A.C. circuits.

26. (i) Microwave oven
(ii) Purification of water
(iii) Security lights
(iv) Treatment of cancers

27. Two drawbacks of astronomical type of telescope:
(1) In normal adjustment of telescope, the final image is formed at infinity.
(2) Magnifying power is less.

28. **Advantages:**
(i) Reflecting telescopes have high resolving power due to large aperture of mirrors.
(ii) Due to availability of parabolic mirror, image is free from chromatic and spherical aberration.

29. **Properties of light**

(1) Light travels along a straight line in a medium or vacuum. The path of light changes only when the medium changes. This is also called the rectilinear propagation of light.

(2) Light travels with a speed nearly equal to 3×10^8 m/s. According to current theories, no material particle can travel at a speed greater than the speed of light.

(3) Light shows different behaviour such as reflection, refraction, interference, diffraction, polarisation etc.

30. Limitations of a refracting type of telescope over a reflecting type telescope :

1. The image formed by a refracting telescope is not as bright as in the case of reflecting type telescope.
2. The image formed by a refracting type telescope suffers both spherical aberration and chromatic aberration which is not in case of reflecting type telescope.

31. Characteristics of image formed by plane mirror :

1. Distance of object from mirror = distance of image from mirror.
2. The image is laterally inverted.
3. The line joining the object point with its image is normal to the reflecting surface.
4. The size of the image is the same as that of the object.

32. The two considerations are:

(i) Objective should be of large focal length and apearture

(ii) Eyepiece should be of small focal length and aperture.

33. Drawbacks of Huygens wave theory

(a) This theory cannot explain Photo-electric, Compton, and Raman effect.

(b) Hypothetical medium in vacuum is not true imagination.

(c) The theory predicted the presence of back wave, which proved to be failure.

34. Three salient features observed in photoelectric effect.

(i) Threshold frequency. For $KE_{max} \leq 0 \quad v \geq v_0$

i.e., the phenomenon of photoelectric effect takes place when incident frequency is greater or equal to a minimum frequency (threshold frequency) :

(ii) KE_{max} of photoelectron : When incident frequency is greater than threshold frequency then KE_{max} of photoelectron is directly proportional to $(v - v_0)$ as

$$KE_{max} = h(v - v_0)$$

$$\Rightarrow \quad KE_{max} \propto (v - v_0)$$

(iii) Effect of intensity of incident light : More number of photons facilitate ejection of more number of photoelectrons from metal surface leads to further increase of photocurrent till its saturation value is reached.

35. The two characteristics features observed in photoelectric effect which support the photon pictures of electromagnetic radiation are :

(i) All photons of light of a particular frequency ν or wavelength λ have the same energy, $E\left(=hv=\frac{hc}{\lambda}\right)$ and momentum, $p\left(=\frac{h}{\lambda}\right)$ whatever the intensity of radiation may be. The increase in intensity of the radiation implies an increase in the number of photons crossing a given area per second.

(ii) Photons are electrically neutral and not deflected by electric hand magnetic fields.

36. Two important observations of photoelectric effect which can be explained by the equation are :

(i) The photoelectric emission takes place only if the incident light has a frequency greater than the threshold frequency ν_0. If $\nu < \nu_0$, then $\frac{1}{2}mv^2$ will be –ve, which is not possible. Hence, electron will not be emited.

(ii) When the frequency of the incident light increases, then $\frac{1}{2}mv^2$ i.e., kinetic energy of electron increases because work function $= h\nu_0$ is fixed. With increase in frequency more and more energy is available to the electron ejected and hence stopping potential also increases.

37. Basic features of photon picture :

(i) A photon of frequency ν is a packet of energy $E = h\nu$, where h is a planck's constant.

(ii) While interacting with matter photons behave as if they are all particles.

(iii) All photons travel in vacuum with the same velocity. However, their velocity in different media is different.

(iv) There is no charge on a photon. They are not deflected by electric and magnetic fields.

(v) The energy of a photon does not depend upon the intensity of radiation.

(vi) When it interacts with a photoelectric material, it is completely absorbed and loses its identity.

(vii) Its collisions with the electron in the photoelectric material is elastic i.e., total energy and momentum are conserved during the collision.

38. Three important properties of photons are :

(i) A definite value of energy.

(ii) Momentum.

(iii) The photon energy is independent of intensity of radiation.

39. The necessary conditions to obtain sustained interference fringes are:

(i) The two sources of light must be coherent.

(ii) The two sources should preferably be monochromatic.

(iii) The coherent sources must be very close to each other.

40. Fringe width is given by

$$\beta = \frac{\lambda D}{d}$$

Hence, if the distance between the slits is reduced then the width of the fringes increases.

41. Two postulates of Bohr's theory of hydrogen atom.

(i) Every atom consists of small and massive central core, known as nucleus around which electron revolve and necessary centripetal force prevailed by electrostatic force of attraction between positively charged nucleus and negatively charged electrons.

(ii) The electrons are revolved around the nucleus in only those circular orbits which satisfy the quantum condition that the angular momentum of electrons is equal to integral multiple of

$\frac{h}{2\pi}$, where, h is Planck's constant.

i.e., $mvr = \frac{nh}{2\pi}$ where, $n = 1, 2, 3, ...$

42. The drawbacks of Rutherford's atomic model are:

(1) It couldn't explain stability of the atom. The electrons are revolving around the nucleus and are continuously accelerated. An accelerated charge would emit radiation hence energy of this electron would decrease continuously till it collapses into the nucleus.

(2) It could not explain line spectrum of atoms like H-atom. According to Rutherford, electron can revolve in orbits of all possible radii, hence it should emit continuous energy spectrum.

43. Limitations of Bohr's model

(1) It could not explain the spectra of atoms containing more than one electron.

(2) There was no theoretical basis for selecting *mvr* to be an integral multiple of $h/2\pi$.

(3) It involved the orbit concept which could not be checked experimentally.

(4) It could not explain Zeeman and Stark effect and fine lines of spectra.
(5) It was against de-Broglie concept and uncertainty principle.

44. Characteristics of nuclear force :

1. It is a short range force effective only in range 10^{-15} m
2. It is charge independent. It acts between proton-proton, proton-neutron and neutron – neutron.
3. It is not a central force.
4. It is spin dependent.
5. It is 10^{38} times stronger than gravitational force and 10^2 times stronger than electric force.
6. The main cause of nuclear force is the exchange of π– mesons between nucleus

$$p \rightarrow n + \pi^+ , \; p \rightarrow p + \pi^{\circ} , \; n \rightarrow p + \pi^-$$

45. Properties of α, β and γ-rays

(A) **Properties of α–rays**

(a) It is a positively charged particle and contains a charge of 3.2×10^{-19} coulomb(exactly double the charge of electron).
(b) The mass of α-particles is 6.645×10^{-27}kg(It is equal to mass of a helium nucleus). Actually α-particle is nucleus of helium, hence it is called doubly ionised helium.
(c) They (α-particles) get deflected in both electric & magnetic fields.
(d) The velocity of α-particle is very less than the velocity of light i.e., $V_\alpha \approx \frac{c}{10}$, where c is velocity of light.
(e) The range of α-particle in air depends on radioactive substance.
(f) The ionisation power of α-particle is higher than both β (100 times of β & 10,000 times of γ) and γ particle.
(g) The penetrating power of α particle is lowest (in comparison to β & γ particles). It is 1/100 times of β-particles & 1/10,000 times of γ-rays.
(h) The α-particles can produce fluorescence in barium platinocynide and zinc sulphide.
(i) They show little effect on photographic plate.
(j) They show heating effect on stopping.

(B) **Properties of β rays or β-particles :**

(a) The beta particles (i.e., β^- or β^+) may be positive & negative particle & contain $\pm 1.6 \times 10^{-19}$C of charge. Actually β^- is electron & β^+ is positron.
(b) They get deflected in both electric & magnetic field.
(c) The velocity of β-particle varies between 0.01c to .99c, where c is velocity of light.

(d) The mass of β particle is relativistic, because its velocity is comparable to velocity of light

(e) They have both ionisation & penetration power. Ionisation power less than α-particle and penetration power more than α-particle.

(f) They produce fluorescence on barium platinocynide & zinc sulphide.

(C) **Properties of γ-rays (or gamma radiation):**

(a) They are electromagnetic waves as x-rays.

(b) They are not deflected in electric & magnetic field, it means that they are chargeless.

(c) The velocity of γ-particle is equal to velocity of light.

(d) The ionisation power of gamma rays is less than β & α rays but penetration power more than β and α-rays.

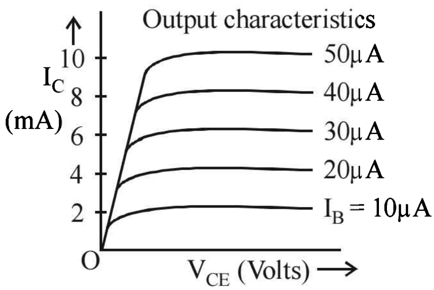
(e) The γ-particles are emitted from the nucleus, while X-rays are obtained, when electron goes from one state to another in an atom.

(f) When γ-rays photon strikes nucleus in a substance, then it gives rise to a phenomenon of pair production i.e.,

$$\underset{(\gamma\text{-rays or photon})}{h\nu} \longrightarrow \underset{(\text{Pair production})}{\beta^{-} + \beta^{+}}$$

The minimum energy of γ-rays required for this phenomena is 1.02 MeV, because the rest mass energy of $\beta^{\pm}$ particle is 0.51 MeV.

46. Output characteristics of an n-p-n transistor in CE configuration :



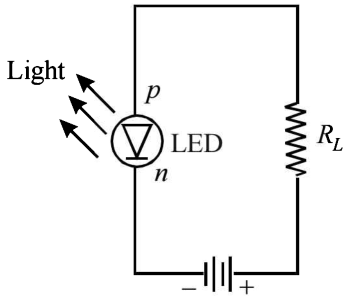
Now, output resistance r_0 is given by

$$r_0 = \frac{\Delta V_{CE}}{\Delta I_C} \text{ for constant } I_B$$

Thus for small values of V_{CE}, I_C almost increases linearly. And after small increase of V_{CE}, the current changes very little. Hence, output resistance is very high.

47. Solid state electronics is used in
(i) LCD (liquid crystal display) monitors.
(ii) detection of radio waves (crystal galena (lead sulphide) with a metal point attached to it is a detector.

48. Two advantages of LEDs over incandescent lamps.
1. Since, LEDs do not have a filament that can burn out, hence they last longer.
2. They do not get hot during use.



49. LEDs are used in remote controls, burgler alarms, optical communication etc.

50. They are used in calculators, digital watches, computers, robots, telecommunications etc.

51. Main use of photodiode: In demodulation of optical signal and detection of optical signal.
Main use of zener diode: As DC voltage regulator.

52. The advantages of semiconductor devices are :
(i) the flow of current is within the semiconductor itself and not in external circuit.
(ii) no external heating or large evacuated space is required.
(iii) they are small in size.
(iv) consume less energy.
(v) operate at low voltages.
(vi) have long life.
(vii) have high reliability.

53. As a detector of optical signals.

54. The material for solar cell fabrication should have
(i) band gap (~ 1.0 eV to 1.8 eV)
(ii) high optical absorption (~ 10^4 cm^{-1})
(iii) electrical conductivity
(iv) easily available
(v) low cost.

55. The transistor acts as an amplifier when the input circuit (emitter–base) is forward biased with low voltage V_{BE} and the output circuit (collector-base) is reverse biased with high voltage V_{CC} .

56. (i) **Transducer :** Its function is to convert one form of energy into another

(ii) **Repeater :** Reconstruct the original signal.

(iii) **Transmitter :** Its function is to convert message into suitable form through a channel and subsequent reception.

57. Communication system which uses space wave mode are television channel, UHF, VHF etc.

58. The harmonics of a *sine* wave of fundamental frequency are

$2v_0, 3v_0, 4v_0, 5v_0$...etc.

This means to accomodate all of them the bandwidth has to be infinite which is practically impossible. The distortions (noise) in received signal would also be large.

59. Uses of microwaves :

(i) In radar communication

(ii) In analysis of molecular and atomic structure.

60. **(i) Transmitter :** A transmitter is a device that converts the message signal from the source of information into a form suitable for transmission through a channel.

(ii) Modulator : Modulator superimposes a low-frequency message signal on a high frequency carrier wave, so that the low-frequency message signal can be transmitted over long distances.

61. Modulation index determines the strength and quality of transmitted signal. Higher modulation index ensures better quality and better strength.

62. The three important factors which justify the need of modulating a message signal are :

(i) Size of the antenna : For transmitting a signal we require an antenna whose size should have a size comparable to the wavelength of the signal $\left(\sim \frac{\lambda}{4}\right)$.

(ii) Effective power radiated by antenna : It is inversely proportional to λ^2. i.e. $p \propto \frac{1}{\lambda^2}$

(iii) **Mixing up of signals :** If a number of transmitter transmit base band signal simultaneously then all these signal cover the same frequency range and will get mixed up. To avoid it, the transmission should be done at high frequency. This provides an adequate bandwidth.

63. Box X is amplitude modulator : Since, the frequency range of signal is quite low and it is associated with very small amount of energy it dies out very soon if transmitted as such. So, it is modulated by mixing with very high frequency waves called carrier waves. This is done by modulator power.

Box Y is power amplifier : Since, the signal gets weaken after travelling through long distances it cannot be transmitted as such. Thus, we use a power amplifier to provide it necessary power before feeding the signal to the transmitting antenna.

64. (i) **Receiver:** The receiver is a device that operates on the received signal picked up from transmitted signal at the channel output and processes it to reproduce the recognisable form of the original message signal for delivering.

(ii) **Demodulator:** A demodulator is a device which separates the low frequency message signal that has been superimposed on high frequency carrier wave and retrieves the information from the carrier wave at the receiver.

65. A repeater is an amplifying device used to increase the range of the transmission in communication systems with the help of a set of receiver and transmitter

66. The list of uses of Internet is given below.

(i) **E-banking:** It is an electronic payment system that enables customers of a financial institution (usualy a bank) to proceed for financial transactions on a website operated by that institution. To bank online with an institution, it is required that the customer is a member of that institution and has the access of Internet.

(ii) **Internet surfing:** Navigation over World Wide Web (www) from one webpage/website to another is called Internet surfing. It is an interesting way of searching and viewing information on any topic of interest.

(iii) E-shopping (E-commerce): It is a form of electronic commerce, by which the consumers can buy the products or the services over Internet.

Apart from the above internet is used for sending e-mail, e-ticketing, etc.

67. The bandpass filter blocks the signal which are d.c. or have frequencies ω, $2\omega_c$ and $2\omega_m$ and allows a particular band of frequency signal to pass.

68. (a) Three segments of a transmitter are (i) Emitter (E), (ii) Base (B) and (iii) Collector.

(i) **Emitter:** It is of moderate size and heavily doped. It supplies a large number of majority carriers for the current flow through the transistor.

(ii) **Base:** It is the control segment and is very thin and lightly doped.

(iii) **Collector:** It is the segment which collects a major portion of the majority carriers supplied by the emitter. It is moderately doped and large in size as compared to the emitter.

69. Functions of

(a) **Transmitter:** A transmitter is an arrangement which processes the incoming message signal to a form suitable for transmission through a channel and subsequent reception.

(b) **Channel:** Channel is the medium through which the signal is transmitted from the transmitter to the receiver.

(c) **Receiver:** A receiver extracts the desired message signals from the received signals at the channel output.

□ □ □

CHAPTER 7

How will you establish relation/deduce expression for ....?

(A) *Electrostatics*

1. Using Gauss's law, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance from it. **[All India 2008, 2009, Delhi 2008C, 2012, 2012C]**

2. Using Gauss's law, derive an expression for the electric field intensity at any point outside a uniformly charged thin spherical shell of radius R and charge density σ C/m^2. **[Delhi 2008]**

3. Derive an expression for the torque experienced by an electric dipole kept in a uniform electric field. **[Delhi 2008]**

4. Derive an expression for the electric field due to an infinitely long straight wire of linear charge density λ Cm^{-1}. **[Delhi 2009]**

5. A thin conducting spherical shell of radius *R* has charge Q spread uniformly over its surface. Using Gauss's law, derive an expression for an electric field at a point outside the shell. **[Delhi 2009C, 2013 All India 2011]**

6. Derive the expression for the electric field of a dipole at a point on the equatorial plane of the dipole. **[Foreign 2009, All India 2013]**

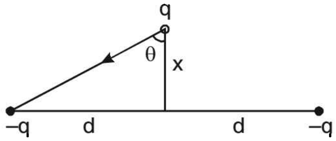
7. A dipole, with a dipole moment of magnitude *p*, is in stable equilibrium in an electrostatic field of magnitude *E*. Find the work done in rotating this dipole to its position of unstable equilibrium. **[All India 2010C]**

8. Deduce the expression for the electric field *E* due to a system of two charges q_1 and q_2 with position vectors r_1 and r_2 at a point r with respect to common origin. **[Delhi 2010C]**

9. A dipole, with its charge, – q and + q, located at the points (0, – b, 0) and (0, + b, 0), is present in a uniform electric field *E*. The equipotential surfaces of this field are planes parallel to the Y-Z plane.
  (i) What is the direction of the electric field *E*?
  (ii) How much torque would the dipole experience in this field?
[Delhi 2010C]

10. Two charge $-q$ each are fixed separated by distance $2d$. A third charge q of mass m placed at the mid-point is displaced slightly by x ($x << d$) perpendicular to the line joining the two fixed charged as shown in Fig. Show that q will perform simple harmonic oscillation of time period.

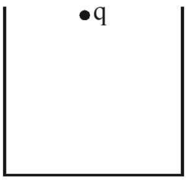
$$T = \left[\frac{8\pi^3 \varepsilon_0 md^3}{q^2}\right]^{1/2}$$



11. Using Gauss's law, derive the expression for the electric field at a point (i) outside and (ii) inside a uniformly charged thin spherical shell. **[All India 2011, 2013, 2013C]**

12. (a) A charge Q located at a point $\vec{r_1}$ is in equilibrium under the combined electric field three charges q_1, q_2 are located at points $\vec{r_1}$ and $\vec{r}$ respectively, find the direction of the force on Q, due to q_3 in terms of q_1, q_2, $\vec{r_1}$, $\vec{r_2}$ and $\vec{r}$.

(b) A charge q is placed at the centre of an open end of a cylindrical vessel, as shown. What is the electric flux through the surface of vessel ?



13. Two charged conducting spheres of radii r_1 and r_2 connected to each other by a wire. Find the ratio of electric fields at the surfaces of the two spheres. **[Delhi 2011C]**

14. Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charges q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii. **[Delhi 2014]**

15. Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor. **[All India 2008, Delhi 2014]**

16. Derive the expression for the electric potential at any point along the axial line of an electric dipole? **[Delhi 2008]**

17. Derive a relation between potential gradient and electric field strength.

18. Derive an expression for the potential energy of an electric dipole of dipole moment $\overline{P}$ in an electric field $\overline{E}$. **[Delhi 2008]**

19. Find out the expression for the potential energy of a system of three charges q_1, q_2 and q_3 located, at r_1, r_2 and r_3 with respect to the common origin O. **[Delhi 2010C]**

20. Deduce the expression for the potential energy of a system of two point charges q_1 and q_2 brought from infinity to the points with positions r_1 and r_2 respectively in presence of external electric field E. **[Delhi 2010]**

21. Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d. **[Delhi 2010, 2014]**

22. A capacitor is charged to potential V_1. The power supply is then disconnected and the capacitor is then connected in parallel to another capacitor of potential V_2.

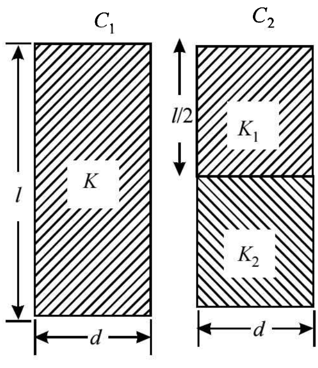
(a) Derive an expression for the common potential of the combination of capacitor.

(b) Show that the total energy of combination is less than the sum of the energy stored in them before they are connected.

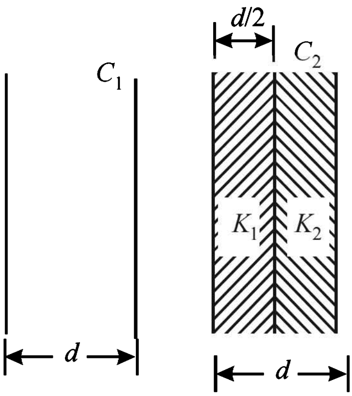
23. Find the ratio of the potential differences that must be applied across the parallel and the series combination of two identical capacitors so that the energy stored, in the two cases, becomes the same. **[Foreign 2010]**

24. A slab of material of dielectric constant K has the same area as that of the plates of a parallel plate capacitor but has the thickness d/2, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor. **[Foreign 2010, All India 2013, Delhi 2013]**

25. Two identical parallel plate (air) capacitors C_1 and C_2 have capacitance C each. The space between their plates is now filled with dielectrics as shown. If the two capacitors still have equal capacitance, obtain the relation between dielectric constants K, K_1 and K_2. **[Foreign 2011]**



26. You are given an air filled parallel plate capacitor C_1. The space between its plates is now filled with slabs of dielectric constants K_1 and K_2 as shown in C_2. Find the capacitance of the capacitor C_2 if area of the plates is A and distance between the plates is d.
A is filled parallel plate capacitor. **[Foreign 2011]**



27. Two identical circular loops '1' and '2' of radius R each have linear charge densities $-\lambda$ and $+\lambda$ C/m respectively. The loops are placed coaxially with their centres $R\sqrt{3}$ distance apart. Find the magnitude and direction of the net electric field at the centre of loop '1'. **[All India 2015]**

28. An electric dipole of dipole moment $\vec{p}$ consists of point charges +q and –q separated by a distance 2a apart. Deduce the expression for the electric field $\vec{E}$ due to the dipole at a distance x from the centre of the dipole on its axial line in terms of the dipole moment $\vec{p}$. Hence show that in the limit $x >> a$,

$\vec{E} \longrightarrow 2\vec{P}/(4\pi\varepsilon_0 x^3)$. **[Delhi 2015]**

29. If two similar large plates, each of area A having surface charge densities $+\sigma$ and $-\sigma$ are separated by a distance d in air, find the expressions for

(a) field at points between the two plates and on outer side of the plates. Specify the direction of the field in each case.

(b) the potential difference between the plates.

(c) the capacitance of the capacitor so formed. **[All India 2016]**

30. A charge is distributed uniformly over a ring of radius 'a'. Obtain an expression for the electric intensity E at a point on the axis of the ring. Hence show that for points at large distance from the ring, it behaves like a point charge. **[Delhi 2016]**

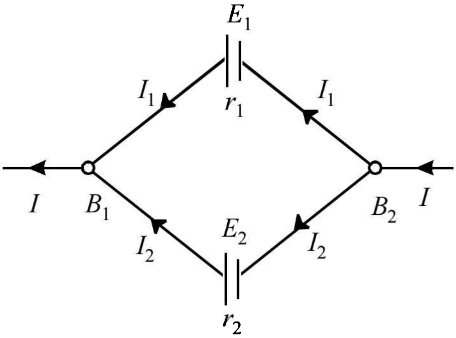
31. Use Gauss's law to find the electric field due to a uniformly charged infinite plane sheet. **[All India 2016, 2017]**

32. Derive an expression for the electric field E due to a dipole of length '2a' at a point distant r from the centre of the dipole on the axial line. **[All India 2017]**

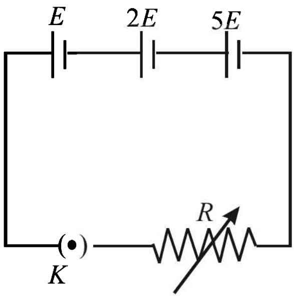
33. An infinitely large thin plane sheet has a uniform surface charge density $+\sigma$. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distant r, infront of the charged plane sheet. **[All India 2017]**

(B) Current Electricity

34. Two cells of emf E_1 and E_2 having internal resistances r_1 and r_2 respectively are connected in parallel as shown. Deduce the expressions for the equivalent emf and equivalent internal resistance of a cell which can replace the combination between the points B_1 and B_2. **[All India 2008, 2010C, 2015, Foreign 2010, 2011]**



35. Three cells of emf, E, $2E$ and $5E$ having internal resistances r, $2r$ and $3r$, variable resistance R is shown in the figure. Find the expression for the current. **[All India 2010C]**



36. Derive an expression for the internal resistance of a cell in terms of e.m.f and terminal potential difference of a cell.

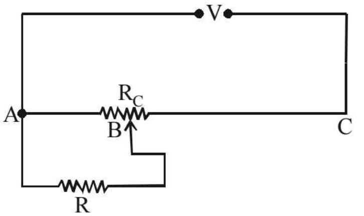
37. With the help of the circuit diagram, explain how a potentiometer is used to compare the emf's of two primary cells. Obtain the required expression used for comparing the emfs. **[Delhi 2011, 2013]**

38. Derive the balanced condition of wheatstone's bridge principle.

39. Deduce the expression for the electrical resistivity of the material. **[All India 2012]**

40. Obtain the expression for the current through a conductor in terms of 'drift velocity'. **[All India 2013]**

41. A resistor of resistance R Ω draws current from a potentiometer, as shown in the figure.



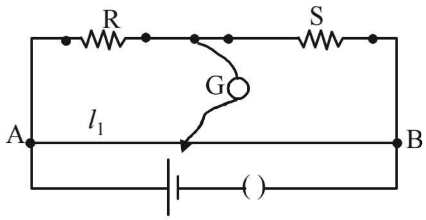
The potentiometer has a total resistance R_0 Ω. A voltage V is supplied to the potentiometer. Derive an expression for the voltage across R when the sliding contact is in the middle of the potentiometer. **[All India 2014]**

42. Derive an expression for drift velocity of free electrons. **[All India 2016]**

43. Two long straight parallel conductors carry steady current 1 and 2A separated by a distance d. If the currents are flowing in the same direction, show how the magnetic field set up in one produces an attractive force on the other. Obtain the expression for this force. **[Delhi 2016]**

44. On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. **[Delhi 2016]**

45. In a metre bridge, the balance point is found at a distance l_1 with resistances R and S as shown in the figure.



An unknown resistance X is now connected in parallel to the resistance S and the balance point is found at a distance l_2. Obtain a formula for X in terms of l_1, l_2 and S.

[All India 2017]

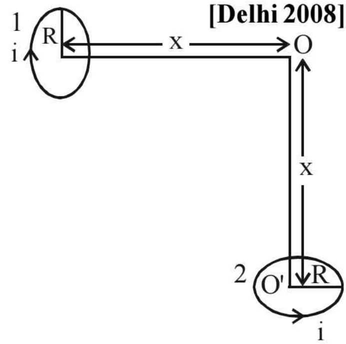
(C) Magnetism

46. A long solenoid of length L having N turns carriers a current I. Deduce the expression for the magnetic field in the interior of the solenoid. **[All India 2008, 2011, 2011C, Foreign 2010]**

47. Using Biot-Savart's law, derive an expression for the magnetic field at the centre of a circular coil of radius r, number of turns n, carrying current i. **[Delhi 2008]**

48. Two small identical circular coils marked 1, 2 carry equal currents and are placed with their geometric axes perpendicular to each other as shown in the figure. Derive an expression for the resultant magnetic field at O.

[Delhi 2008]

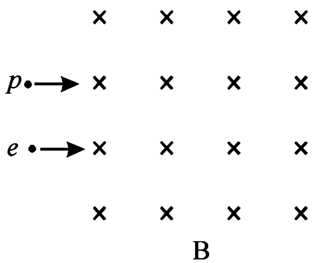


49. Deduce an expression for the period of revolution of charged particle in cyclotron and show that it does not depend on the speed of the charged particle. **[Delhi 2008]**

50. Derive the expression for the torque on the rectangular current carrying loop suspended in a uniform magnetic field.

[Foreign 2009, Delhi 2009, 2013, All India 2013]

51. An electron and a proton moving with a same speed enter the same magnetic field region at right angles to the direction of the field. Show the trajectory followed by the two particles in the magnetic field. Find the ratio of the radii of the circular paths which the particles may describe. **[Foreign 2010]**



52. Write the expression for the magnetic moment (m) due to a planar square loop of side l carrying a steady current I in a vector form. **[Delhi 2010]**

53. A moving coil galvanometer of resistance G, gives its full scale deflection when a current I_g flows through its coil. It can be converted into a ammeter of range (0 to I) ($I > I_g$) when a shunt of resistance S is connected is converted into an ammeter of range 0 to 1, find the expression for the shunt required in terms of I_g and G. **[Delhi 2010C]**

54. Deduce the expression for the force acting between the two conductors. Mention the nature of this force. **[Foreign 2010, All India 2012, Delhi 2016]**

55. Obtain, with the help of necessary diagram, the expression for the magnetic field in the interior of a toroid carrying current. **[All India 2011C]**

56. The parallel coaxial circular coils of equal radius R and equal number of turns N carry equal currents I in the same direction and are separated by a distance 2 R. Find the magnitude and direction of the net magnetic field produced at the mid-point of the line joining their centres.

57. Using Biot-Savart law, deduce an expression for the magnetic field on the axis of a circular current carrying loop. **[Foreign 2010, Delhi 2011, All India 2013]**

58. A small compass needle of magnetic moment 'm' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B'. The moment of inertia of the needle about the axis is 'I'. The needle is slightly disturbed from its stable position and then released. Prove that it executes simple harmonic motion. Hence deduce the expression for its time period. **[Delhi 2011C, 2013]**

59. A straight wire of length L is bent into a semi-circular loop. Use Biot-Savart law to deduce an expression for the magnetic field at its centre due to the current, I passing through it. **[Delhi 2011C]**

60. Two circular coils X and Y having radii R and R/2 respectively are placed in horizontal plane with their centres coinciding with each other. Coil X has a current I flowing through it in the clockwise sense. What must be the current in coil Y to make the total magnetic field at the common centre of the two coils, zero?

With the same currents flowing in the two coils, if the coil Y is not lifted vertically upwards through a distance R, what would be the net magnetic field at the centre of coil Y?

61. When a current carrying loop PQRS is placed in a magnetic field B, find out the expression for the torque acting on it. **[Foreign 2011]**

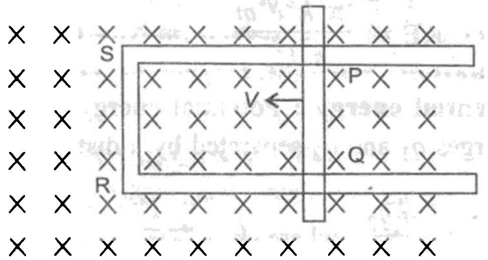
62. Write the expression for the force, F, acting on a charged particle of charge q, moving with a velocity v in the presence of both electric field E and magnetic field B. Obtain the condition under which the particle moves undeflected through the fields. **[All India 2012]**

63. Derive the expression for the kinetic energy acquired by the charged particles in cyclotron. **[Delhi 2012, All India 2013]**

64. A particle of charge, *q* and mass, m is moving with velocity, *v*. It is subjected to a uniform magnetic field, *B* directed perpendicular to its velocity. Show that, it describes, a circular path. Write the expression for its radius. **[Foreign 2012]**

65. Find out the expression for the magnetic field inside a toroid for N turns of the coil having the average radius *r* and carrying a current I. **[All India 2013]**

66. Figure shows a conducting rectangular loop PQRS in which the arm PQ is free to move. A uniform magnetic field acts in the direction perpendicular to the plane of the loop. Arm PQ is moved with a velocity v towards the arm RS. Assuming that the arms QR, RS and SP have negligible resistances and the moving arm PQ has the resistance r, obtain the expression for (i) the current in the loop (ii) the force and (iii) the power required to move the arm PQ. **[Delhi 2013]**



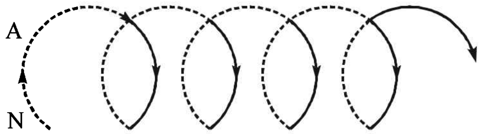
67. Starting from the expression for the energy W = ½ LI², stored in a solenoid of self-inductance L to build up the current I, obtain the expression for the magnetic energy in terms of the magnetic field B, area A and length *l* of the solenoid having *n* number of turns per unit length. **[Delhi 2013C]**

68. A rod of length *l* is moved horizontally with a uniform velocity 'v' in a direction perpendicular to its length through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod. **[All India 2014]**

69. Derive expression for magnetic field strength at a point lies on the equatorial line of bar magnet.

70. Two infinitely long straight parallel wires, '1' and '2', carrying steady currents I_1 and I_2 in the same direction are separated by a distance d. Obtain the expression for the magnetic field $\vec{B}$ due to the wire '1' acting on wire '2'. Hence find out, with the help of a suitable diagram, the magnitude and direction of this force per unit length on wire '2' due to wire '1'. **[All India 2015]**

71. An observer to the left of a solenoid of N turns each of cross-section area 'A' observes that a steady current I in it flows in the clockwise direction. Depict the magnetic field lines due to the solenoid specifying its polarity and show that it acts as a bar magnet of magnetic moment m = NIA **[Delhi 2015]**



72. Use Biot-Savart law to derive the expression for the magnetic field on the axis of a current carrying circular loop of radius R.
[All India 2016]

73. Write the expression for the magnetic force acting on a charged particle moving with velocity v in the presence of magnetic field B. **[Delhi 2016]**

(D) EMI, Alternating Current & EM Waves

74. A metallic rod of length l is rotated at a constant angular speed ω, normal to a uniform magnetic field B. Derive an expression for the emf induced in the rod . **[Delhi 2008]**

75. A coil of number of turns N, area A, is rotated at a constant angular speed in a uniform magnetic field B, and connected to a resistor R. Deduce expression for : **[Delhi 2008]**

(i) Maximum emf induced in the coil

(ii) Power dissipation in the coil.

76. Derive an expression for the self inductance of a long solenoid of cross sectional area A, length l having n turns per unit length.
[Delhi 2008, 2009, All India 2013C]

77. Two concentric circular coils C_1 and C_2, radius r_1 and r_2 $(r_1 << r_2)$ respectively are kept coaxially. If current is passed through C_2, then find an expression for mutual inductance between the two coils.
[All India 2009C, 2011, Foreign 2011]

78. A metallic ring of mass m and radius l (ring being horizontal) is falling under gravity in a region having a magnetic field. If z is the vertical direction, the z-component of magnetic field is $B_z = B_o(1 + \lambda z)$. If R is the resistance of the ring and if the ring falls with a velocity v, find the energy lost in the resistance. If the ring has reached a constant velocity, use the conservation of energy to determine v in terms of m, B, λ and acceleration due to gravity g.

79. A metallic rod length 'l' is rotated with a frequency ν with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius r, about an axis passing through the centre and perpendicular to the plane of the ring. A constant uniform magnetic field B parallel to the axis is present everywhere. Using Lorentz force, explain how emf is induced between the centre of the metallic ring and hence obtain the expression for it.

[Delhi 2012, 2013, All India 2013C]

80. If r is the resistance of the rod and the metallic ring which has negligible resistnace. Obtain the expression for the power generated. **[All India 2013C]**

81. Obtain the expression for the magnetic energy stored in an inductor of self-inductance L to build up a current I through it.

[All India 2014]

82. An ac source of voltage $v = v_0 \sin \omega t$ is connected across a series combination of an inductor, a capacitor and a resistor. Use the phasor diagram to obtain the expression for the (i) impedance of the circuit and (ii) phase angle between the voltage and the current. **[All India 2009, 2013C]**

83. Derive an expression for the average power consumed in a series LCR circuit connected to a.c. source in which the phase difference between the voltage and the current in the circuit is ϕ. **[Delhi 2009]**

84. An alternating voltage $V = V_m \sin\omega t$ applied to a series L-C-R circuit drives a current given by $I = I_m \sin(\omega t + \phi)$. Deduce an expression for the average power dissipated over a cycle.

[Delhi 2009, Foreign 2011]

85. Derive an expression for the mean or average value of alternating current. What is the mean value of a.c. over a complete cycle?

86. A voltage $V = V_0 \sin \omega t$ is applied to a series LCR circuit. Derive the expression for the average power dissipated over a cycle.

[Delhi 2009, Foreign 2011, All India 2014]

87. A series LCR circuit is connected to an AC source. Using the phasor diagram, derive the expression for the impedance of the circuit.

[All India 2012]

88. Derive an expression for the average power consumed in a pure resistive circuit over a complete cycle.

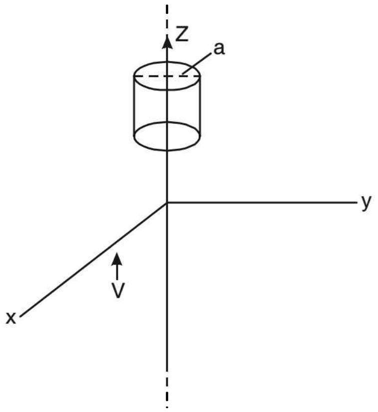
89. For a given ac, $i = i_m \sin \omega t$, show that the average power dissipated in a resistor R over a complete cycle is $\frac{1}{2} i_m^2 R$. **[All India 2013]**

90. Express the velocity of propagation of an electromagnetic wave in terms of the peak value of the electric and magnetic fields.

[All India 2010C]

91. Derive the relation: $i = \varepsilon_0 \left(\frac{d\phi_E}{dt}\right)$.

92. An infinitely long thin wire carrying a uniform linear static charge density λ is placed along the z-axis (Fig.). The wire is set into motion along its length with a uniform velocity $\mathbf{v} = v\hat{\mathbf{k}}_z$. Find the poynting vector $\mathbf{S} = \frac{1}{\mu_o}(\mathbf{E} \times \mathbf{B})$.



93. A capacitor, made of two parallel plates each of area A and separated by a distance d, is being charged by an external ac source. Show that the displacement current inside the capacitor is the same as the current charging the capacitor. **[All India 2013]**

94. Write the relation between the velocity of propagation of wave and the magnitudes of electric and magnetic fields.

[All India 2015]

95. Draw a necessary arrangement for winding of primary and secondary coils in a step-up transformer. State its underlying principle and derive the relation between the primary and secondary voltages in terms of number of primary and secondary turns.

[All India 2015]

96. Derive an expression for the mutual inductance of two long co-axial solenoids of same length wound one over the other.

[Delhi 2015, All India 2017]

97. (a) Explain the meaning of the term mutual inductance. Consider two concentric circular coils, one of radius r_1 and the other of radius r_2 ($r_1 < r_2$) placed coaxially with centres coinciding with each other. Obtain the expression for the mutual inductance of the arrangement.

(b) A rectangular coil of area A, having number of turns N is rotated at 'f' revolutions per second in a uniform magnetic field B, the field being perpendicular to the coil. Prove that the maximum emf induced in the coil is $2\pi f NBA$. **[All India 2016]**

98. An a.c. source of voltage $V = V_0 \sin \omega t$ is connected to a series combination of L.C and R. Use the phasor diagram to obtain expression for impedance of the circuit and phase angle between voltage and current. **[Delhi 2016]**

99. Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other.
[All India 2017]

(E) Optics

100. Write the relation between the refractive index and critical angle for a given pair of optical media. **[All India 2009, Delhi 2013]**

101. Derive the expression for the total magnification of a compound microscope. **[Delhi 2009]**

102. Obtain lens maker's formula using the expression

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R}$$

Here, the ray of light propagating from a rarer medium of refractive index (μ_1) to a denser medium of refractive index (μ_2) is incident on the convex side of spherical refracting surface of radius of curvature *R*.
[Delhi 2011]

103. Derive an expression for the refractive index of the material of the prism in terms of the angle of minimum deviation and its refracting angle. **[Foreign 2011]**

104. Derive the relation, $\delta = (n_{12} - 1)A$.

105. Deduce the relation $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ for two thin lenses kept in contact coaxially. **[Foreign 2012]**

106. The mixture a pure liquid and a solution in a long vertical column (i.e., horizontal dimensions << vertical dimensions) produces diffusion of solute particles and hence a refractive index gradient along the vertical dimension. A ray of light entering the column at right angles to the vertical is deviated from its original path. Find the deviation in travelling a horizontal distance $d << h$, the height of the column.

107. Obtain the conditions for the bright and dark fringes in diffraction pattern due to a single narrow slit illuminated by a monochromatic source. **[Foreign 2012]**

108. In Young's double slit experiment, show that $\frac{I_{max}}{I_{min}} = \frac{(a+b)^2}{(a-b)^2}$

109. Two polaroids P_1 and P_2 are placed with their axes perpendicular to each other. An unpolarised light of intensity I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 30° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3. **[All India 2014]**

110. In a double slit interference experiment, the two coherent beams have slightly different intensities I and $I + \delta I$ $(\delta I << I)$. Show that the resultant intensity at the maxima is nearly 4I while that at the minima is nearly $\frac{(\delta I)^2}{4I}$.

111. Light waves each of amplitude "a" and frequency "ω", emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by $y_1 = a \cos \omega t$ and $y_2 = a \cos(\omega t + \phi)$ where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point.
[Delhi 2014]

112. Derive an expression for stopping potential from Einstein's photo electric equation.

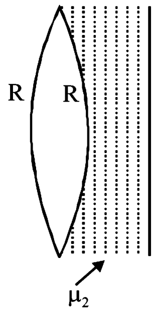
113. Two particles A and B of de Broglie wavelengths λ_A and λ_B combine to form a particle C. The process conserves momentum. Find the de Broglie wavelenth of the particle C. (The motion is one dimensional).

114. Establish the relationship of de-Broglie wavelength λ associated with a particle of mass *m* in terms of its kinetic energy *E*.
[Delhi 2011C]

115. Use Huygens' principle to show the propagation of a plane wavefront from a denser medium to a rarer medium. Hence find the ratio of the speeds of wavefronts in the two media.
[All India 2015]

116. Derive the expression of Brewster's law when unpolarised light passing from a rarer to a denser medium gets polarised on reflection at the inteface. **[All India 2015]**

117. A biconvex lens with its two faces of equal radius of curvature R is made of a transparent medium of refractive index μ_1. It is kept in contact with a medium of refractive index μ_2 as shown in the figure.



(a) Find the equivalent focal length of the combination.
(b) Obtain the condition when this combination acts as a diverging lens.
(c) Draw the ray diagram for the case $\mu_1 > (\mu_2 + 1) / 2$, when the object is kept far away from the lens. Point out the nature of the image formed by the system. **[All India 2015]**

118. Use the mirror equation to show that an object placed between f and 2f of a concave mirror produces a real image beyond 2f. **[Delhi 2015]**

119. Find an expression for intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids. In which position of the polaroid sheet will the transmitted intensity be maximum? **[Delhi 2015]**

120. The maximum kinetic energy of the photoelectrons gets doubled when the wavelength of light incident on the surface changes from λ_1 to λ_2. Derive the expressions for the threshold wavelength λ_0 and work function for the metal surface. **[Delhi 2015]**

121. Show that the angular width of the first diffraction fringe is half that of the central fringe. **[Delhi 2015]**

122. Derive the mathematical relation between refractive indices n_1 and n_2 of two radii and radius of curvature R for refraction at a convex spherical surface. Consider the object to be a point since lying on the principal axis in rarer medium of refractive index n_1 and a real image formed in the denser medium of refractive index n_2. Hence, derive lens maker's formula. **[All India 2016]**

123. Derive an expression for refractive index of the prism in terms of angle of minimum deviation and angle of prism. **[Delhi 2016]**

124. Unpolarised light is passed through a polaroid P_1. When this polarised beam passes through another polaroid P_2 and if the pass axis of P_2 makes angle θ with the pass axis of P_1, then write the expression for the polarised beam passing through P_2.
[All India 2017]

125. Using photon picture of light, show how Einstein's photoelectric equation can be established. **[All India 2017]**

(F) *Atoms and Nuclei*

126. Using Bohr's postulates, obtain the expressions for (i) kinetic energy and (ii) potential energy of the electron in stationary state of hydrogen atom. **[Delhi 2010, 2013]**

127. From Bohr's model, derive an expression for the radius of a stationary orbit. Prove that the various stationary orbits are not equally placed.

128. Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state, (n_f). **[Foreign 2011, All India 2013]**

129. Show that from Bohr's postulates linear velocity of electron 'v' is inversely proportional to principal quantum number 'n'.

130. Deduce the expression, $N = N_0 e^{-\lambda t}$, for the law of radioactive decay. **[All India 2011C, Delhi 2014]**

131. Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron? **[All India 2014]**

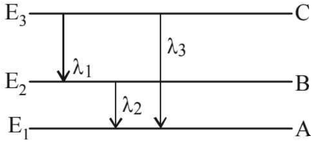
132. Obtain the relation between the decay constant and half life of a radioactive sample. **[All India 2015]**

133. A proton and an α-particle have the same de-Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speeds. **[Delhi 2015]**

134. Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum numbers of the atom. **[Delhi 2015]**

135. From the relation $R = R_0 A^{1/3}$, where R_0 is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A. **[Delhi 2015]**

136. Find the relation between the three wavelengths l_1, l_2 and l_3 from the energy level diagram shown below. **[Delhi 2016]**



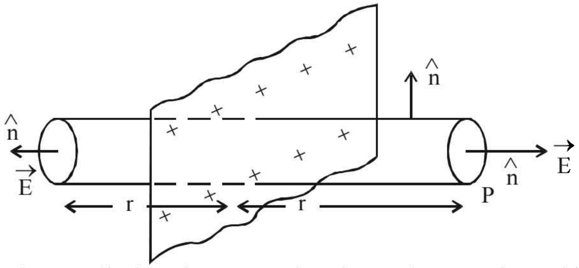
(G) *Electronics and Communication systems*

137. Express amplitude modulation by square law device.

138. If the whole earth is to be connected by LOS communication using space waves (no restriction of antenna size or tower height), what is the minimum number of antennas required? Express the tower height of these antennas in terms of earth's radius?

SOLUTIONS

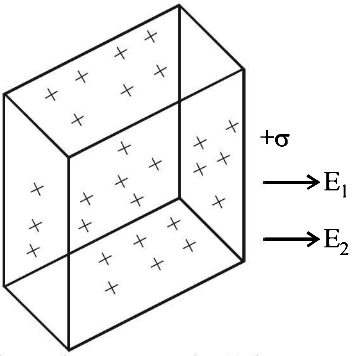
1. Electric field intensity due to a thin infinite sheet of charge: Let σ be the surface density of charge and P be a point at a distance r from the sheet where $\vec{E}$ has to be calculated. $\vec{E}$ on either side is perpendicular to the sheet.



Imagine a cylinder of cross-sectional area ds around P and length 2r, piercing through the sheet. At the two edges, $\vec{E} \parallel \hat{n}$ (or $\overrightarrow{dS}$).
At the curved surfaces $\vec{E} \perp \hat{n}$ (or $\overrightarrow{dS}$). So, there is no contribution to electric flux from the curved surfaces of the cylinder.
Electric flux over the edges $= 2\vec{E}.\overrightarrow{dS} = 2EdS$
Total charge enclosed by the cylinder $= \sigma$ dS

By Gauss's theorem, $2EdS = \dfrac{q}{\varepsilon_0} = \dfrac{\sigma dS}{\varepsilon_0}$ $\therefore$ $E = \dfrac{\sigma}{2\varepsilon_0}$.

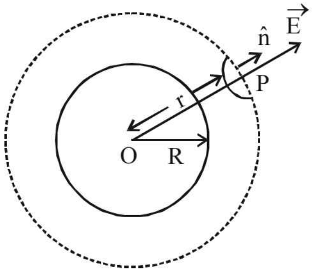
If the infinite plane sheet has uniform thickness, the surface density of charge is same on both the surfaces of the sheet.



Electric field intensity at any point P due to each surface
$= E_1 = E_2 = \sigma / 2\varepsilon_0$
$\therefore$ By superposition principle, total electric field intensity,
$E = E_1 + E_2 = \dfrac{\sigma}{2\varepsilon_0} + \dfrac{\sigma}{2\varepsilon_0} = \dfrac{\sigma}{\varepsilon_0}$.

From the expression, it is clear that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance from it.

2. Consider a uniformly charged thin spherical shell of radius R and charge density $\sigma\ C/m^2$.



The charge on the sphere, $q = (4\pi R^2).\sigma$

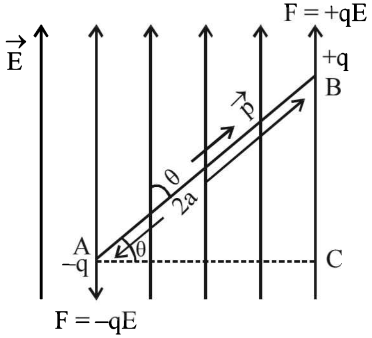
According to Gauss's theorem,

$$\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$$

$$E \times 4\pi r^2 = \frac{(4\pi R^2).\sigma}{\epsilon_0} \qquad \left[\because \oint ds = 4\pi r^2\right]$$

$$E = \frac{(4\pi R^2).\sigma}{\varepsilon_0 .4\pi r^2} \quad \text{or,} \qquad E = \frac{\sigma R^2}{\varepsilon_0 r^2}$$

3. Let an electric dipole consisting of $-q$ and $+q$ charges is placed in a uniform electric field $\vec{E}$.



Let the dipole moment $\vec{p}$ makes an angle θ with the direction of $\vec{E}$.

Force on the charge $-q = -qE$

Force on the charge $+q = +qE$

These forces are equal in magnitude but act along parallel lines at different points hence form a couple which tends to rotate the dipole in the anticlockwise direction.

As, torque = moment of force.

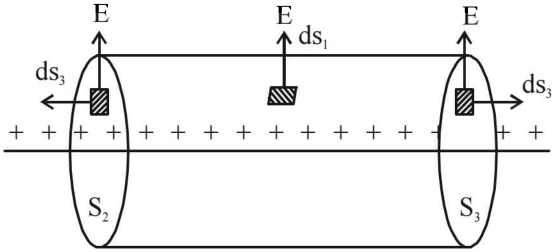
$\tau = F \times AB \sin\theta = (qE)(2a \sin\theta) = (q \times 2a)\, E \sin\theta$

$(p = q \times 2a)$

$= pE \sin\theta$

or, $\vec{\tau} = \vec{p} \times \vec{E}$

4. Electric field due to an infinitely long straight wire : Consider an infinitely long line charge having linear charge density λ. To determine its electric field at distance r, consider a cylindrical Gaussian surface of radius r and length l coaxial with the charge. By symmetry, the electric field E has same magnitude at each point of the curved surface S_1 and is directed radially outward.



Total flux through the cylindrical surface,

$$\oint_S \vec{E}.\vec{ds} = \oint_{S_1} \vec{E}.\vec{ds_1} + \oint_{S_2} \vec{E}.\vec{ds_2} + \oint_{S_3} \vec{E}.\vec{ds_3}$$

$$= \oint_{S_1} Eds_1.\cos 0° + \oint_{S_2} Eds_2.\cos 90° + \oint_{S_3} Eds_3.\cos 90°$$

$= E\int ds_1 = E \times 2\pi r l$ As λ is the charge per unit length and l is the length of the wire, so charge enclosed, $q = \lambda l$

By Gauss's theorem,

$$\oint_S \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0} \quad \text{or,} \quad E \times 2\pi r l = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

This is the required expression.

5. Electric field intensity at any point outside a uniformly charged spherical shell.

Consider a thin spherical shell of radius R with centre O. Let charge $+q$ is uniformly distributed over the surface of the shell.

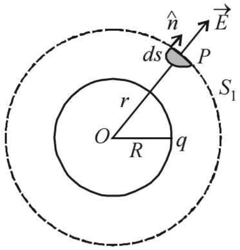
Let P be any point on the sphere S_1 with centre O and radius r.

According to Gauss's law

$$\oint_s \vec{E}.\vec{ds} = \frac{q}{\epsilon_0} \Rightarrow \oint_E \vec{E}.\hat{n}\,ds = \frac{q}{\epsilon_0}$$

$$\therefore \quad E\oint ds = \frac{q}{\epsilon_0} \Rightarrow E.4\pi r^2 = \frac{q}{\epsilon_0}$$

$$\therefore \quad E = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r^2}$$



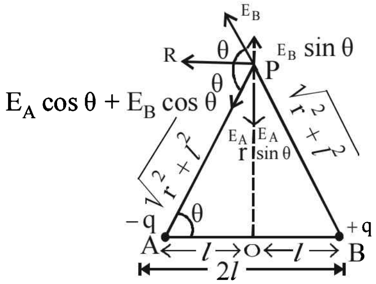
6. Electric dipole moment is defined as the product of either charge of the dipole and the distance between them.

i.e. $\vec{p} = q \times \vec{2l}$, where $\vec{2l}$ is the vector distance from the –ve to +ve charge.

Expression for the electric field of a dipole at a point on the equatorial plane of the dipole :

Let there be a point P (on the equatorial plane of the dipole) at a distance r from the centre of a dipole formed by two charges –q and +q and having dipole moments $\vec{p} = 2\,q\vec{l}$.

We have to find the electric field intensity at point P.



Electric field intensity at point P due to +q (at B)

$$E_B = \frac{1}{4\pi\epsilon_0}.\frac{q}{\left(r^2 + l^2\right)} \text{ along BP}$$

Electric field intensity at P due to – q charge (at A)

$$E_A = \frac{1}{4\pi\epsilon_0}.\frac{q}{\left(r^2 + l^2\right)} \text{ along PA}$$

Clearly, $E_A = E_B$ in magnitude.

E_A and E_B can be resolved into two rectangular components.

Components of E_A

(i) $E_A \cos\theta$ along PX

(ii) $E_A \sin\theta$ along PY

Components of E_B

(i) $E_B \cos\theta$ along PX

(ii) $E_B \sin\theta$ along YP

Vertical components being equal and opposite cancel each other.

Therefore, net electric field intensity along PX

$$E = E_A \cos\theta + E_A \cos\theta \qquad (\because E_A = E_B)$$

$$= 2E_A \cos\theta \text{ along PX}$$

$$= 2 \cdot \frac{1}{4\pi \epsilon_0} \cdot \frac{q}{(r^2+l^2)} \cdot \frac{1}{\sqrt{r^2+l^2}}$$

or, $$E = \frac{1}{4\pi \epsilon_0} \cdot \frac{p}{(r^2+l^2)^{3/2}} \text{ along PX} \qquad (\because p = q \times 2l)$$

If $l << r$ so that it can be neglected, then

$$E = \frac{1}{4\pi \epsilon_0} \cdot \frac{p}{r^3} \text{ along PX}$$

$$\therefore \quad E \propto \frac{1}{r^3}$$

7. For stable equilibrium, angle between p and E

$$\theta_1 = 0°.$$

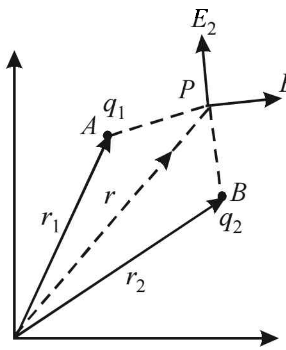
For unstable equilibrium $\theta_2 = 180°$.

Work done in rotating the dipole from angle θ_1 to θ_2.

$$W = pE(\cos\theta_1 - \cos\theta_2) = pE(\cos 0° - \cos 180°) = 2pE$$

8. Let two point charges q_1 and q_2 situated at points A and B have position vectors $\vec{r}_1$ and $\vec{r}_2$.

$\therefore$ AP = $\vec{r} - \vec{r}_1$ and BP = $\vec{r} - \vec{r}_2$



Electric field intensity at point P due to q_1,

$$E_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{|AP|^3} AP$$

Similarly, $E_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{|BP|^3} BP$

$\therefore$ Net electric field intensity at point P,

$$E = E_1 + E_2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{|r - r_1|^3}(r - r_1) + \frac{q_2}{|r - r_2|^3}(r - r_2)\right]$$

9. (i) The direction of electric field is along *X*-axis as it should be perpendicular to equipotential surface lying in *Y*-*Z* plane.

(ii) Length of the dipole = 2b

As dipole's axis is along the Y-axis.

$\therefore$ Electric dipole moment $p = q(2b)\,\hat{j}$

Electric field $E = E\hat{i}$

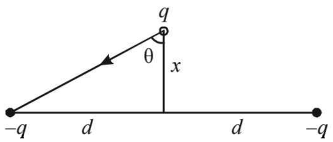
$\because \tau = p \times E = q(2b)\,\hat{j} \times E\hat{i} = +2qbE\left(\hat{j} \times \hat{i}\right) = 2qbE\left(-\hat{k}\right)$

Torque $|\tau| = 2qbE$

10. Net force F on q towards the centre O

$$F = 2\frac{q^2}{4\pi\varepsilon_0 r^2}\cos\theta = -\frac{2q^2}{4\pi\varepsilon_0 r^2}\cdot\frac{x}{r}$$

$$F = \frac{-2q^2}{4\pi\varepsilon_0}\frac{x}{(d^2 + x^2)^{3/2}} \approx \frac{-2q^2}{4\pi\varepsilon_0 d^3}x = -k \text{ for } x << d.$$



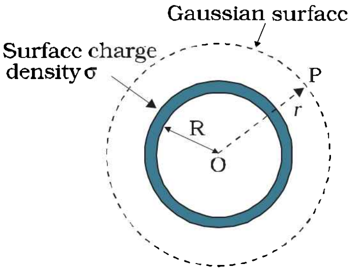
Thus, the force on the third charge q is proportional to the displacement and is towards the centre of the two other charges. Therefore, the motion of the third charge is harmonic with frequency

$$\omega = \sqrt{\frac{2q^2}{4\pi\varepsilon_0 d^3 m}} = \sqrt{\frac{k}{m}}$$

and hence $T = \frac{2\pi}{\omega}\left[\frac{8\pi^2\varepsilon_0 m d^3}{q^2}\right]^{1/2}$

11. Let there be a thin spherical shell whose centre is O and radius R. Let σ be the uniform surface charge density and q be the total charge on it. The charge distribution is spherically symmetric. We have to find electric field

(i) At a point outside the spherical shell, (r >> R) :



We have to find the electric field at a point P at a distance r outside the shell. Let us consider a Gaussian surface in the form of a sphere of radius r (r >> R).
By symmetry, the electric field acts radically outwards and has a normal component at all points on the Gaussian surface. Therefore electric flux

$$\phi = E \times A = E \times 4\pi r^2 \quad ...(i)$$

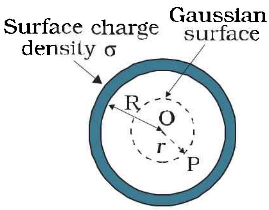
($\because$ A is the area of Gaussian surface)
According to Gauss's law

$$\phi = \frac{Q}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0} = \frac{\sigma \times 4\pi R^2}{\varepsilon_0} \quad ...(ii)$$

From equations (i) and (ii)

$$E \times 4\pi r^2 = \frac{\sigma \times 4\pi R^2}{\varepsilon_0} \quad \text{or} \quad E = \frac{\sigma R^2}{\varepsilon_0 r^3} = \frac{Q}{4\pi\varepsilon_0 r^2}$$

(ii) At a point inside the spherical shell : In this case (r << R) the Gaussian surface drawn inside the shell does not enclose any charge.



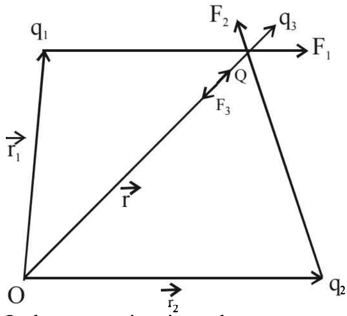
Hence, according to Gauss's theorem

$$\phi = \frac{q}{\varepsilon_0} = 0 \quad (\because q_m = 0)$$

$$\therefore \quad E \times 4\pi r^2 = \frac{0}{\varepsilon_0} \quad \text{or} \quad E = 0$$

12. (a) Force on Q due to q_1 is given by,

$$\vec{F}_1 = \frac{1}{4\pi \in_0} \frac{Qq_1}{\left|\vec{r} - \vec{r}_1\right|^3} (\hat{r} - \hat{r}_1)$$



Force on Q due to q_2 is given by,

$$\vec{F}_2 = \frac{1}{4\pi \in_0} \frac{Qq_2}{\left|\vec{r} - \vec{r}_2\right|^3} = (\hat{r} - \hat{r}_2)$$

Let the force between the charge Q and q_3 be $\vec{F}_3$

Since the forces are in equilibrium

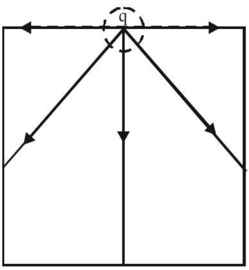
$$\therefore \vec{F}_3 = \vec{F}_1 + \vec{F}_2 = \frac{1}{4\pi \in_0} \frac{Qq_1}{\left|\vec{r} - \vec{r}_1\right|^3} (\hat{r} - \hat{r}_1) + \frac{Qq_2}{\left|\vec{r} - \vec{r}_2\right|^3} (\hat{r} - \hat{r}_2)$$

$$= \frac{1}{4\pi \in_0} \left| \frac{Qq_1}{\left|\vec{r} - \vec{r}_1\right|^3} (\hat{r} - \hat{r}_1) + \frac{Qq_2}{\left|\vec{r} - \vec{r}_2\right|^3} (\hat{r} - \hat{r}_2) \right|$$

Direction of net force will be just opposite the resulting direction from q_1 and q_2.

(b) If a spherical surface is imagined to be drawn with the charge q at its centre, the total electric flux emanated from the charge and passing through the lower half of spherical surface and hence, passing through the surface of vessel is, (according to the Gauss's law).

$$\phi_E = \frac{q}{2\varepsilon_0}$$



13. Electric potential on the surface of connected charged conducting sphere would be equal.

i.e., $v_1 = v_2$

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1} = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2}$$

[Assuming q_1 and q_2 are charges on the spheres connected to each other and r_1, r_2 are their radii.]

$$\frac{q_1}{r_1} = \frac{q_2}{r_2} \qquad \text{or,} \qquad \frac{q_1}{q_2} = \frac{r_1}{r_2} \qquad ...(i)$$

Now, ratio of electric field intensities.

$$\frac{E_1}{E_2} = \frac{\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1}{r_1^2}}{\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_2}{r_2^2}} = \frac{q_1}{q_2}\times\frac{r_2^2}{r_1^2}$$

$$\frac{E_1}{E_2} = \frac{r_1}{r_2}\times\frac{r_2^2}{r_1^2} \qquad \text{[From eq. (i)]}$$

$$\frac{E_1}{E_2} = \frac{r_2}{r_1}$$

14. The surface charge density for a spherical conductor is given by,

$$\sigma = \frac{Q}{4\pi r^2}$$

For spherical conductor R_1, the surface charge density,

$$\sigma_1 = \frac{q_1}{4\pi R_1^2}$$

Similarly, for spherical conductor R_2, the surface charge density,

$$\sigma_2 = \frac{q_2}{4\pi R_2^2}$$

$$\therefore \quad \frac{\sigma_1}{\sigma_2} = \left(\frac{q_1}{q_2}\right)\left(\frac{R_2^2}{R_1^2}\right)$$

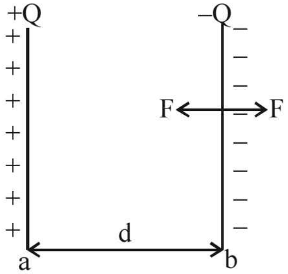
Since the two conductors are connected, we have,

$$q_1 = q_2$$

$$\therefore \quad \frac{\sigma_1}{\sigma_2} = \frac{R_2^2}{R_1^2} = \left(\frac{R_2}{R_1}\right)^2$$

15. Let Q = Total charge on each plate of the capacitor,

A = Area of each plate,



Suppose the plates of the capacitor are almost touching each other and a charge Q is given to the capacitor. One of the plates, say *a*, is kept fixed and other say *b*, is slowly pulled away from plate *a* to increase the separation from zero to *d*. The attractive force on the plate b at any instant due to first plate is given by, $F = \frac{Q^2}{2A\varepsilon_0}$

The person pulling the plate b must apply an equal and opposite force (F) in the opposite direction. If the plate is moved slowly Work done by the person during the displacement of the second plate; $W = F.d = \frac{Q^2 d}{2A\varepsilon_0} = \frac{Q^2}{2C}$

Here, $C = \frac{A\varepsilon_0}{d}$ which is the capacitance of the capacitor in the final position.

The work done by the person must be equal to the increase in the energy of the system.

Thus, the capacitor has a stored energy, $U = \frac{Q^2}{2C}$

Now, if we pull the plates of the capacitor apart, we have to do work against the electrostatic attraction between the plates.

When we increase the separation between the plates from d_1 to d_2, an amount $\frac{Q^2}{2A\varepsilon_0}(d_2 - d_1)$ of work is performed by us and this much energy goes into the capacitor.

On the other hand, new electric field is created in a volume $A(d_2 - d_1)$.

The energy stored per unit volume is thus given by,

$$u = \frac{Q^2 (d_2 - d_1)}{2A\varepsilon_0}$$

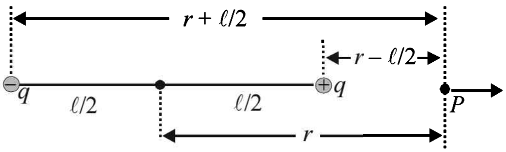
$$A(d_2 - d_1) = \frac{Q^2}{2A^2\varepsilon_0}$$

$$= \frac{1}{2}\varepsilon_0 \left(\frac{Q}{A\varepsilon_0}\right)^2 = \frac{1}{2}\varepsilon_0 E^2$$

Here, E is the intensity of the electric field.

16. The potential at a point due to the dipole is the sum of potentials due to the charges q and – q.

Let these be a dipole consist of charge +q and –q separated by a small distance ℓ. We have to find electric potential at point P along axial line.



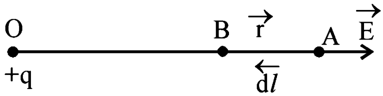
$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{r-\ell/2} - \frac{q}{r+\ell/2}\right] = \frac{1}{4\pi\varepsilon_0}\left[\frac{q\ell}{r^2-\ell^2/4}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{P}{r^2-\ell^2/4}\right]$$

As $\ell << r$,

$$\therefore \quad V = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{P}{r^2}.$$

17.



Consider two points A and B in the electric field of point charge +q.

To move a test charge q_0 from A to B, the applied force $= -q_0\vec{E}$.

Workdone $= -q_0\vec{E}.d\vec{\ell} = -q_0 E d\ell \cos 180° = q_0 E dl \; [\because \cos 180° = -1]$

$$= -q_0 Edr \; [\because \overrightarrow{d\ell} = -d\vec{r}]$$

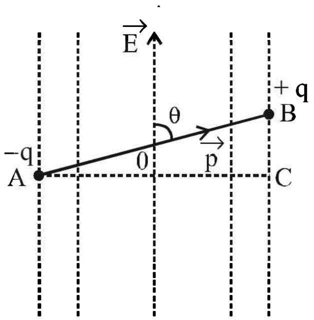
$$\therefore \quad \frac{\text{work done}}{q_0} = -Edr$$

$\therefore$ Potential difference between A and B

$dV = -Edr$

$E = -dV/dr$

18. Consider an electric dipole consisting of two equal and opposite charges – q at A and +q at B separated by a small distance 2a, as shown in figure.



The torque experienced by the dipole in a uniform external electric field $\vec{E}$ at an angle θ with the direction of $\vec{E}$ is,

$$\tau = pE\sin\theta.$$

It tries to rotate the dipole. Small amount of work done in rotating the dipole through a small angle $d\theta$ against the torque is,

$$dW = \tau = d\theta = pE\sin\theta.d\theta$$

$\therefore$ Total work done in rotating the dipole from orientation θ_1 to θ_2 is

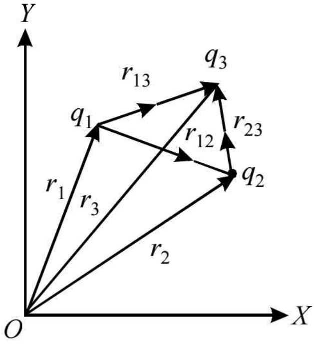
$$W = \int_{\theta_1}^{\theta_2} pE\sin\theta\, d\theta = pE[-\cos\theta]_{\theta_1}^{\theta_2} = -pE[\cos\theta_2 - \cos\theta_1].$$

$\therefore$ Potential energy of dipole, $U = -pE[\cos\theta_2 - \cos\theta_1]$.

When the dipole is initially at right angle to $\vec{E}$, then $\theta_1 = 90°$ and $\theta_2 = \theta$ (say)

$\therefore$ $U = -pE(\cos\theta - \cos 90°) = -pE\cos\theta = -\vec{p}.\vec{E}$

19. Let three point charges q_1, q_2 and q_3 have position vectors r_1, r_2 and r_3.



Potential energy of the charges q_1 and q_2.

$$U_{12} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{|r_{12}|} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{|r_2 - r_1|}$$

i.e., when a third charge q_3 is placed at r_3 then work done is stored as potential energy.

$$U_{23} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2 q_3}{|r_3 - r_2|} \quad ; \quad U_{31} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_3}{|r_3 - r_1|}$$

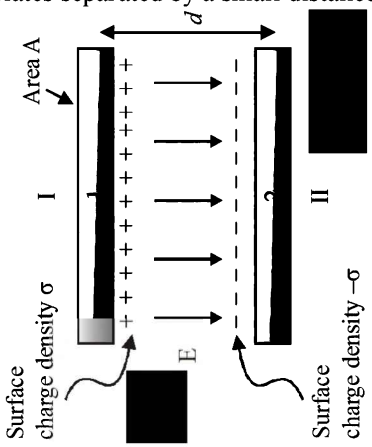
$\therefore$ Net potential energy of the system $U = U_{12} + U_{23} + U_{31}$

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_2}{|r_2 - r_1|} + \frac{q_2 q_3}{|r_3 - r_2|} + \frac{q_1 q_3}{|r_3 - r_1|}\right]$$

20. By definition, electric potential energy of any charge q placed in the region of electric field is equal to the work done in bringing charge q from infinity to that point and given by $U = qV$
Now, considering the electric potentials at positions r_1 and r_2 as V_1 and V_2 respectively. Therefore, total potential energy of the system of two charges q_1 and q_2 placed at points with position vectors r_1 and r_2 in the region of E is given by
U = Work done in bringing charge q, from infinite to that position in E is equal to work done for charge q_2 from infinite to that position in E + work done to that of charge q_2 at these positions in presence of q_1.

i.e., $U = q_1 V_1 + q_2 V_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{|r_2 - r_1|}$

21. A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance d.



Let A be the area of each plate and d be the separation between them. The two plates have charges Q and –Q. Plate 1 has surface charge density, = Q/A
And plate 2 has a surface charge density –
Electric field in, outer region I,

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

Similarly, electric field in outer region II,

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

In the inner region between plates 1 and 2, the electric fields due to the two charged plates add up.

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$$

The direction of electric field is from positive to the negative plate. For uniform electric field, potential difference is simply the electric field times the distance between the plates.

$$V = E\,d = \frac{1}{\varepsilon_0}\frac{Qd}{A}$$

Capacitance (C) of the parallel plate capacitor,

$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d}$$

22. (a) Let C_1 and C_2 are the capacitances, q_1 and q_2 are the charges, V_1 and V_2 are potential of the capacitors respectively.

$\therefore \quad q_1 = C_1V_1 \qquad$ and $q_2 = C_2V_2$

Before sharing, total charge $= q_1 + q_2$

$= C_1V_1 + C_2V_2$

When the capacitors are joined by a wire, charge will flow from higher to lower potential till both the potentials are equal. This equal potential is called common potential (V)

If q'_1 and q'_2 are charges on C_1 and C_2 after redistribution of charges, then

$q'_1 = C_1V$ and $q'_2 = C_2V$

$\because$ Total charge after connecting them together remains same as before.

$q = q'_1 + q'_2 = C_1V + C_2V = (C_1 + C_2)V$

$\therefore \quad (C_1 + C_2)\,V = C_1V_1 + C_2V_2$

$$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

(b) P.E. before sharing $= \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$

P.E. after sharing $= \frac{1}{2}C_1V^2 + \frac{1}{2}C_2V^2 = \frac{1}{2}(C_1 + C_2)V^2$

$$= \frac{1}{2}(C_1 + C_2)\left[\frac{C_1V_1 + C_2V_2}{C_1 + C_2}\right]^2 = \frac{1}{2}\frac{(C_1V_1 + C_2V_2)^2}{(C_1 + C_2)}$$

$\therefore$ Loss of energy $= \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2 - \frac{1}{2}\frac{(C_1V_1 + C_2V_2)^2}{(C_1 + C_2)}$

$$= \frac{1}{2(C_1 + C_2)}\left[(C_1V_1^2 + C_2V_2^2)(C_1 + C_2) - (C_1V_1 + C_2V_2)^2\right]$$

$$= \frac{1}{2(C_1 + C_2)}$$

$$[C_1^2V_1^2 + C_1C_2V_1^2 + C_1C_2V_2^2 + C_2V_2^2 - C_1^2V_1^2 - C_2^2V_2^2 - 2C_1C_2V_1V_2]$$

$$= \frac{1}{2(C_1 + C_2)}C_1C_2(V_1^2 + V_2^2 - 2V_1V_2)$$

$$= \frac{C_1C_2}{2(C_1 + C_2)}(V_1 - V_2)^2 = \text{Positive}$$

$\therefore$ Energy is lost due to sharing of charges.

23. Let V_1 and V_2 be the potential differences across the series and parallel combination of two identical capacitors each of capacitance C. Equivalent capacitance in series combination

$$C_s = \frac{C}{2}$$

Equivalent capacitance in parallel combination.

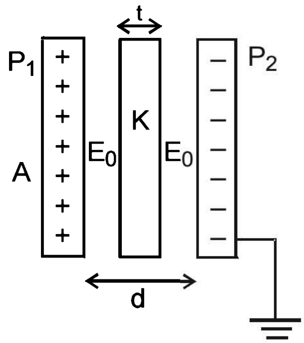
$$C_p = 2C$$

According to problem $\quad U_s = U_p$

or, $\frac{1}{2}C_sV_s^2 = \frac{1}{2}C_pV_p^2 \Rightarrow \frac{V_s^2}{V_p^2} = \frac{C_p}{C_s} = \frac{2C}{\left(\frac{C}{2}\right)}$

$$\frac{V_s^2}{V_p^2} = 4 \Rightarrow \frac{V_s}{V_p} = 2$$

24. Let V be the potential difference between the plates and E_0 the electric field :



$$E_0 = \frac{V}{d} = \frac{q}{A \in_0}$$

where q is he charge and A is the area of the plates.

When a slab of thickness $t = \frac{d}{2}$ is introduced between the plates, then potential

$$V = E_0\left(d - \frac{d}{2}\right) + E\,.\,\frac{d}{2} \qquad ...(i)$$

where E is the elctric field inside the dielectric of dielectric constant K

$$E = \frac{E_0}{K}$$

Putting this value of E in eq. (i)

$$V = E_0\frac{d}{2} + \frac{E_0}{K}\frac{d}{2} \Rightarrow V = \frac{E_0 d}{2}\left(1 + \frac{1}{K}\right)$$

$$V = \frac{q}{A \in_0}\cdot\frac{d}{2}\left(1 + \frac{1}{K}\right)$$

Therefore capacitance,

$$C = \frac{Q}{V} = \frac{2A \in_0}{d\left(1 + \frac{1}{K}\right)}$$

25. The capacity of condenser is proportional to the area and inversely proportional to the distance between its plates. If a medium of dielectric constant *K* is filled in the space between the plates, its capacity becomes *K* times the capacity when there is air between the plates.

After inserting the dielectric medium, let their capacitances become C_1' and C_2'.

For C_1, $C_1' = KC$

For C_2, $C_2' = \dfrac{K_1\varepsilon_0(A/2)}{d} + \dfrac{K_2\varepsilon_0 A/2}{d}$

$$C_2' = \frac{\varepsilon_0 A}{d}\left[\frac{K_1}{2} + \frac{K_2}{2}\right]$$

$$C_2' = C\left[\frac{K_1 + K_2}{2}\right] \qquad \left[\because C = \frac{\varepsilon_0 A}{d}\right]$$

According to question,

$$C_1' = C_2'$$

$$\therefore \quad KC = C\left(\frac{K_1 + K_2}{2}\right) \Rightarrow \text{or, } K = \frac{K_1 + K_2}{2}$$

26. After introduction of dielectric medium of dielectric constants K_1 and K_2, capacitor acts as if it consists of two capacitors, each having plates of area A and separation $\frac{d}{2}$ connected in series combination for

$$\therefore \frac{1}{C_2} = \frac{1}{\left(\frac{K_1\varepsilon_0 A}{d/2}\right)} + \frac{1}{\left(\frac{K_2\varepsilon_0 A}{d/2}\right)}$$

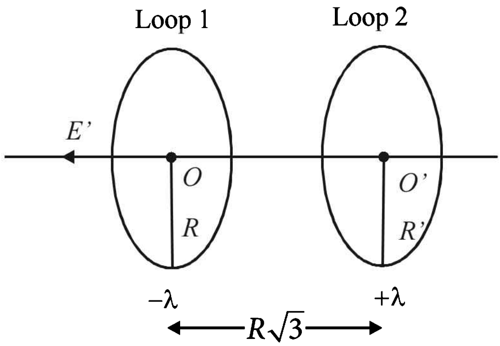
$$\frac{1}{C_2} = \frac{1}{\left(\frac{\varepsilon_0 A}{d}\right)}\left[\frac{1}{2K_1} + \frac{1}{2K_2}\right]$$

$$\frac{1}{C_2} = \frac{1}{2C_1}\left[\frac{K_2 + K_1}{K_1 K_2}\right] \qquad \left[\because C_1 = \frac{\varepsilon_0 A}{d}\right]$$

$$\text{or,} \quad C_2 = C_1\left(\frac{2K_1K_2}{K_1 + K_2}\right)$$

27. Magnitude of electric field at any point on the axis of a uniformly charged loop is given by,

$$E = \frac{\lambda}{2\in_0}\frac{rR}{(r^2 + R^2)^{\frac{3}{2}}} \qquad \ldots(i)$$

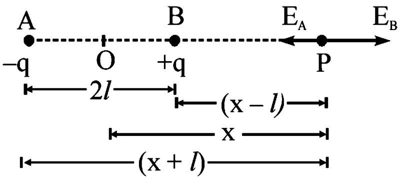


Electric field at the centre of loop 1 due to charge present on it is zero. [From (i), when $r = 0$]
Hence, electric field at the centre of the loop 1 due to charge present on the loop 2 is,

$$E = \frac{+\lambda}{2\in_0}\frac{(R\sqrt{3})R}{[(R\sqrt{3})^2+R^2]^{3/2}} = \frac{\lambda}{2\varepsilon_0}\frac{R^2\sqrt{3}}{8R^3} \Rightarrow E = \frac{\sqrt{3}}{16\in_0}\frac{\lambda}{R}$$

The direction of this net field is from loop 2 to loop 1 as shown.

28. We have to calculate the field intensity (E) at a point P on the axial line of the dipole and at a distance OP = x from the centre O of the dipole.



Electric field on axial line of an electric dipole

Resultant electric field intensity at the point P is

$$E_p = E_A + E_B$$

The vectors E_A and E_B are collinear and opposite.

$$\therefore \quad E_p = E_B - E_A$$

Here, $$E_A = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(x+l)^2}$$

$$E_B = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{(x-l)^2}$$

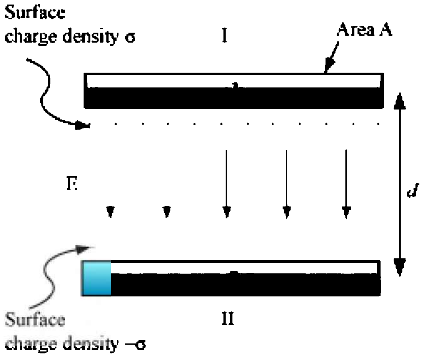
$$\therefore \quad E_p = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(x-l)^2} - \frac{q}{(x+l)^2}\right].$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{4qlx}{(x^2 - l^2)^2}$$

Hence, $E_p = \frac{1}{4\pi\varepsilon_0} \frac{2px}{(x^2 - l^2)^2}$ (as p = 2ql)

If dipole is short, 2l << x, then $E_p = \frac{2p}{4\pi\varepsilon_0 x^3}$

29. We are given two similar large plates separated by a small distance (d) and having area (A).



Let charge on each plate be Q

Surface charge density of plate 1, σ = Q/A, and that of plate 2 is –σ.

Electric field in different regions :

Outer region I,

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

Outer region II,

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

In the inner region between plates 1 and 2, the electric fields due to the two charged plates add up. So,

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$$

The direction of electric field is form the positive to the negative plate.

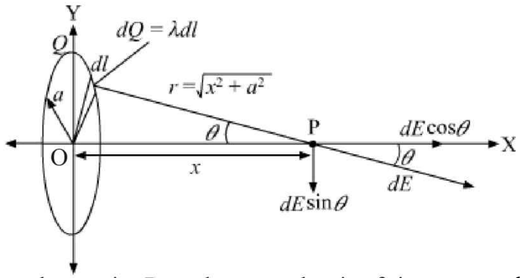
(b) For uniform electric field, potential difference is simply the electric field multiplied by the distance between the plates,

i.e. $V = Ed = \frac{1}{\varepsilon_0} \frac{Qd}{A}$

(c) Capacitance C of the parallel plate capacitor,

$$C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{\varepsilon_0 A}} = \frac{\varepsilon_0 A}{d}$$

30. Figure shows, a ring of radius a that carries a uniformly distributed positive total charge Q.



Let there be a point P on the central axis of ring perpendicular to the plane of the ring, at which we have to calculate electric field Intersity. As the charge is distributed uniformly over the ring, the charge density $\lambda = \frac{Q}{2\pi a}$

Along the x-axis, the perpendicular components of the electric fields due to each other will cancil out.

As there is same charge on both sides of the ring, the magnitude of electric field of the segment of charge dQ is given by

$$dE = K_e \frac{dQ}{r^2}$$

$$E_x = \int_{ring} k \frac{dQ}{r^2} \cos\theta \qquad \cos\theta = \frac{x}{r} \text{ from } \Delta OPA$$

$$= \int_0^{2\pi a} k \frac{\lambda dl}{r^2} \frac{x}{r} = k\lambda \frac{x}{r^3} \int_0^{2\pi a} dl = k \frac{Q}{2\pi a} \frac{x}{r^3} 2\pi a$$

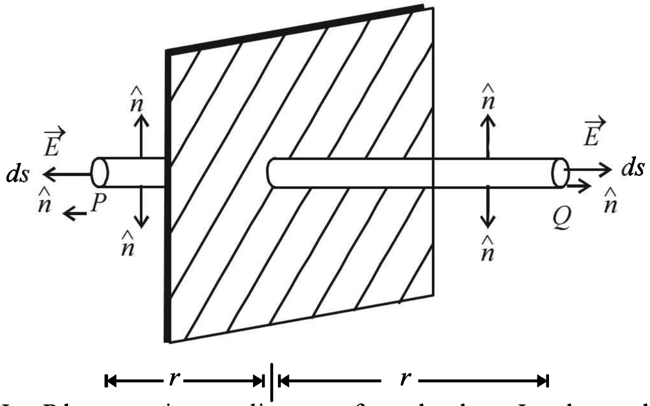
$$kQ \frac{x}{r^3} = kQ \frac{x}{\sqrt{\left(x^2 + a^2\right)^3}}$$

1. At the centre of the ring, the electric field is zero as $x = 0$.
2. When $x >> a$, a can be neglected in the denominator compared to charge at large distances.

$$E = kQ \frac{x}{\sqrt{\left(x^2 + a^2\right)^3}} E \quad \text{or,} \quad E = k\frac{Q}{x^2}, \ (\because x >> a)$$

31. Electric fields due to a uniformly charged infinite plane sheet: Suppose a thin non-conducting infinite sheet of uniform surface, charge density σ.

Electric field intensity $\vec{E}$ on either side of the sheet must be perpendicular to the plane of sheet having same magnitude at all points from sheets.



Let P be any point at a distance r from the sheet. Let the small area element $\vec{ds} = ds\hat{n}$.

$\vec{E}$ and $\hat{n}$ are parallel on the two cylinderical edges P and Q, which contributes electric flux.

$\therefore$ Electric flux over the edges P and Q of the cylinder is 2ϕ

$$\Rightarrow \quad 2\oint \vec{E}.\vec{ds} = \frac{q}{\epsilon_0} \Rightarrow 2E\pi\, r^2 = \frac{q}{\epsilon_0}$$

$$E = \frac{q}{2\pi \epsilon_0 r^2}$$

Charge density, $\sigma = \frac{q}{s} \Rightarrow q = \pi\, r^2\, \sigma$ [Where S – area of circle]

$$E = \frac{\pi r^2 \sigma}{2\pi \epsilon_0 r^2}$$

$$E = \frac{\sigma}{2\epsilon_0}, \text{ Vectorically } \vec{E} = \frac{\sigma}{2\epsilon_0}\hat{n}$$

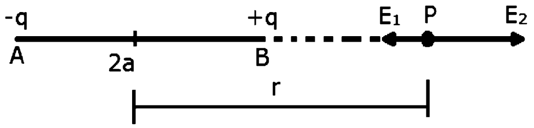
where $\hat{n}$ is a unit vector normal to the plane and going away from it. When $\sigma > 0$, E is directed away from both sides. Hence electric field intensity is independent of r.

32. Consider an electric dipole consisting of two point charges +q and –q separated by a small distance 2a.

Electric field intensity at point P due to charge –q

$$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{q}{AP^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}$$

It is along PA.



Electric field intensity at point P due to charge +q

$$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{BP^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}$$

It is along BP.

Hence, the resultant field $E = E_2 - E_1$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{4ar}{(r^2-a^2)}\right]$$

$$E = \frac{q}{4\pi\varepsilon_0}\frac{2a \times 2r}{(r^2-a^2)^2}$$

Now, the dipole moment is $q \times 2a = p$

$$\therefore \quad E = \frac{p}{4\pi\varepsilon_0}\frac{2r}{(r^2-a^2)^2}$$

33. Let V_0 be the potential at the point in front of the large thin plane sheet. This point is at a distance r from its surface.

$dV = E \cdot dr$

$$\therefore V_0 - V = \frac{\sigma}{2\varepsilon_0} r = W \text{ (Work done)}$$

34. By Kirchhoff's current rule

$$I = I_1 + I_2$$

Across cell E_1, potential difference (V)

$$V = V_{B_2} - V_{B_1} = E_1 - I_1 r_1$$

Across cell E_2, potential difference (V)

$$V = V_{B_2} - V_{B_1} = E_2 - I_2 r_2$$

$$\therefore \quad I = \left(\frac{E_1 - V}{r_1}\right) + \left(\frac{E_2 - V}{r_2}\right)$$

$$I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$V\left(\frac{r_1 + r_2}{r_1 r_2}\right) = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right) - I$$

$$V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$$

Let equivalent emf and equivalent internal resistance of combination are E_{eq} and r_{eq}, then potential difference across combination is by

$$V = E_{eq} - Ir_{eq}$$

On comparing we get,

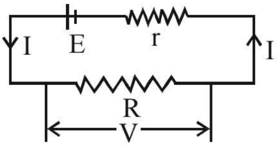
$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} \quad \text{and} \quad r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

35. Net emf of combination = E – 2E + 5E = 4E

Net resistance = r + 2r + 3r + R = 6r + R

$$\therefore \qquad I = \frac{4E}{6r + R}$$

36. Let R be the external resistance and r be the internal resistance of the cell of e.m.f E.



$\therefore$ In closed circuit, total resistance of the circuit = R + r

$$\therefore \quad \text{Current} = I = \frac{E}{R + r}$$

Potential difference = V = E – Ir

(Ir = Potential drop across internal resistance)

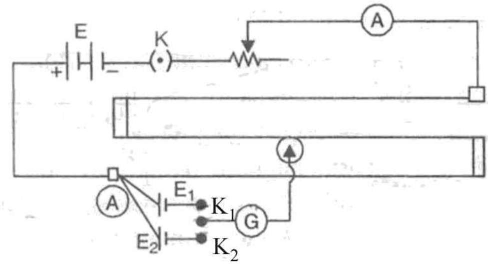
$$Ir = E - V \Rightarrow r = \frac{E - V}{I}$$

By ohm's law, V = IR

$$\therefore \quad I = \frac{V}{R}$$

$$\therefore \quad r = \left(\frac{E - V}{V}\right)R = \left(\frac{E}{V} - 1\right)R.$$

37. The circuit diagram for comparing the emfs of two cells has been shown below.



When the key K_1 is closed, the galvanometer is connected to the cell of emf E_1 in the circuit. The jockey is moved on the wire to obtain a balance point, i.e., a point on the wire where the galvanometer gives zero deflection. Let the balancing length be L_1. Therefore, by the potentiometer principle,

$$E_1 \propto L_1 \qquad ...(i)$$

Now, the key K_2 is closed. The galvanometer is connected to the cell of emf E_2 in the circuit. The jockey is again moved on the wire to obtain the balance point. Let the balancing length be L_2. Then by potentiometer principle,

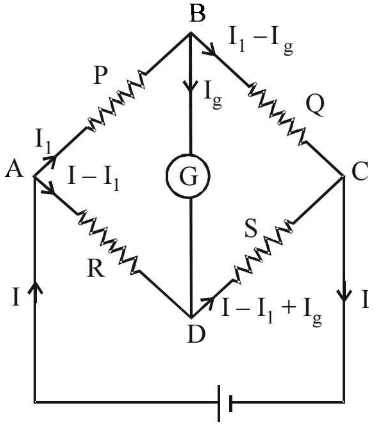
$$E_2 \propto L_2 \qquad ...(ii)$$

Dividing equation (i) by (ii),

$$\frac{E_1}{E_2} = \frac{L_1}{L_2} \qquad ...(iii)$$

This is the required expression for comparing emf's.
Knowing the values of L_1 and L_2, the emf's of the cells can be compared.

38.



The currents in different branches are shown in the figure according to Kirchhoff's first law.

In the loop ABDA applying Kirchhoff's second law,

$I_1P + IgG - (I - I_1)R = 0$ .... (1)

[G = Galvanometer resistance]

In the loop BCDB,

$(I_1 - Ig)Q - (I - I_1)S - Ig G = 0$ .... (2)

In the balanced condition of the bridge the value of R is so adjusted that the galvanometer shows no deflection,

i.e. $I_g = 0$

∴ Putting $I_g = 0$ in (1) and (2)

$I_1P - (I - I_1)R = 0 \Rightarrow I_1P = (I - I_1)R$ ..... (3)

$I_1Q - (I - I_1)S = 0 \Rightarrow I_1Q = (I - I_1)S$ .... (4)

Dividing (3) and (4) we get, $\frac{P}{Q} = \frac{R}{S}$

39. Drift speed and relaxation time are related as:

$$v_d = -\frac{eE\tau}{m}$$

As current $I = -ne\,Av_d$

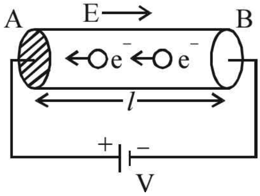
$$I = -neA\left(-\frac{eE\tau}{m}\right)$$

$$I = \frac{ne^2A\tau}{m}\left(\frac{V}{l}\right) \qquad \left(\because E = \frac{V}{l}\right)$$

$$\Rightarrow \qquad \frac{V}{I} = \frac{ml}{ne^2A\tau} = \rho\frac{l}{A} = R$$

$$\rho = \frac{m}{ne^2\tau}$$

40. When potential difference V is applied across the conductor, an electric field is produced and the electrons are accelerated from one end to the other. On the way, they suffer collisions, come to rest and are again accelerated. Thus, they drift from one end to the other with a very small velocity called the drift velocity and is denoted by v_d.



Let n = no. of electrons or charge carriers per unit volume

a = area of cross-section

I = current through the conductor
t = time taken by the electrons to drift from one end to other end of the conductor.

Clearly, in time t, whole charge Q will move from one end to the other.

Now, $Q = Ne$, where N is the total number of electrons

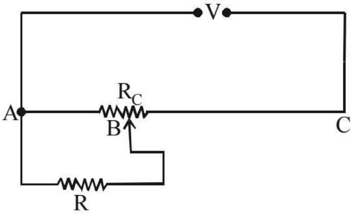
$= a \times l \times ne$

or $Q = nale$

$\therefore$ Current $i = \frac{Q}{t} = \frac{nale}{t}$ or $i = naev_d$ $\left[\because v_d = \frac{l}{t}\right]$

41. Total resistance between A and B

$$R_{AB} = \frac{\frac{R_0}{2} \times R}{R + \frac{R_0}{2}} = \frac{RR_0}{2R + R_0}$$



Total resistance between A and C

$$R_{AC} = R_{AB} + \frac{R_0}{2} = \left[\frac{RR_0}{2R + R_0} + \frac{R_0}{2}\right]$$

The current through the potentiometer wire

$$I = \frac{V}{R_{AC}}$$

The potential difference between A and B

$$V_{AB} = I\ R_{AB} = \frac{V}{R_{AC}} \times R_{AB}$$

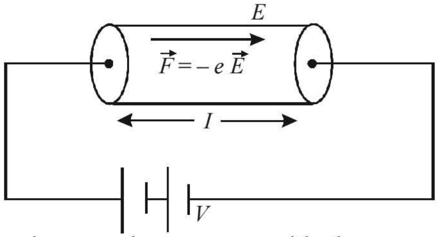
$$= \frac{V}{\frac{RR_0}{R+R_0} + \frac{R_0}{2}} \times \frac{RR_0}{(2R+R_0)}$$

$$= \frac{V}{\frac{2RR_0 + R_0(2R+R_0)}{2(2R+R_0)}} \times \frac{RR_0}{(2R+R_0)} = \frac{2V\ RR_0}{R_0[2R+2R+R_0]}$$

$$V_{AB} = \frac{2VR}{R_0 + 4R}$$

42. Free electrons are in continuous random motion, They undergo change in direction at each collision and the thermal velocities are randomly distributed in all directions.

$\therefore$ Average thermal velocity, $u = \dfrac{u_1 + u_2 + ... + u_n}{n} = 0$



Free electrons in a conductor move with the same speed but in random directions. Thus, the average velocity of all N electrons will be zero.

$$\frac{1}{N}\sum_{i=1}^{N} \vec{v}_i = 0$$

When an electric field (E) is applied across the conductor electrons will be accelerated towards the positive end.

$$\vec{a} = \frac{-eE}{m}$$

Where $-e$ is the charge and m is the mass of an electron. As electrons move, they suffer collision with the heavy fixed ions. The collisions of the electrons do not occur at regular intervals but at random times. The average value of time between successive collisions is known as relaxation time (τ).

The average velocity of N electrons at any given time t is called the drift velocity (V_d).

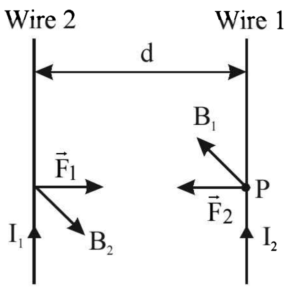
$$\vec{V}_d = (\vec{V}_i)_{average} - \frac{e\vec{E}}{m}(t_i)_{average} = 0 - \frac{e\vec{E}}{m}\tau$$

or, $\vec{V}_d = -\dfrac{e\vec{E}}{m}\tau$

Hence average drift velocity, $\vec{V}_d = \dfrac{e\vec{E}}{m}\tau$

43. Magnetic field induction a point P on wire 2 due to current

$$B_1 = \frac{\mu 2I_1}{4\pi d}$$



As the current carrying wire 2 lies in magnetic field produced by wire 1, the unit length of wire 2 will experience a force, which is given by

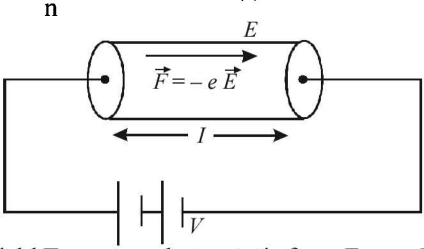
$$F_2 = B_1 I_2 \times 1 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d} \qquad ...(1)$$

According to Fleming's left-hand rule, the force on wire 2 acts in the plane of paper perpendicular to wire 2, directed towards wire 1. Similarly, wire 1 also experiences the same force towards wire 2. Thus, both the conducting wires attract each other with the same force F.

44. Free electrons are in continuous random motion. They undergo change in direction at each collision and the thermal velocities are randomly distributed in all directions.

$\therefore$ Average thermal velocity

$$u = \frac{u_1 + u_2 + ... + u_n}{n} = 0 \quad ......(1)$$



The electric field E exert an electrostatic force F = – e E

Acceleration of each electron is, $\vec{a} = \frac{-e\vec{E}}{m}$ ....(2)

Here,

m → Mass of an electron

e → Charge on an electron

Drift velocity is given by

$$\vec{v_d} = \frac{\vec{v_1} + \vec{v_2} + ... + \vec{v_n}}{n}$$

$$\vec{v}_d = \frac{(\vec{u}_1 + \vec{a}t_1) + (\vec{u}_2 + \vec{a}t_2) + ...(\vec{u}_n + \vec{a}t_n)}{n}$$

Here,

$\vec{u}_1, \vec{u}_2 \rightarrow$ Thermal velocities of the electrons

$\vec{a}t_1, \vec{a}t_2 \rightarrow$ Velocities acquired by electrons

$T_1, T_2 \rightarrow$ Time elapsed after the collision

$$\vec{v}_d = \frac{(\vec{u}_1 + \vec{u}_2 + ... + \vec{u}_n)}{n} + \frac{\vec{a}(t_1 + t_2 + ... + t_n)}{n}$$

Since $\frac{\vec{u}_1 + \vec{u}_2 + ... + \vec{u}_n}{n} = 0,$

$\therefore v_d = at$ ......(3)

Here, $t = \dfrac{t_1 + t_2 + t_3 = \ldots\ldots\ldots + t_n}{n}$ is the average time elapsed.

Substituting for $\vec{a}$ from equation 2

$$\vec{v}_d = \frac{-e\vec{E}}{m}t \qquad \text{......(4)}$$

Because of the external electric field, electrons are accelerated. They move from one place to another and current is flowing from one direction to other.

For small interval dt, we have

Idt = –q

Let n be the free electrons per unit area. Then, the total charge crossing area A, Idt = $neAv_d dt$

Substituting the value of v_d, we get

$$|J| = n\frac{e^2}{m}|E|T$$ Here, J is the current density.

From Ohm's law, $J = \sigma E$

Here, σ is the conductivity of the material through which the current is flowing.

Thus, $\sigma = n\dfrac{e^2}{m}T$

We know, resistivity, $\rho = \dfrac{1}{\sigma}$ (resistivity is reciprocal of conductivity)

Substituting the value of conductivity, we get

$$\rho = \frac{m}{ne^2T}$$

Here, T is the relaxation time.

45. For balancing length l_1, the condition is

$$\frac{R}{S} = \frac{l}{100 - l_1} \qquad \text{...(i)}$$

When a resistance x is connected in parallel with S, the net resistance becomes

$$S_{new} = \frac{XS}{X+S}$$

For balancing length l_2, the condition is

$$\frac{R}{S_{new}} = \frac{l_2}{100 - l_2}$$

$$\therefore \frac{R(X+S)}{XS} = \frac{l_2}{100 - l_2} \qquad \text{...(ii)}$$

From eqn. (i) and (ii)

$$\frac{l_1}{100-l_1} \times \frac{X \times S}{X} = \frac{l_2}{100-l_2}$$

$$\therefore \frac{X+S}{X} = \frac{l_2}{100-l_2} \times \frac{100-l_1}{l_1}$$

$$\therefore \frac{X+S}{X} = \frac{l_2(100-l_1)}{l_1(100-l_2)} \Rightarrow \frac{S}{X}+1 = \frac{l_2(100-l_1)}{l_1(100-l_2)}$$

$$\therefore \frac{S}{X} = \frac{l_2(100-l_1)}{l_1(100-l_2)} - 1 = \frac{l_2(100-l_1)-l_1(100-l_2)}{l_1(100-l_2)}$$

$$\therefore \frac{X}{S} = \frac{l_1(100-l_2)}{l_2(100-l_1)-l_1(100-l_2)}$$

or, $X = S \times \dfrac{l_1(100-l_2)}{l_2(100-l_1)-l_1(100-l_2)}$

46. Let n be the number of turns per unit length of the solenoid.
I is the current through the solenoid.
At a point outside the solenoid the magnetic field is almost zero.
Consider a rectangle PQRS where PQ = L
Line integral of magnetic field over PQRS

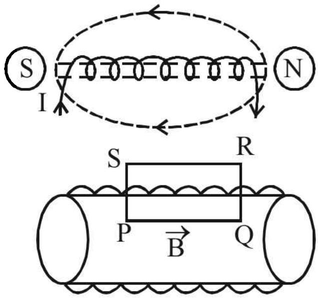
$$\oint \vec{B}.d\vec{\ell} = \int_P^Q \vec{B}.d\vec{\ell} + \int_Q^R \vec{B}.d\vec{\ell} + \int_R^S \vec{B}.d\vec{\ell} + \int_S^P \vec{B}.d\vec{\ell}$$

$$\Rightarrow \int_P^Q \vec{B}.d\vec{\ell} = \int_P^Q Bd\ell \cos 0° = BL$$

$$\int_Q^R \vec{B}.d\vec{\ell} = \int_S^P \vec{B}.d\vec{\ell} = \int Bd\ell \cos 90° = 0$$

$$\Rightarrow \int_R^S \vec{B}.d\vec{\ell} = 0$$

($\because$ outside the solenoid B = 0)



$$\oint \vec{B}.d\vec{\ell} = BL$$

∴ By Ampere's circuital law,

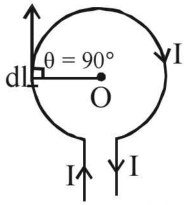
BL = μ_0 × total current through PQRS.

BL = μ_0 × no. of turns in rectangle × I

BL = μ_0 NLI ⇒ B = μ_0 nI

47. From Biot – Savart's law, the magnetic field due to an element of length 2*l* of the current carrying conductor

$$dB = \frac{\mu_0}{4\pi}\frac{Id\ell \sin\theta}{r^2}$$



Here $\theta = 90°$ ($\because$ $d\ell$ is tangential, angle between the radius and the tangent is 90°)

$$\therefore\ dB = \frac{\mu_0}{4\pi}.\frac{Id\ell}{r^2}$$

∴ Total magnetic field at the centre O due to the whole circular coil

$$= B = \int dB = \frac{\mu_0 I}{4\pi r^2}\int d\ell = \frac{\mu_0 I}{4\pi r^2}.2\pi r = \frac{\mu_0 I}{2r}$$

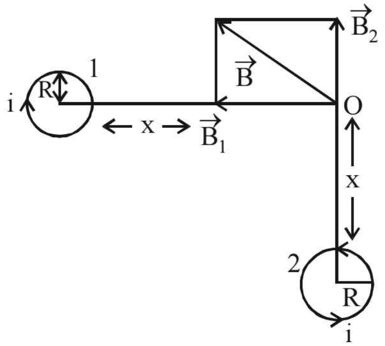
For a coil of n number of turns, $B = \frac{\mu_0 nI}{2r}$

It is perpendicular to the plane of the coil and directed inwards.

48. Magnetic field at O due to circular coil 1 carrying current i is,

$$B_1 = \frac{\mu_0\ i\ R^2}{2\ (x^2 + R^2)^{3/2}}$$

The magnetic field acts along the axis of the coil. It is directed towards the coil 1.



Magneticfield at O due to circular coil 2 carrying current i is,

$$B_2 = \frac{\mu_0 \, i R^2}{2 (x^2 + R^2)^{3/2}}$$

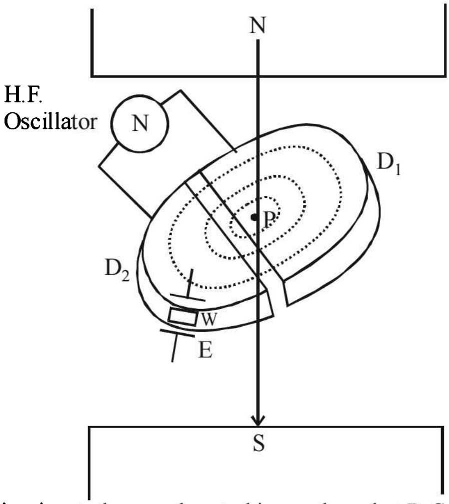
It acts along the axis of the coil, vertically upwards.

∴ Resultant magnetic field at O will be

$$B = \sqrt{B_1^2 + B_2^2} = \sqrt{2}\, B_1$$

$$= \sqrt{2}\left(\frac{\mu_0 \, i R^2}{2 (x^2 + R^2)^{3/2}}\right) = \frac{\mu_0 \, i R^2}{\sqrt{2}(x^2 + R^2)^{3/2}}.$$

49. A cyclotron is a device used to accelerate positively charged particles like proton, electron etc.



The positive ion to be accelerated is produced at P. Suppose, D_1 is at negative potential and D_2 is at positive potential. Then the ion will be accelerated towards D_1. Inside the dee D_1, it will move with a constant speed. Due to perpendicular magnetic field B, the ion will describe a circular path of radius r in D_1 given by $Bqv = \frac{mv^2}{r}$.

Where m and q are the mass and charge of the ion.

$$\therefore \quad r = \frac{mv}{Bq}.$$

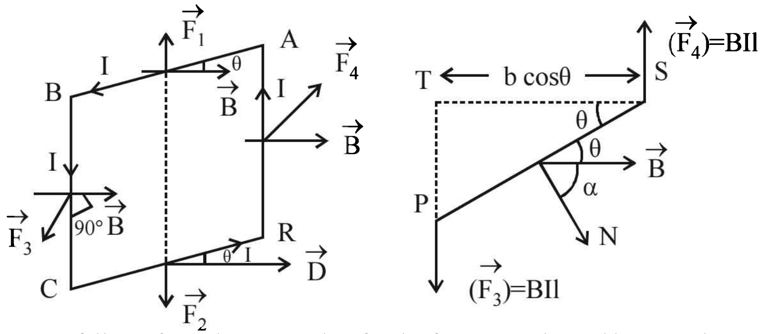
Period of revolution, $T = \frac{2\pi r}{v} = \frac{2\pi}{v} \cdot \frac{mv}{Bq} = \frac{2\pi m}{qB}$

Clearly, the period of revolution is independent of the speed of the charged particle. The alternating p.d accelerates the particles in the gap and the magnetic field makes them to move in circular path.

50. Let there be a rectangular current carrying loop ABCD placed in a uniform magnetic field B as shown in figure.

The loop can be considered to be consisting of a series of a straight line segments. We will find that the total force acting on the loop is zero but there is net torque acting on it.

Let the forces acting on the various sides of the loop be $\vec{F_1}, \vec{F_2}, \vec{F_3}$ and $\vec{F_4}$ as shown.



It follows from the expression for the force experienced by a conductor in a magnetic field that force on arm AB is

$$\vec{F_1} = I(\overrightarrow{AB} \times \vec{B}) \quad ...(i)$$

Here, I $(\overrightarrow{AB})$ is a vector in the direction of the current. In accordance with Fleming's left hand rule, this force acts in the plane of the paper and is directed upwards as shown in figure.

The force on arm CD is

$$\vec{F_2} = I(\overrightarrow{CD} \times \vec{B}) \quad ...(ii)$$

Here, I $(\overrightarrow{CD})$ is a vector in the direction of the current. In accordance with Fleming's left hand rule, this force acts in the plane of the paper and is directed downwards as shown.

The sides with length 'b' i.e., AB and CD make an angle $(90° - \theta)$ with the direction of the magnetic field. Therefore, the forces acting on these two sides given by equations (i) and (ii) are equal and opposite. Since, these two forces are equal and opposite and have the same line of action therefore, they cancel out each others effect and their resultant effect on the coil is zero.

Now, the force on arm BC is

$$\vec{F_3} = I(\overrightarrow{BC} \times \vec{B}) \quad ...(iii)$$

Here, I $(\overrightarrow{BC})$ is a vector in the direction of the current. In accordance with Fleming's left hand rule, this force acts perpendicular to the plane of the paper and is directed downwards.

Finally, the force on arm DA is

$$\vec{F_4} = I(\overrightarrow{DA} \times \vec{B}) \qquad ...(iv)$$

Here, $I(\overrightarrow{DA})$ is a vector in the direction of the current. In accordance with Fleming's left hand rule, this force acts perpendicular to the plane of the paper and is directed inwards.

Forces F_3 and F_4 make an angle of 90° with the direction of magnetic field. Therefore, in magnitude these forces are given by

$$F_3 = F_4 = I\,l\,B \sin 90° = I\,l\,B \quad ...(v)$$

The lines of action of both these forces are perpendicular to the plane of the paper.

The two forces F_3 and F_4 lie along, different lines and each gives rise to a torque about the X-axis. The two torques, produce a resultant torque in +X direction.

Arm of couple = $b \sin \theta$ [From fig.] ...(vi)

By definition of torque

Torque = either force × arm of couple

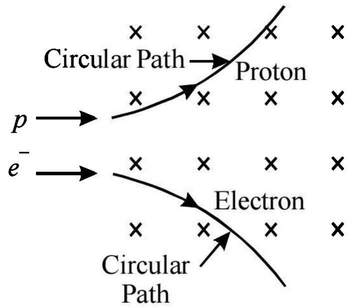
Using equations (v) and (vi)

$$\text{Torque} = I\,B\,a \times b \sin \theta$$

But $ab = A$, area of the coil, therefore, torque

$$\tau = I\,BA \sin \theta$$

51. When a charged particle enters the magnetic field at right angle, then the particle experiences a magnetic force due to which it follows a circular path.



Radius of the circular path, $r = \dfrac{mv}{qB}$

For same speed v, and same charge, magnetic field $r \propto m$

As, $m_e < m_p$

$\Rightarrow$ therefore, $r_e < r_p$

The curvature of path of Proton is much more and in opposite direction of the curvature of path of electron.

52. The magnetic moment of a current carrying loop

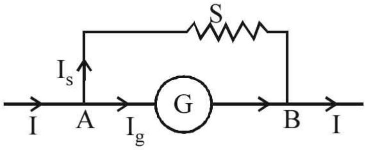
$m = IA = Il^2 n$

where, A = area of the loop (square)

$\therefore \quad A = l^2 n$

Here, n is unit vector normal to the area.

53. A galvanometer is converted into an ammeter by connecting a low resistance (shunt) in parallel with it.



Let I be the total current through the combination. I_g and I_s be the currents through the galvanometer and the shunt respectively. G and S are the galvanometer resistance and shunt resistance respectively.

Here, $\quad I = I_g + I_s$

$\because$ Potential difference between A and B are same

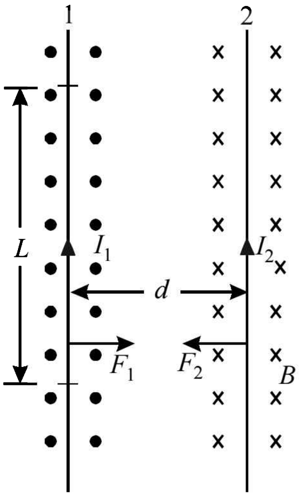
$\therefore \quad I_g G = I_s S \Rightarrow I_g G = (I - I_g)S \Rightarrow I_g(G + S) = IS$

$\therefore \quad I_g = I\left(\dfrac{S}{G+S}\right)$ and $S = \left(\dfrac{I_g}{I - I_g}\right)G$

The range of the ammeter is 0 to IA. The effective resistance of the ammeter

$$\frac{1}{R} = \frac{1}{S} + \frac{1}{G} \Rightarrow R = \frac{SG}{S+G}$$

54. Let two straight wires of infinite length are carrying currents, I_1 and I_2 in the same direction and separated, by distance d apart from each other.



The magnetic field due to wire 1 at any point on wire 2, is perpendicular to plane of paper and directed inward.

$$B_1 = \frac{\mu_0}{4\pi}\frac{2I_1}{d}$$

Magnetic force on wire 2, in L length of it.

$$F_2 = I_2 B_1 L \sin 90°$$

$$= I_2\left(\frac{\mu_0}{4\pi}.\frac{2I_1}{d}\right)L$$

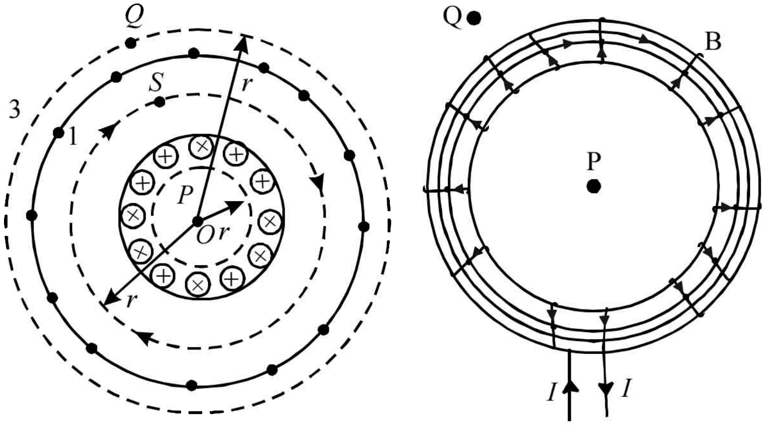
$$\therefore \quad F_2 = \frac{\mu_0}{4\pi}.\frac{2I_1 I_2}{d}$$

Similarly, force on wire 1 due to wire 2 is $F_1 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d}$

Thus, the nature of force is attractive.

55. Toroid is a hollow circular ring on which a large number of insulated turns of a metallic wire are closely wound. The direction of the magnetic field at a point P is given by tangent to the magnetic field line at that point.

Let B is the magnetic field in the open space interior to the toroid. Considering a loop coplanar with toroid of radius x such that x < R (radius of toroid) as shown in the figure.



Applying Ampere's circuital law over loop, we have

$\oint B.dl = \mu_0 \times$ Current passes through the loop

But no current passes through the loop.

$\therefore \quad \oint B.dl = \mu_0 \times 0 = 0$

Therefore, magnetic field, $B = 0$

This is the magnetic field exist in the interior of toroid.

56. Magnetic field induction at the mid-point due to current loop 1 is

$$B_1 = \frac{\mu_0}{4\pi}\frac{2\pi IR^2}{(R^2+R^2)^{3/2}} = \frac{\mu_0 IR^2}{2(2R^2)^{3/2}},$$

acting towards right.

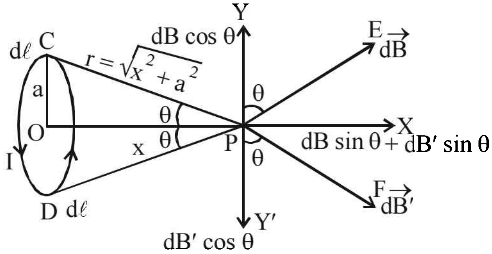
Magnetic field induction at the mid point due to current loop 2 is

$$B_2 = \frac{\mu_0 IR^2}{2(R^2+R^2)^{3/2}} = \frac{\mu_0 IR^2}{2(2R^2)^{3/2}}, \text{ acting towards right.}$$

Total magnetic field induction is

$$B = B_1 + B_2 = \frac{\mu_0 IR^2}{2(2R^2)^{3/2}} + \frac{\mu_0 IR^2}{2(2R^2)^{3/2}} = \frac{\mu_0 IR^2}{2\sqrt{2}R^3} = \frac{\mu_0 I}{2\sqrt{2}R}$$

57. Let these be a current carrying loop of radius *a*. Current flowing through the loop is I_0.



Consider two small elements of coil of length dl each, at C and D diametrically opposite to each other.

PC = PD = r

$= \sqrt{a^2 + x^2}$ and $\angle CPO = \angle DPO = \theta$

Magnetic field at P due to current element $d\ell$ at

$$C = dB = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell \sin 90°}{r^2} [\theta = 90°]$$

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{r^2} = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{(a^2 + x^2)}$$

Direction of dB is along PE perpendicular to CP.

Magnetic field at P due to current element $d\ell$ at $D = dB' = \frac{\mu_0}{4\pi}$.

$$\frac{Id\ell \sin 90°}{r^2} = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{(a^2 + x^2)}$$ acting along PF ⊥ DP.

$$\therefore \quad dB = dB' = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{(a^2 + x^2)}$$

Resolving dB and dB' in rectangular components,

(i) $dB\cos\theta$ along PY and $dB\sin\theta$ along PX

(ii) $dB'\cos\theta$ along PY' and $dB'\sin\theta$ along PX

Cosine components being equal and opposite will cancel each other. Total magnetic field at P due to current through the whole circular coil.

$$B = \int dB \sin\theta = \int \frac{\mu_0 Id\ell \sin\theta}{4\pi(a^2 + x^2)}$$

$$= \frac{\mu_0 I \sin\theta}{4\pi(a^2 + x^2)} \int d\ell \quad \left[\because \sin\theta = \frac{a}{\sqrt{a^2 + x^2}} \text{ and } \int d\ell = 2\pi a\right]$$

$$B = \frac{\mu_0 I}{4\pi(a^2+x^2)} \cdot \frac{a}{(a^2+x^2)^{1/2}} .2\pi a$$

$$= \frac{\mu_0 I a^2}{2(a^2+x^2)^{3/2}} \text{ along PX}$$

If there are n number of turns of the coil,

$$B = \frac{\mu_0 n I a^2}{2(a^2+x^2)^{3/2}} = \frac{\mu_0}{4\pi} \cdot \frac{2nIA}{x^3} = \frac{\mu_0}{4\pi} \cdot \frac{2M}{x^3}$$

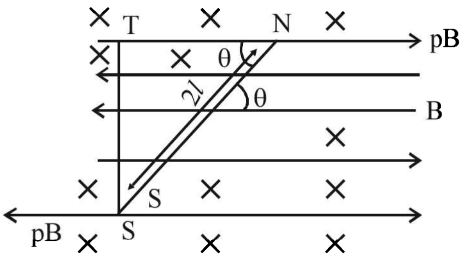
[Here $A = \pi a^2$ = area of the coil and $x >> a$

$\therefore$ $a^2 + x^2 \approx x^2$, $M = nIA$ = magnetic dipole moment of the coil]

58. Let there be a compass needle of magnetic moment m and pole strength p is placed in a uniform magnetic field.

Magnetic moment $m = P \times 2l$

where 2l is the magnetic length.



Let the needle is turned through an angle θ from the direction of the magnetic field, both north and south poles experience a magnetic force pB but their directions are opposite. These two forces form a couple

τ = either force × arm of the couple

$= pB \times NT$

$\therefore$ $\frac{NT}{2l} = \sin\theta$ or $NT = 2l \sin\theta$

$\therefore$ $\tau = pB\, 2l \sin\theta = (p \times 2l) B \sin\theta$

As $p \times 2l = m$

$\therefore$ $\tau = mB\sin\theta$ ... (i)

This torque tries to align the magnet in the direction of the electric field. And due to inertia, it over shoots the mean position and begins to vibrate in SHM.

Also, $\tau = I\alpha$ ... (ii)

α is the angular acceleration and I moment of inertia of the needle about the axis.,

Therefore, from e.q. (i) and (ii), we have

$I\alpha = -mB\sin\theta$ (–ve sign shows it is a restoring torque)

$$= -mB\theta$$

or, $\alpha = \frac{-mB\theta}{I}$

$\therefore$ $\alpha \propto -\theta$

Thus, motion is SHM

Time period T is given by

$$T = 2\pi\sqrt{\frac{\theta}{\alpha}} = 2\pi\sqrt{\frac{\theta}{\frac{mB\theta}{I}}} \quad \text{or} \quad T = 2\pi\sqrt{\frac{I}{mB}}$$

This is the required expression for its time period.

59. Length of wire = Circumference of semi circular loop.

$\therefore$ $L = \pi r$ or, $r = \frac{L}{\pi}$

Considering a small element *dI* on current loop. The magnetic field *dB* due to small current element *Idl* at centre *C*. By Biot-Savart law,

$$dB = \frac{\mu_0}{4\pi}\cdot\frac{Idl}{r^2}$$

Net magnetic field at *C* due to semicircular loop,

$$B = \int_L \frac{\mu_0}{4\pi}\frac{Idl}{r^2} = \frac{\mu_0}{4\pi}\cdot\frac{I}{r^2}\int_L dl$$

$$B = \frac{\mu_0}{4\pi}\cdot\frac{I}{r^2}(L)$$

$$B = \frac{\mu_0}{4\pi}\cdot\frac{IL}{(L/\pi)^2} \qquad \left[\because r = \frac{L}{\pi}\right]$$

$$B = \frac{\mu_0 I\pi}{4L}$$

This is required expression.

60. Let n be the no. of turns in both coils. Magnetic field B_1 at the centre of circular coil X of radius R carrying current I is $B_1 = \frac{\mu_0}{4\pi}\cdot\frac{2\pi nI}{R}$

and magnetic field B_2 at the centre of circular coil Y of radius $\frac{R}{2}$ carrying current I_1 is

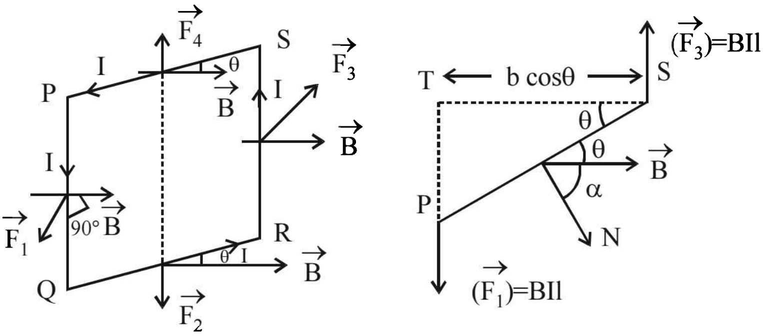
$$B_2 = \frac{\mu_0}{4\pi}\cdot\frac{2\pi nI_1}{R/2} = \frac{\mu_0}{4\pi}\cdot\frac{2\pi nI_1}{R}\cdot 2$$

Since the total magnetic field at the common centre of two coils is zero.

$$B_2 = B_1$$

$$\frac{\mu_o}{4\pi}.\frac{2\pi n I_1}{R}.2 = \frac{\mu_o}{4\pi}.\frac{2\pi n I}{R} \quad (\because 2I_1 = I \text{ or } I_1 = \frac{I}{2}.)$$

61. Let PQRS be the current carrying wire, through which current I is flowing.



Here PQ = RS = ℓ = length of the coil

QR = SP = b = breadth of the coil

θ is the angle between plane of the coil and $\vec{B}$.

$\vec{F_1}, \vec{F_2}, \vec{F_3}, \vec{F_4}$ are forces on four arms PQ, QR, RS and SP respectively.

$\vec{F_4} = I(\overrightarrow{SP} \times \vec{B}) \Rightarrow IB\,(SP)\sin(180° - \theta) = IbB\sin\theta$

$\vec{F_2} = I(\overrightarrow{QR} \times \vec{B}) \Rightarrow F_2 = IB\,(QR)\sin\theta = IbB\sin\theta$

They are equal in magnitude but opposite in direction, and will cancel each other.

$\vec{F_1} = I(\overrightarrow{PQ} \times \vec{B}) \Rightarrow F_1 = IB\,(PQ)\sin 90°$

$= I\ell B\ (\because \overrightarrow{PQ} \perp \vec{B})$

This is perpendicular to the plane of the coil and directed outwards.

$\vec{F_3} = I(\overrightarrow{RS} \times \vec{B}) \Rightarrow F_3 = I(RS)\,B\sin 90°$

$= I\ell B\ (\because \overrightarrow{RS} \perp \vec{B})$

This is perpendicular to the plane of the coil and directed inwards. They are equal, parallel but oppositely directed along their line of action, so they will form a couple which will try to rotate the coil in anticolockwise direction about its axis.

Torque on the coil = moment of the couple

$= \vec{F} \times \vec{r}$

$\Rightarrow \quad \tau = I\ell B \times b\cos\theta$ [$\because$ perpendicular distance between the force = b cos θ]

$\Rightarrow \tau = IBA\cos\theta$ where A = ℓb = area of the coil

If the coil has n number of turns, $\tau = nIBA\cos\theta$.

If the angle between the normal on the plane of the coil and $\vec{B}$ is α then, $\theta + \alpha = 90°$

$\Rightarrow \theta = 90° - \alpha$

$\Rightarrow \cos\theta = \cos(90° - \alpha) = \sin\alpha$

$\therefore \tau = nIBA\sin\alpha = MB\sin\alpha = |\vec{M} \times \vec{B}|$

When M = magnetic dipole moment of the coil = nIA

62. Lorentz force act on the charged particle due to electric and magnetic field, i.e., $F = qE + q(v \times B)$

For undeflected motion, $F = 0$

Therefore, $qE + q(v \times B) = 0$

$\Rightarrow E + (v \times B) = 0$

$E = -(v \times B)$

$\Rightarrow |E| = |-v \times B|$

$E = vB\sin\theta$, when $\theta = 90°$

$v = E/B$

63. The combination of crossed electric and magnetic fields is used to increase the energy of the charged particle. Cyclotron uses the fact that the frequency of revolution of the charged particle in a magnetic field is independent of its energy. Inside the dees the particle is shielded from the electric field and magnetic field acts on the particle and makes it to go round in a circular path inside a dee. Every time the particle moves from one dee to dee to the other it comes under the influence of electric field which ensures to increase the energy of the particle as the sign of the electric field changed alternately. The increased energy increases the radius of the circular path so the accelerated particle moves in a spiral path.

Since radius of trajectory

$$r = \frac{vm}{qB} \quad \therefore \quad v = \frac{rqB}{m}$$

Hence, the kinetic energy of ions $= \frac{1}{2}mv^2$

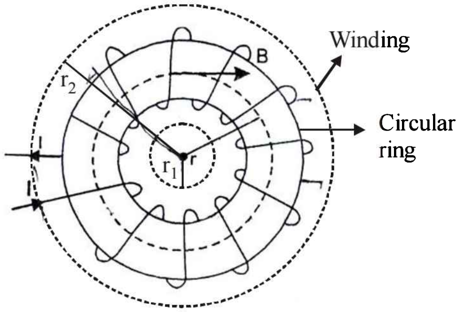
$$= \frac{1}{2}m\frac{r^2q^2B^2}{m^2} = \frac{1}{2}\frac{r^2q^2B^2}{m}$$

64. A charge q projected perpendicular to the uniform magnetic field B with velocity v, then by fleming left hand rule a perpendicular force, $F = qv \times B$, acts on the particle which provides the necessary centripetal force.

Due to which the path followed by charge is circular

$$\text{or, } qvB = \frac{mv^2}{r} \qquad \therefore r = \frac{mv}{qB}$$

65. Let N be the number of turns and I be the current passed through the toroid. r be the average radius. If the coils are closely spaced, the field inside the toroidal coil is tangent to the dotted circular path and is same at all points.



By Ampere's circuital law,

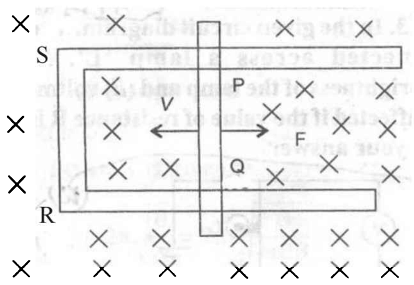
$$\oint \vec{B}\,.\,\overrightarrow{dL} = B\oint dL = B(2\pi r) = \mu_0 NI$$

or $\quad B = \dfrac{\mu_0 NI}{2\pi r} = \mu_0 nI \qquad \left[\because\ n = \dfrac{N}{2\pi r}\right.$

(number of turns per unit length)]

This is the expression for magnetic field inside a toroidal solenoid.

66. Let the length of the arm PQ be l moving towards the end RS with a velocity v in a uniform magnetic field B. As PQ moves there takes place a change of magnetic flux and hence an emf is induced.



Let the PQ is moved by a distance dx in small time dt, then Change of flux = $-Bl\,dx$

$$\therefore \quad e = -\frac{d\phi}{dt} = -\frac{d}{dt}(-B\,l\,dx) = Bl\frac{dx}{dt} = B\,l\,v$$

The end P of the rod will become +ve and the end Q is –ve.

(i) Current in the loop, $i = \dfrac{e}{R} = \dfrac{Blv}{r}$

(ii) Force acting on the loop

$$F = Bil = B\frac{Blv}{r}l \quad \text{or,} \quad F = \frac{B^2l^2v}{r}$$

(iii) Power required to move arm PQ against the backward force F,

$$P = F \times v = \frac{B^2l^2v}{r} \times v = \frac{B^2l^2v^2}{r}$$

67. Given : Energy stored in a solenoid, $W = \frac{1}{2}LI^2$

Now, $L = \mu_0 n^2 Al$, and from $B = \mu_0 n I$

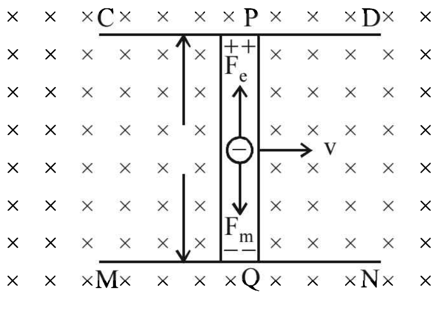
$$I = \frac{B}{\mu_0 n}$$

Therefore magnetic energy

$$U_B = W = \frac{1}{2}LI^2 = \frac{1}{2}(\mu_0 n^2 Al)\left(\frac{B}{\mu_0 n}\right)^2 = \frac{1}{2\mu_0}B^2Al$$

68. When a charge q moves with velocity $\vec{v}$ in a magnetic field of strength $\vec{B}$, making an angle q, then magnetic Lorentz force,

$$F = qvB \sin\theta$$



If $\vec{v}$ and $\vec{B}$ are mutually perpendicular, then $\theta = 90°$

$\therefore F = qvB\sin 90° = qvB$

F is perpendicular to both $\vec{v}$ and $\vec{B}$.

Let a conducting rod PQ is placed on two parallel metallic wires CD and MN in a magnetic field of strength $\vec{B}$. The direction of $\vec{B}$ is perpendicular to the plane of paper, downward represented by (X). Let the rod is moving with velocity $\vec{v}$, perpendicular to its own length, towards the right. Since a metallic conductor contain free electrons, they will move within the metal rod. Charge on each electron

$= -e$.

$\therefore$ Force experienced by each electron $= f_m = evB$ and will be directed from P to Q.

$\therefore$ The end P of the rod becomes positively charged and Q is negatively charged.

So a potential difference is produced across the ends of the conductor. This is the induced e.m.f.

$\therefore$ Electric field produced in the rod, $E = \dfrac{V}{\ell}$

It is directed from P to Q.

The force on a free electron due to this electric field

$$F_e = eE$$

The direction of this force is from Q to P opposite to the electric field. The emf produced opposes the force within electrons caused due to Lorentz force by Lenz's law. As the number of electrons at Q becomes more and more, the magnitude of electric force F_e goes on increasing and at a stage F_e become equal and opposite to F_m. Under this condition the potential difference produced across the ends of rod becomes constant.

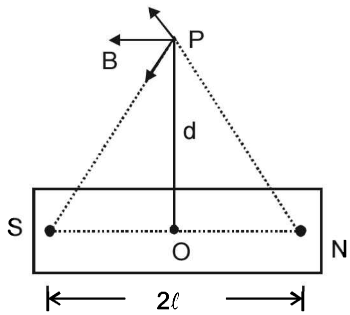
In this case, $F_e = F_m \Rightarrow eE = evB \Rightarrow E = Bv$

$\therefore$ Potential difference produced, $V = El = Blv$

$\therefore$ Induced current, $= I = \dfrac{V}{R} = \dfrac{B\ell v}{R}$

69. $B_2 = \dfrac{\mu_0}{4\pi} \dfrac{M}{(d^2 + \ell^2)^{3/2}}$

The direction of B_2 is along a line parallel to NS.



$B_N = \dfrac{\mu_0}{4\pi} \dfrac{m\overrightarrow{NP}}{NP^3}$, $B_S = \dfrac{\mu_0}{4\pi} \dfrac{m\overrightarrow{PS}}{PS^3}$

Now, $NP = PS = (d^2 + \ell^2)^{3/2}$

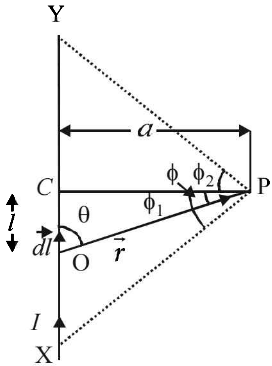
Resultant field at P is, $\vec{B} = \overrightarrow{B_N} + \overrightarrow{B_S}$

$$\Rightarrow \vec{B} = \frac{\mu_0}{4\pi}.\frac{m}{(d^2+\ell^2)^{3/2}}(\overrightarrow{NP}+\overrightarrow{PS}) = \frac{\mu_0}{4\pi}.\frac{m}{(d^2+\ell^2)^{3/2}}(\overrightarrow{NS})$$

$$|\vec{B}| = \frac{\mu_0}{4\pi}\frac{2ml}{(d^2+\ell^2)^{3/2}} = \frac{\mu_0}{4\pi}\frac{M}{(d^2+\ell^2)^{3/2}};$$

If $d >> \ell$, the $|\vec{B}| = \frac{\mu_0}{4\pi}\frac{M}{d^3}$

70. Consider a straight conductor XY lying in the plane of paper. Consider a point P at a perpendicular distance '*a*' from straight conductor.



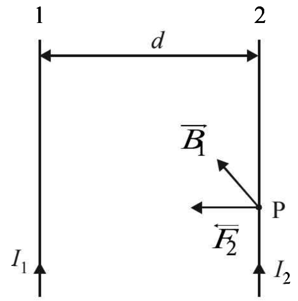
Now Magnetic field induction at a point P due to current I passing through conductor XY is given by

$$B = \frac{\mu_0 I}{4\pi a}[\sin\phi_1 + \sin\phi_2]$$

At the centre of the infinite long wire,

$\phi_1 = \phi_2 = 90°$

$$\therefore\ B = \frac{\mu_0 I}{4\pi a}[\sin 90° + \sin 90°] \Rightarrow B = \frac{\mu_0}{4\pi}\frac{2I}{a} \quad ....(1)$$



Consider two infinite straight conductors 1 and 2. Let I_1 and I_2

current flowing through the conductor 1 and 2 and they are d distance apart from each other.
The magnetic field induction (B) at a point P on conductor 2 due to current I_1 passing through conductor 1 is given by $B_1 = \frac{\mu_0 2I_1}{4\pi d}$
According to right hand rule, the direction of this magnetic field is perpendicular to the plane of the paper inward.
Now force experienced (F_2) by unit length of conductor 2 will be

$$F_2 = B_1 I_2 \times 1 = B_1 I_2$$

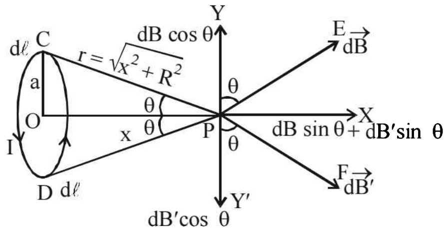
$$\therefore \quad F_2 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d}$$

Conductor 1 also experiences the same amount of force, directed towards the conductor 2. Hence, conductor 1 and conductor 2 attract each other. Thus, two linear parallel conductors carrying currents in the same direction attract and repel each other when the current flows in the opposite direction.
Let $I_1 = I_1 = 1\text{A}$; $r = 1\ m$

Then, $\quad F_1 = F_2 = F = 10^{-7}\ \frac{2 \times 1 \times 1}{1} \Rightarrow F = 2 \times 10^{-7}$ N/m

71. Given, the current is flowing in the clockwise direction for on observer on the left side of the solenoid, This means that left face of the solenoid acts as south pole and right face acts as north pole. Inside a bar magnet, the magnetic field are lines directed from south to north. Therefore, the magnetic field lines are directed from left to right in the solenoid.
Magnetic moment of single current carrying loop is given by m'= IA
where, $\quad I$ = Current flowing through the loop
A = Area of the loop
So, magnetic moment of the whole solenoid is given by m = Nm = NIA

72. Let these be a current carrying loop of radius R. Current flowing through the loop is I_0.



Consider two small elements of coil of length dl each, at C and D diametrically opposite to each other.

PC = PD = r

$= \sqrt{R^2+x^2}$ and $\angle CPO = \angle DPO = \theta$

Magnetic field at P due to current element $d\ell$ at C

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell \sin 90°}{r^2} [\theta = 90°]$$

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{r^2} = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{(R^2+x^2)}$$

Direction of dB is along PE perpendicular to CP.

Magnetic field at P due to current element $d\ell$ at D = $dB' = \frac{\mu_0}{4\pi}$.

$$\frac{Id\ell \sin 90°}{r^2} = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{(R^2+x^2)}$$ acting along PF $\perp$ DP.

$$\therefore \quad dB = dB' = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{(R^2+x^2)}$$

Resolving dB and dB' in rectangular components,

(i) $dB \cos\theta$ along PY and $dB \sin\theta$ along PX

(ii) $dB' \cos\theta$ along PY' and $dB' \sin\theta$ along PX

Cosine components being equal and opposite will cancel each other. Total magnetic field at P due to current through the whole circular coil.

$$B = \int dB \sin\theta = \int \frac{\mu_0 Id\ell \sin\theta}{4\pi(R^2+x^2)}$$

$$= \frac{\mu_0 I \sin\theta}{4\pi(R^2+x^2)} \int d\ell \quad [\because \sin\theta = \frac{R}{\sqrt{R^2+x^2}} \text{ and } \int d\ell = 2\pi a]$$

$$B = \frac{\mu_0 I}{4\pi(R^2+x^2)} \cdot \frac{R}{(R^2+x^2)^{1/2}} \cdot 2\pi a = \frac{\mu_0 IR^2}{2(R^2+x^2)^{3/2}}$$ along PX

If there are n number of turns of the coil,

$$B = \frac{\mu_0 nIR^2}{2(R^2+x^2)^{3/2}} = \frac{\mu_0}{4\pi} \cdot \frac{2nIA}{x^3} = \frac{\mu_0}{4\pi} \cdot \frac{2M}{x^3}$$

[Here $A = \pi R^2$ = area of the coil and $x >> R$

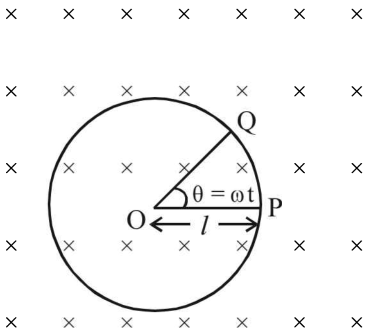
Figure showing magnetic field lines due to a circular wire carrying current I.

73. (a) The force $\vec{F}$ due to the magnetic field (B) acting on the charged particle moving with the velocity (v) is given by

$$\vec{F} = q(\vec{v} \times \vec{B})$$

This force is called Lorentz force.
The direction of this force is given by the right-hand rule and it is perpendicular to the plane containing v and B.

74. Let the rotating metallic rod subtends an angle θ in time t with the centre of the circle.



The area of the sector OPQ is given by,

$$A = \pi \ell^2 \times \frac{\theta}{2\pi} = \frac{1}{2}\ell^2\theta$$

The induced emf is $\varepsilon = B.\frac{dA}{dt} = B.\frac{d\left(\frac{1}{2}\ell^2\theta\right)}{dt} = \frac{1}{2}B\ell^2.\frac{d\theta}{dt}$

$$\varepsilon = \frac{1}{2}B\ell^2.\omega \qquad \left(\text{where } \omega = \frac{d\theta}{dt}\right)$$

75. (i) Consider a coil of number of turns N, area A rotated in a magnetic field of strength B at an angle θ which normal to the coil makes with $\vec{B}$ at any instant t, then
Magnetic flux linked with the coil in this position,

$$\phi = N(\vec{B}.\vec{A}) = NBA\cos\theta = NBA\cos\omega t$$

where ω is the angular velocity of the coil.
As the coil is rotated, θ changes and hence flux ϕ linked with the coil changes and hence an e.m.f. is induced in the coil.

Induced emf, $e = -\frac{d\phi}{dt} = -\frac{d}{dt}(NAB\cos\omega t) = -NAB$

$\frac{d}{dt}(\cos\omega t) = -NAB(-\sin\omega t)\omega.$

or $\quad e = NAB\,\omega\sin\omega t.$

The induced emf will be maximum, when $\sin\omega t = 1$

$\therefore \quad e_{max} = e_0 = NAB\omega.$

Hence $e = e_0 \sin \omega t$.

(ii) Power dissipation in the coil:

Over a complete cycle of a.c., $i_{av} = 0$.

Similarly, $e_{av} = 0$.

$\therefore$ Power dissipated in the coil = 0.

76. Let us consider a uniformly wound solenoid with n turns per unit length l. Let the length of the solenoid be large as compared to its radius and the core of the solenoid have air. Due to this the interior field is uniform. Therefore, the magnetic field in the interior of the solenoid

$$B = \mu_0 nI \quad \text{...(i)}$$

And the flux through each turn

$$\phi_m = BA = \mu_0 nIA \quad \text{...(ii)}$$

A = area of cross section of the solenoid.

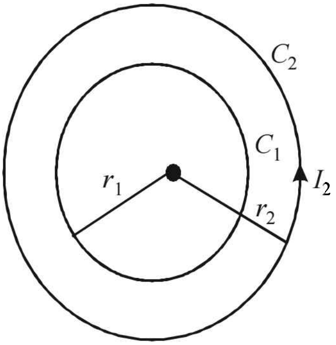
Therefore, self inductance

$$L = \frac{N\phi_m}{I} = \mu_0 n^2 Al \quad \text{where} \quad N = nl$$

77. Let current I_2 passes through the coil C_2.

Magnetic field at centre due to current loop, C_2.

$$B_2 = \frac{\mu_0 N_2 I_2}{2r_2}$$



$\therefore$ Total magnetic flux linked with coil C_1

$$\phi_1 = N_1 B_2 A_1$$

$$\phi_1 = N_1 \left(\frac{\mu_0 N_2 I_2}{2r_2}\right)\left(\pi r_1^2\right)$$

But, $\phi = \mu I_2$

$$MI_2 = \frac{\mu_0 N_1 N_2 I_2}{2r_2}\left(\pi r_1^2\right)$$

$$M = \frac{\mu_0 \pi N_1 N_2 r_1^2}{2r_2}$$

78. $\frac{d\phi}{dt}$ = rate of change in flux = $(\pi l^2)\, B_o l \frac{dz}{dt} = IR$.

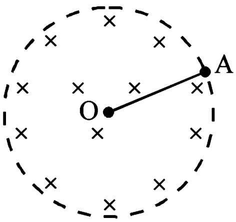
$$I = \frac{\pi l^2 B_o \lambda}{R} v$$

Energy lost/second $= I^2 R = \dfrac{(\pi l^2 \lambda)^2 B_o^{\,2} v^2}{R}$

This must come from rate of change in PE $= mg\dfrac{dz}{dt} = mgv$ (as kinetic energy is constant for v = constant)

Thus, $mgv = \dfrac{(\pi l^2 \lambda B_o)^2 v^2}{R}$ or, $v = \dfrac{mgR}{(\pi l^2 \lambda B_o)^2}$.

79. Let there be a metallic rod of length l whose one end is hinged at the centre O of the metallic ring of radius r and other end at point A on the circumference of the ring.



When rod revolves, free electrons in the rod move towards the outer end due to Lorentz force and get distributed over the ring. This results in the production of an induced emf across the ends of the rod in the steady state when there is no further flow of electrons. Let us consider a small element at a distance x from the centre O. The small induced emf produced across this element

$$de = Bv\,dx$$

where v is the velocity of the element at a distance x.

∴ The emf produced across the length of the conductor i.e., between centre O and circumference of the ring

$$e = \int_0^r Bv\,dx$$

If ω is the angular frequency of the rod, then

$$v = x\omega$$

∴ $$e = \int_0^r Bx\omega\,dx = B\omega \cdot \left[\frac{x^2}{2}\right]_0^r$$

or $$e = \frac{1}{2}B\omega r^2$$

Also, $$e = \frac{1}{2}B \cdot 2\pi \nu r^2 \qquad (\because \omega = 2\pi\nu)$$

or, $$e = \pi B \nu r^2$$

80. Let us consider a small length element dl which the rod covers. The emf generated across a length dl of the rod as it moves at right angles to the magnetic field

$$d\varepsilon = B\,v\,dl = B\,\omega l\,dl$$

Since, $v = \omega R = \omega l$ as $R = l$

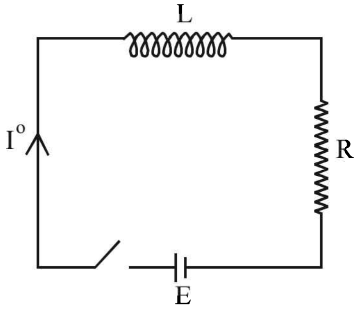
Hence, total emf induced

$$\varepsilon = \int d\varepsilon = \int_0^l B\omega l\,dl = \frac{1}{2}B\omega l^2$$

Power generated

$$P = \frac{\varepsilon^2}{r} = \frac{B^2\omega^2 l^4}{2r}$$

81. The self-inductance of a solenoid is defined as the ratio of magnetic flux through the solenoid to the current passing through it i.e., $\frac{\phi}{i^o}$



Consider the circuit shown above consisting of a inductor L and a resistor R, connected to a source of emf E. As the connections are made, the current grows in the circuit and the magnetic field increases in the inductor. Part of the work done by the battery during the process is stored in the inductor as magnetic field energy and the rest appears as thermal energy in the resistor. After sufficient time, the current, and hence the magnetic field, becomes constant and further work done by the battery appears completely as thermal energy. If i be the current in the circuit at time t, we have $E - \frac{Ldi}{dt} = iR \Rightarrow Eidt = L^2Rdt + Lidi$

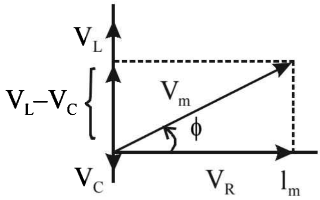
$$\Rightarrow \int_0^t Eidt = \int_0^t i^2Rdt + \int_0^i Lidi$$

$$\Rightarrow \int_0^t Eidt = \int_0^t i^2Rdt + \frac{1}{2}Li^2 \qquad \text{..... (i)}$$

Now (idt) is the charge flowing through the circuit during the time t to t+dt. Thus, (Eidt) is the work done by the battery in this period. The quantity on the left-hand side of the equation (i) is, therefore, the total work done by the battery in time 0 to t. Similarly, the first term on the right-hand side of equation (i) is the total thermal energy developed in the resistor at time t.

Thus $\frac{1}{2}Li^2$ is the energy stored in the inductor as the current in it increases from 0 to i. As the energy is zero when the current is zero, when the current is zero, the energy in an inductor carrying a curretn i, is $U = \frac{1}{2}Li^2$.

82. Phasor diagram



From the diagram, phasor V_m makes an angle ϕ with the current phasor I_m. Since the voltage phasors V_L and V_C are in opposite direction, therefore, a difference phasor $(V_L - V_C)$ is drawn which is perpendicular to the phasor V_R. Adding vectorially, we have

$$V_m = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(I_m R)^2 + (I_m X_L - I_m X_C)^2}$$

or $V_m = I_m \sqrt{R^2 + (X_L - X_C)^2}$

Where XL = ωL and $X_C = 1/\omega C$, therefore, the maximum current

$$I_m = \frac{V_m}{\sqrt{R^2 + (X_L - X_C)^2}}$$

(i) The impedance of the circuit

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

(ii) The phase angle between voltage and current

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

83. The instantaneous voltage and current in an LCR circuit are given by, $E = E_0 \sin wt$ and $I = I_0 \sin(wt - j)$

$$\text{Power, } P = \frac{1}{T}\int_0^T EI = \frac{1}{T}\int_0^T E_0 \sin\omega t\, I_0 \sin(\omega t - \varphi)dt$$

$$= \frac{E_0 I_0}{2T}\int_0^T (\sin\omega t(\sin\omega t \cos\varphi - \cos\omega t.\sin\varphi)dt$$

$$= \frac{E_0 I_0}{T}\left[\int_0^T \sin^2\omega t\cos\varphi dt - \int_0^T \sin\omega t.\cos\omega t.\sin\varphi)dt\right]$$

$$= \frac{E_0 I_0}{2T}\left[\int_0^T 2\sin^2\omega t\cos\varphi dt - \int_0^T 2\sin\omega t.\cos\omega t.\sin\varphi)dt\right]$$

$$= \frac{E_0 I_0}{2T}\left[\int_0^T (1-\cos 2\omega t)\cos\varphi dt - \int_0^T 2\sin\omega t.\cos\omega t.\sin\varphi dt\right]$$

$$\therefore \int_0^T \cos 2\omega t dt = 0 \text{ and } \int_0^T \sin 2\omega t dt = 0$$

$$\therefore P = \frac{E_0 I_0}{2T}.T\cos\varphi = \frac{E_0}{\sqrt{2}}.\frac{I_0}{\sqrt{2}}\cos\varphi$$

$\therefore P = E_{rms} I_{rms} \cos\varphi$, where $\cos\varphi$ is called **power factor.**

84. Let at any instant, the current and voltage in an *L-C-R* series AC circuit is given by

$$I = I_0 \sin\omega t$$

$$V = V_0 \sin(\omega t + \phi)$$

The instantaneous power is given by

$$P = VI = V_0 \sin(\omega t + \phi).I_0 \sin\omega t$$

$$P = \frac{V_0 I_0}{2}\left[2\sin\omega t.\sin(\omega t + \phi)\right]$$

$$P = VI = \frac{V_0 I_0}{2}\left[\cos\phi - \cos(2\omega t + \phi)\right] \qquad ...(i)$$

$[\because 2\sin A \sin B = \cos(A-B) - \cos(A+B)]$

Work done for a very small time interval, *dt* is given by

$$dW = Pdt$$

$$dW = VIdt$$

$\therefore$ Total work done over *T*, a complete cycle is given by

$$W = \int_0^T VI\, dt$$

But, $P_{av} = \frac{W}{T} = \frac{\int_0^T VIdt}{T} \Rightarrow P_{av} = \frac{1}{T}\int_0^T VI\,dt$

$$\frac{1}{T}\int_0^T \frac{V_0 I_0}{2}\left[\cos\phi - \cos(2\omega t + \phi)\right]dt$$

or $$P_{av} = \frac{V_0 I_0}{2T}\left[\int_0^T \cos\phi dt - \int_0^T \cos(2\omega t + \phi)\,dt\right]$$

$$= \frac{V_0 I_0}{2T}\left[\cos\phi\,[t]_0^T - 0\right] \text{ (By trigonometry)}$$

or $$P_{av} = \frac{V_0 I_0}{2T} \times \cos\phi \times T = \frac{V_0 I_0}{2} \times \cos\phi$$

$$= \frac{V_0}{\sqrt{2}} \times \frac{I_0}{\sqrt{2}}\cos\phi$$

$\Rightarrow P_{av} = V_{rms} \times I_{rms} \times \cos\phi$

This is required expression.

85. Let the input alternating current is $I = I_0 \sin\omega t$.
If I remains constant for a small time dt, small amount of charge sent in time dt = dq = Idt
Total charge sent by a.c. in the first half cycle

$$= q = \int_0^{T/2} Idt = \int_0^{T/2} I_0 \sin\omega t = I_0\left[-\frac{\cos\omega t}{\omega}\right]_0^{T/2}$$

$$= -\frac{I_0}{\omega}\left[\cos\frac{\omega t}{2} - \cos 0\right] = -\frac{I_0}{\omega}(\cos\pi - \cos 0°)$$

$$= -\frac{I_0}{\omega}(-1-1)$$

If I_m be the mean or average value of a.c. over first half cycle then

$$q = I_m \times \frac{I}{2} \text{ (by definition)}$$

$$\therefore\ I_m \times \frac{T}{2} = \frac{2I_0}{\omega} = \frac{2I_0.T}{2\pi}$$

$$\therefore\ I_m = \frac{2}{\pi}I_0 = 0.637\ I_0$$

Average value of a.c. over a complete cycle is zero.

$$I_{av} = \frac{\int_0^T I_0 \sin \omega t \, dt}{\int_0^T dt}$$

86. The power is defined as the rate at which work is being done in the circuit.
When $V = V_0 \sin\omega t$ is applied to a series LCR circuit.
Current is $I = I_0 \sin(\omega t + \phi)$

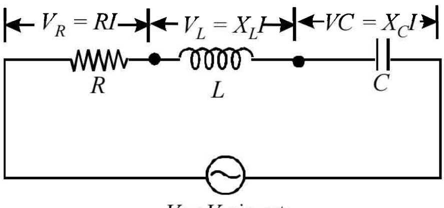
$$I_0 = \frac{V_0}{Z} \text{ and } \phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$$

Instantaneous power supplied by the source is
$P = VI = (V_0 \sin \omega t) \times (I_0 \sin(\omega t + \phi)$
$= V_0 \sin \omega t \, I_0 \sin(\omega t + \phi)$
The average power $P_{av} = V_{rms} I_{rms} \cos\phi$

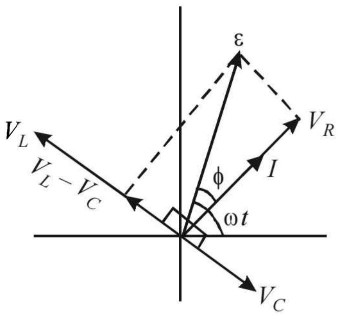
$$= \frac{V_0}{\sqrt{2}} . \frac{I_0}{\sqrt{2}} . \cos\theta$$

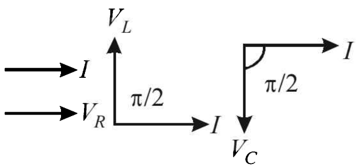
In this expression $\cos\phi$ is known as the power factor.

87. In the circuit shown, inductor L, capacitor C and resistor R are connect in series with an ac source.



Phasor diagram :





Assuming, $X_L > X_C \Rightarrow V_L > V_C$

$\therefore$ Net voltage, $V = \sqrt{V_R^2 + (V_L - V_C)^2}$

where, V_L, V_C and V_R are PD across L, C and R respectively.

But, $V_R = IR, V_L = IX_L, V_C = IX_C$

$$V = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

$$\frac{V}{I} = \sqrt{R^2 + (X_L - X_C)^2}$$

Impedance, $Z = \frac{V}{I} = \sqrt{R^2 + (X_L - X_C)^2}$

88. Instantaneous power

$$= P = EI = E_0 \sin \omega t . I_0 \sin \omega t$$

as current and voltage are in phase with each other in a pure resistive circuit.

Average power over a full cycle of period T

$$= P = \frac{1}{T}\int_0^T EI dt = \frac{E_0 I_0}{T}\int_0^T \sin^2 \omega t dt$$

$$= \frac{E_0 I_0}{2T}\int_0^T (1 - \cos 2\omega t) dt$$

$$P = \frac{E_0 I_0}{2T}\left[\int_0^T dt - \int_0^T \cos 2\omega t \, dt\right] = \frac{E_0 I_0}{2T}\left[t\Big|_0^T - \frac{\sin 2\omega t}{2\omega}\Big|_0^T\right]$$

$$= \frac{E_0 I_0}{2T}\left[(T - 0) - \frac{1}{2\omega}(\sin 2\omega T - \sin 0)\right]$$

$$= \frac{E_0 I_0}{2T}\left[T - \frac{1}{2\omega}(\sin 4\pi - \sin 0)\right] \quad [\because \omega T = 2\pi]$$

$$= \frac{E_0 I_0}{2T}.T = \frac{E_0 I_0}{2} = \frac{E_0}{\sqrt{2}}.\frac{I_0}{\sqrt{2}} = E_{rms}.I_{rms}.$$

$$\therefore P = E_{rms} . I_{rms} = \frac{E_{rms}}{R}$$

89. Average power

$$P_a = \frac{1}{T}\int_0^T P_i dt = \frac{1}{T}\int_0^T i^2 R \, dt$$

$$= \frac{1}{T}\int_0^T i_m^2 \sin^2 \omega t\, R\, dt \qquad [\because\ i = i_m \sin \omega t]$$

$$= \frac{1}{T} i_m^2 R \int_0^T \frac{(1-\cos 2\omega t)}{2} dt = \frac{1}{T}\frac{I_m^2}{2} R \left[T - \frac{\sin 2\omega t}{2\omega}\right]_0^T$$

$$= \frac{1}{T}\frac{I_m^2}{2} R\,[T-0] = \frac{1}{2} I_m^2 R$$

90. Velocity of propagation of EM wave in terms of peak values of electric and magnetic field vectors.

$$C = \frac{|E_0|}{|B_0|}$$

91. The electric flux between the plates of a capacitor is given by

$$\phi_E = EA = \frac{Q}{\varepsilon_0 A}.A = \frac{Q}{\varepsilon_0}$$

$$\therefore \quad \frac{d\phi_E}{dt} = \frac{d}{dt}\left(\frac{Q}{\varepsilon_0}\right) = \frac{1}{\varepsilon_0}\frac{dQ}{dt}$$

$$\frac{d\phi_E}{dt} = \frac{1}{\varepsilon_0}.i \qquad \left(\text{As, } i = \frac{dQ}{dt}\right)$$

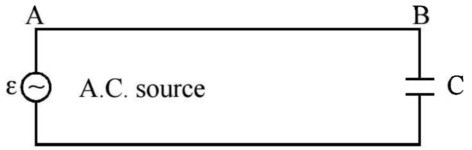
$$\therefore \quad i = \varepsilon_0 \left(\frac{d\phi_E}{dt}\right)$$

92. $\mathbf{E} = \frac{\lambda \hat{\mathbf{e}}_s}{2\pi\varepsilon_o a}\hat{\mathbf{j}}$ and $\mathbf{B} = \frac{\mu_o i}{2\pi a}\hat{\mathbf{i}} = \frac{\mu_o \lambda v}{2\pi a}\hat{\mathbf{i}}$

$$\mathbf{S} = \frac{1}{\mu_o}(\mathbf{E}\times\mathbf{B}) = \frac{1}{\mu_o}\left(\frac{\lambda \hat{\mathbf{j}}_s}{2\pi\varepsilon_o a}\hat{\mathbf{j}} \times \frac{\mu_o \lambda v}{2\pi a}\hat{\mathbf{i}}\right) = \frac{-\lambda^2 v}{4\pi^2 \varepsilon_0 a^2}\hat{\mathbf{k}}$$

93. Current I thorugh the capacitor is given by

$$I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$



$$E = E_0 \sin \omega t$$

As we know, the displacement current

$$I_d = \epsilon_0 \frac{d}{dt}(\phi_E) = \epsilon_0 \frac{d}{dt}(AE)$$

where A is area and E be the instantaneous electric field intensity between the plates of the capacitor.

$$I_d = A \epsilon_0 \frac{d}{dt}\left(\frac{V}{d}\right) \qquad \left[\because E = \frac{V}{d}\right]$$

$$= \left(\frac{A \epsilon_0}{d}\right) \frac{d}{dt}(V_0 \cos\omega t)$$

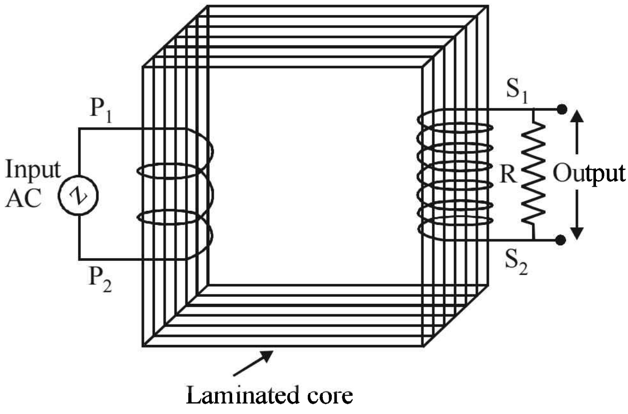
$$= \frac{A \epsilon_0}{d} V_0 \cos\omega t \, . \, \omega = CV_0\omega \sin\left(\omega t + \frac{\pi}{2}\right)$$

where $\quad C = \frac{A \epsilon_0}{d} = \frac{V}{\frac{1}{C\omega}} \sin\left(\omega t + \frac{\pi}{2}\right)$

$$I_d = I_0 \sin\left(\omega t + \frac{\pi}{2}\right) = I \quad \text{(Instantaneous current)}$$

94. The relation between the velocity of propagation and the magnitudes of electric and magnetic fields is E = CB.

95. **Transformer** Arrangement for winding of primary and secondary coils.



Principle: It works on the principle of mutual induction. Whenever magnetic flux linked with coil changes, an emf is induced in the neighbouring coil.

Working: When an alternating emf is supplied to the primary coil then magnetic flux linked with the secondary coil changes. As a result, an emf is induced in the secondary coil. Voltage at the primary and the secondary coils depends on the number of turns.

Magnetic flux that is linked with the primary coil is also linked with the secondary coil. The induced emf in each turn (E_{turn}) of the secondary coil is equal to that of the primary coil.

Let E_p be the alternating emf applied to primaiy coil and n_p be the number of turns in it. If ϕ be the electric flux associated with it, then

$$E_p = -n_p \frac{d\phi}{dt} \quad ....(1)$$

Let E_s be the emf across the secondary coil and n_s be the no of turns in it. Then,

$$E_s = -n_s \frac{d\phi}{dt} \quad ....(2)$$

Dividing (2) by (1),

$$\frac{E_s}{E_p} = \frac{n_s}{n_p} = k$$

For step up transformer, $k > 1$

$\therefore \quad E_S > E_P$

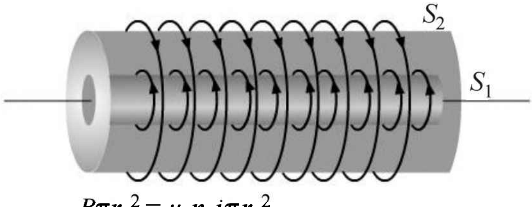
For step down transformer, $k < 1$

$\therefore \quad E_S < E_P$

96. Suppose a current i is passed through the inner solenoid S_1.

A magnetic field $B = \mu_0 n_1 i$ is produced inside S_1, whereas the field outside it is zero.

The flux through each turn S_2 is



$$B\pi r_1^2 = \mu_0 n_1 i \pi r_1^2$$

The total flux through all the turns in a length l of S_2 is

$\phi = (\mu_0 n_1 i \pi r_1^2) n_2 l = (\mu_0 n_1 n_2 \pi r_1^2 l) i$

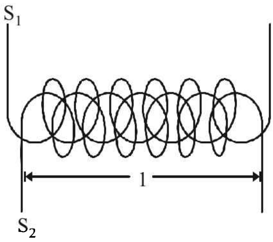
$\Rightarrow M = \mu_0 n_1 n_2 \pi r_1^2 l$

97. (a) **Mutual Inductance:** Consider two coils (Primary and secondary) placed very near to each other. Let N_1 and N_2 be the number of turns in the coils and i_1 be the current flowing in the first coil.

Let, due to this current, the magnetic flux linked with each turn of the secondary coil be ϕ_2. If N_2 be the number of turns in the secondary coil, then the number of flux-linkages in the coil will be $N_2\phi_2$. This number is proportional to the current i_1 flowing in the primary coil,

i.e. $N_2\phi_2 \propto i_1$ or $\quad N_2\phi_2 = M i_1$, where M is a constant called the **'coefficient of mutual induction'** or **'mutual inductance'** between the two coils.

Mutual Inductance of two concentric coils, one of radius R_1 and the other of radius R_2 ($R_1 < R_2$) placed coaxially with centres coinciding with each other:



Let the number of turns in the primary and secondary coils be N_1 and N_2 respectively and the current in the primary be i_1 ampere. The magnetic field at the centre of primary coil is

$$B = \frac{\mu_0 N_1 i_1}{2R_1}$$

where R_1 is the radius of the primary coil. Considering this magnetic field uniform over the entire surface area of the secondary coil, the magnetic-flux passing through the secondary coil is $\phi_2 = BA$

where $A = \pi R_2^2$ is the area of the secondary coil. Substituting for B

in this equation, we get $\phi_2 = \frac{\mu_0 N_1 i_i}{2R_1} \times \pi R_2^2$

Now, according to definition, the mutual inductance between the coils is

$$M = \frac{N_2 \phi_2}{i_1} \qquad \therefore \quad M = \frac{\mu_0 N_1 N_2 \pi R_2^2}{2R_1}$$

(b) We know that flux $\phi = N\,B\,A\cos\theta$

And induced emf

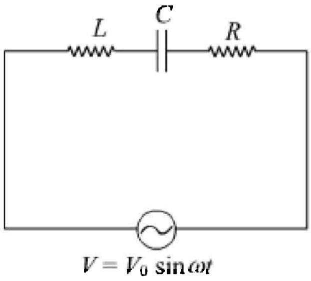
$$e = -\frac{d\phi}{dt} = \left(-NBA(-\sin\theta)\frac{d\theta}{dt}\right) = NBA\sin\theta\,(2\pi f)$$

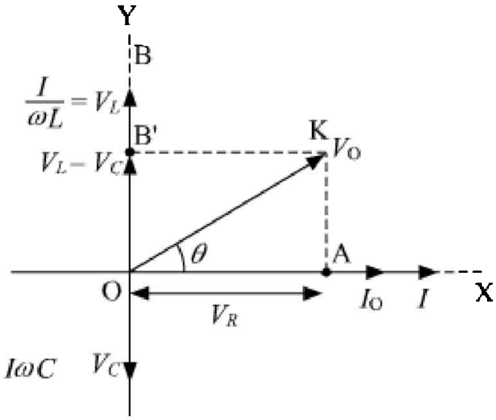
For maximum induced emf $\sin\theta = 1$

$\therefore \quad e_{max} = NBA\sin\theta\,(2\theta\,f) = NBA\,(2\pi f)$

98. (i) Voltage of the source is given as $V = V_0 \sin\omega t$

Let current of the source be $I = I_0 \sin\omega t$





The maximum voltage across R is $\overline{V_R} = I_0 R$, represented along OX.

The maximum voltage across L is $\overline{V_L} = \overline{I_0} X_L$, represented along OY and is 90° ahead of $\overline{V_0}$.

The maximum voltage across C is $\overline{V_C} = \overline{V_0} X_C$ represented along OC and is lagging behind $\overline{I_0}$ by 90°.

Hence, reactive voltage is $\overline{V_L} - \overline{V_C}$, represented by OB'.

The vector sum of $\overline{V_R}, \overline{V_L}$ and $\overline{V_C}$ is resultant of OA and OB', represented along OK.

$$OK = V_0 = \sqrt{OA^2 + OB^2}$$

$$\Rightarrow V_0 = \sqrt{{V_R}^2 + (V_L - V_C)^2}$$

$$= \sqrt{(I_0 R)^2 + (I_0 X - V_C)^2} \Rightarrow V_0 = I_0 \sqrt{R^2 + (X_L - X_C)^2}$$

The impedance can be calculated as follows:

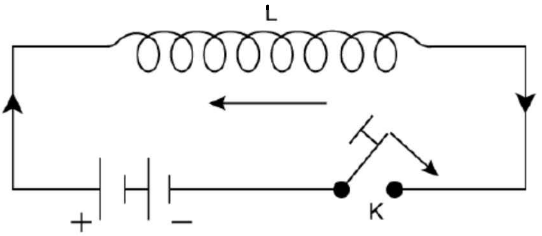
$$Z = \frac{V_0}{I_0} = \sqrt{R^2 + (X_L - X_C)^2}$$

When $X_L = X_C$, the voltage and current are in the same phase. In such a situation, the circuit is known as non-inductive circuit.

99. Expression for the energy stored in an inductor : Consider a simple circuit having a coil, a battery and a key. The coil has a self-inductance L. On pressing the key K, current flows through the circuit. However, self-inductance gives rise to induced current which opposes the growth of current in the circuit.

Thus, to increase the current from zero to its maximum value I_o, some work has to be done.

This work done is stored as the magnetic field of the inductor. Similarly, when the key is opened, the induced emf tends to maintain current in the circuit.



Let, *I* current flows through the coil of self-inductance *L* at any instant t when rate of change of current in coil is $\frac{dI}{dt}$.

$\therefore$ Induced emf, $E = -L\frac{dI}{dt}$

$\therefore$ Work done in establishing the current in small time interval *dt* is given by

$$dW = Pdt = -\varepsilon Idt = -\left(-L\frac{dI}{dt}\right)Idt$$

$$dW = LIdI$$

$\therefore$ Total work done in increasing the current from zero to *I*.

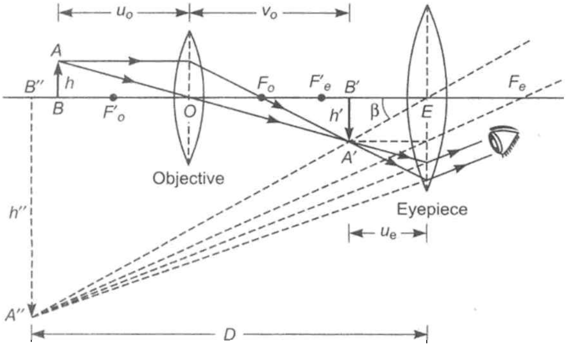
$$\therefore \quad W = \int_0^I LIdI = L\int_0^I IdI = L\left[\frac{I^2}{2}\right]_0^I = \frac{1}{2}L\left(I^2 - 0^2\right)$$

$$W = \frac{1}{2}LI^2$$

100. If ${}^a\mu_b$ is the refractive index of the denser medium (b) w.r.t. the rarer medium (a) and C be the critical angle, then

$${}^a\mu_b = \frac{1}{\sin C}$$

101. Microscope is an optical instrument used to magnify tiny objects.



The objective lens forms real, inverted magnified image A'B' of object AB in such a way that AB' fall some where between pole and focus of eye lens. So, A'B' acts as an object for eye lens and its virtual magnified image A"B" formed by the lens.

Magnifying power : The magnifying power of a compound microscope is defined as the ratio of the visual angle subtended by final image at eye (β) and the visual angle subtended by object at naked eye when both are at the least distance of distance vision from the eye.

i.e., magnification, $m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha}$

$$= \frac{\frac{B'A'}{u_e}}{\frac{BA}{D}} = \left(\frac{B'A'}{BA}\right) \times \frac{D}{u_e} = m_o m_e u_e$$

$m = m_o m_e$, where m_o and m_e are magnification produced by objective and eye lens respectively.

Now, $m_o = \frac{B'A'}{BA} = \frac{v_o}{-u_o}$

$$m_e = \frac{D}{u_e} = 1 + \frac{D}{f_e}$$

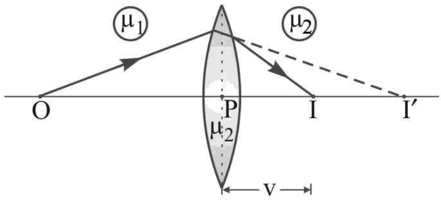
$$\therefore \quad m = -\left(\frac{v_o}{u_o}\right)\left(1 + \frac{D}{f_e}\right)$$

This is required expression

102. Consider a thin lens made of a material of refractive index μ_2 and situated in a medium of refractive index μ_1 on its both sides. Let R_1

and R_2 be the radii of curvature of the two co-axial spherical surfaces. Suppose an object O is placed at a distance u from the optical centre of the lens.

An image I' is formed by refraction at the first surface of the lens, at a distance v' from the pole of the surface.



Then by refraction formula, we have

$$\frac{\mu_2}{v'} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1}. \qquad ...(i)$$

The image I' becomes the virtual object for the second surface of the lens, and which forms the image I at a distance v from this surface. Then

$$\frac{\mu_1}{v} - \frac{\mu_2}{v'} = \frac{\mu_1 - \mu_2}{R_2}. \qquad ...(ii)$$

In this case rays are going from medium of refractive index μ_2 to the medium of refractive index μ_1. Moreover do not place the sign with R_1 and R_2, because they have already signed.

Adding equations (i) and (ii), we have

$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = (\mu_2 - \mu_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or
$$\frac{1}{v} - \frac{1}{u} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

If the lens is placed in air, then $\mu_1 = 1$, and putting $\mu_2 = \mu$, we have

$$\frac{1}{v} - \frac{1}{u} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad ...(1)$$

Equation (1) is known as the thin lens formula and is usually written in the form

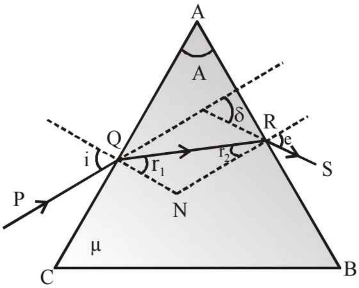
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}. \qquad ...(2)$$

where f is known as focal length of the lens, and is given by

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad ....(3)$$

The above formula is known as lens maker's formula.

103.



Let, PQ and RS are incident and emergent rays. Let, incident ray get deviated by δ by prism, i.e.,

$\angle TMS = \delta$

Suppose δ_1 and δ_2 are deviation produced at refractors taking place at *AB* and *AC* respectively.

$\therefore \quad \delta = \delta_1 + \delta_2$

$\delta = (i_1 - r_1) + (i_2 - r_2)$

$\delta = (i_1 + i_2) - (r_1 + r_2) \quad ...(i)$

Also, in quadilateral, *AQNR*,

$A + \angle QNR = 180°$

[$\because$ *QN* and *RN* are normal on two surfaces]

Also, In ΔQNR,

$\angle QNR + r_1 + r_2 = 180°$

$\Rightarrow \quad A = r_1 + r_2 \quad ...(ii)$

From Eqs. (i) and (ii), we get

$\delta = (i_1 + i_2) - A \quad ...(iii)$

Angle of deviation produced by prism varies with angle of incidence. When prism is adjusted at angle of minimum deviation, then

$i_1 = i_2 = i$

At $\delta = \delta_{m'}$

$\Rightarrow \quad r_1 = r_2 = r$

From Eqs. (i) and (ii), we have

$\delta_m = 2i - 2r$

and 2r = A

$\Rightarrow \quad i = \frac{A + \delta_m}{2}$

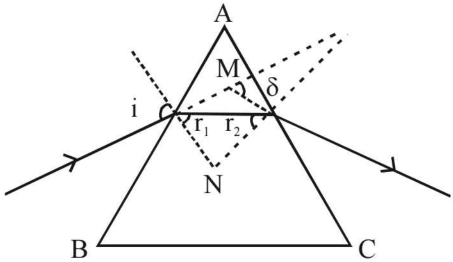
$$r = \frac{A}{2}$$

$\therefore$ Refractive index of material of prism is,

$$\mu = \frac{\sin i}{\sin r} \Rightarrow \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

This is required expression.

104.



$\angle i$ = angle of incidence

$\angle e$ = angle of emergence

δ = angle of deviation

In the quadrilateral AQNR,

$\angle A + \angle QNR = 180°$ ...(i)

In the traingle QNR

$r_1 + r_2 + \angle QNR = 180°$ ...(ii)

$\therefore\ r_1 + r_2 = \angle A$ ...(iii)

The angle of deviation ,

$\delta = (i - r_1) + (e - r_2) = i + e - (r_1 + r_2)$

$\therefore\ \delta = i + e - A$ ...(iv)

According to snell's law, $\frac{\sin i}{\sin r_1} = n_{21}$

or, $\frac{i}{r_1} = n_{21}$ (since angles are small) $\therefore\ i = r_1 . n_{21}$

Also,

$\frac{\sin e}{\sin r_2} = n_{21} \Rightarrow \frac{e}{r_2} = n_{21}\ \therefore e = r_2.n_{21}$ using the equation (iv)

$\delta = r_1.n_{21} + r_2.n_{21} - A = (r_1 + r_2)n_{21} - A$

$= A.\ n_{21} - A$

$\therefore\ \delta = (n_{21} - 1) - A$

105. Consider two thin lenses of focal lengths f_1 and f_2 are placed in contact on the same optic axis. An object O is placed at a distance u from the lenses. The image I_1 formed by first lens becomes the object for second lens; second lens forms the image I at a distance v from it. If v_1 is the distance of I_1, then for first lens;

$$\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1} \quad ...(i)$$

For the second lens;

$$\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2} \quad ...(ii)$$

Adding equations (i) and (ii), we get

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \quad ...(iii)$$

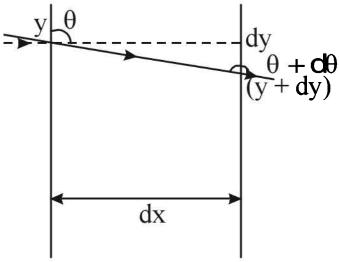
If f_e is the focal length of the equivalent lens, then

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_e} \quad ...(iv)$$

On comparing equations (iii) and (iv), we get

$$\frac{1}{f_e} = \frac{1}{f_1} + \frac{1}{f_2} \quad ...(14)$$

106. Consider a portion of a ray between x and $x + dx$ inside the liquid. Let the angle of incidence at x be θ and let it enter the thin column at height y. Because of the bending it shall emerge at $x + dx$ with an angle $\theta + d\theta$ and at a height y + dy.



From Snell's law

$\mu(y) \sin \theta = \mu(y + dy) \sin (\theta + d\theta)$

or $\quad \mu(y) \sin \theta$

$$\simeq \left(\mu(y) + \frac{d\mu}{dy} dy\right)(\sin \theta \cos d\theta + \cos \theta \sin d\theta)$$

$$\simeq \mu(y) \sin \theta + \mu(y) \cos \theta d\theta + \frac{d\mu}{dy} dy \sin \theta$$

or $\mu(y) \cos\theta \, d\theta \simeq \frac{-d\mu}{dy} dy \sin\theta$

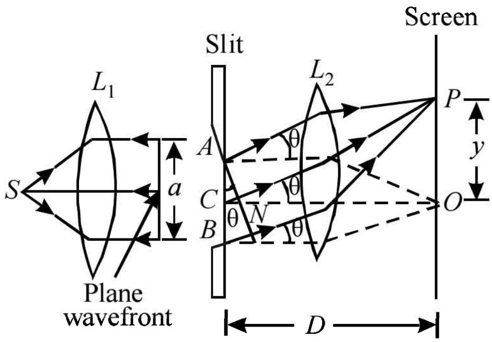
$d\theta \simeq \frac{-1}{\mu}\frac{d\mu}{dy} dy \tan\theta$

But $\tan\theta = \frac{dx}{dy}$ (from the Fig.)

$\therefore \; d\theta = \frac{-1}{\mu}\frac{d\mu}{dy} dx$

$\therefore \; \theta = \frac{-1}{\mu}\frac{d\mu}{dy}\int_o^d dx = \frac{-1}{\mu}\frac{d\mu}{dy} d$

107.



Consider a point P on the screen at which wavelets travelling in a direction, making angle θ with CO, are brought to focus by the lens. The wavelets from points A and B will have a path difference equal to BN.

From the right-angled ΔANB, we have

$$BN = AB\sin\theta$$

$$BN = a\sin\theta \qquad ...(i)$$

Suppose, $BN = \lambda$ and $\theta = \theta_1$

Then, the above equation gives

$$\lambda = a\sin\theta_1$$

$$\Rightarrow \quad \sin\theta_1 = \frac{\lambda}{a} \qquad ...(ii)$$

Such a point on the screen will be the position of first secondary minima.

If, $BN = 2\lambda$ and $\theta = \theta_2$, then

$$2\lambda = a\sin\theta_2$$

$$\sin\theta_2 = \frac{2\lambda}{a} \qquad ...(iii)$$

Such a point on the screen will be the position of second secondary minima.

In general, for *n*th minima at point P,

$$\sin\theta_n = \frac{n\lambda}{a} \qquad ...(iv)$$

If, y_n is the distance of the nth minima from the centre of the screen, then from right-angled ΔCOP, we have

$$\tan\theta_n = \frac{OP}{CO} = \frac{y_n}{D} \qquad ...(v)$$

In case of θ_n is small, $\sin\theta_n \approx \tan\theta_n$

From eqs. (iv) and (v)

$$\frac{y_n}{D} = \frac{n\lambda}{a} \Rightarrow y_n = \frac{n\lambda D}{a}$$

If, $BN = \frac{3\lambda}{2}$ and $\theta = \theta_1'$, then from eq. (i), we have

$$\sin\theta_1' = \frac{3\lambda}{2a}$$

Such a point on the screen will be the position of the first secondary maxima corresponding to path difference :

If, $BN = \frac{5\lambda}{2}$ and $\theta = \theta_2'$, the second secondary maxima is produced.

In general, for the *n*th maxima at point P,

$$\sin\theta_n' = \frac{(2n+1)\lambda}{2a} \qquad ...(vi)$$

where, $n = 1, 2, 3, ...$ an integer.

If y_n is the distance of nth maximum from the centre of the screen, then the angular position of the nth maximum is given by,

$$\tan\theta_n' = \frac{y_n}{D} \qquad ...(vii)$$

In case of θ_n' is small,

$$\sin\theta_n' = \tan\theta_n' \Rightarrow y_n' = \frac{(2n+1)\lambda D}{2a}$$

108. Suppose two waves of amplitudes a and b respectively and a phase difference ϕ, travelling in a medium, superimpose each other.

$y_1 = a \sin\omega t$; $\qquad y_2 = b\sin(\omega t + \phi)$

According to superposition principle,

$$y = y_1 + y_2 = a\sin\omega t + b\sin(\omega t + \phi)$$

$= a \sin\omega t + b \sin\omega t .\cos\phi + b \cos\omega t. \sin\phi$

$y = (a + b \cos\phi) \sin\omega t + b \sin\phi .\cos\omega t$ ....(i)

Put, $(a + b \cos\phi) = R \cos \theta$ ....(ii)

$b \cos\phi = R \sin \theta$ ....(iii)

$\therefore \quad y = R \cos\theta.\sin\omega t + R \sin \theta.\cos\omega t$

or $\quad y = R \sin (\omega t + \phi)$ ...(iv)

This is the displacement of the resultant wave where R is the amplitude of the wave.

Squaring and adding eqn. (ii) and (iii)

$$R = \sqrt{a^2 + b^2 + 2ab\cos\phi}$$

As, intensity $\propto$ (amplitude)^2

$I \propto R^2$

$\therefore \quad I = a^2 + b^2 + 2ab \cos\phi$

If $\cos\phi = + 1$, the intensity is maximum,

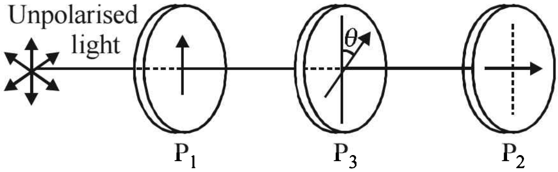
$\therefore \quad I_{max} = (a+b)^2$

If $\cos\phi = - 1$, the intensity is minimum.

$I_{min} = (a - b)^2$

$$\frac{I_{max}}{I_{min}} = \frac{(a+b)^2}{(a-b)^2}$$

109. According to the question P_1, P_2 and P_3 are placed as shown in the diagram.



Intensity of light after falling on P_1, $I' = \frac{I_0}{2}$

Intensity of light after falling on P_3, $I'' = I' \cos^2\theta$

$$I'' = \frac{I_0}{2}\cos^2(30°)$$

$$I'' = \frac{I_0}{2}\left(\frac{\sqrt{3}}{2}\right)^2$$

$$I'' = \frac{3I_0}{8}$$

Therefore, a light of intensity $3I_0/8$ will pass through P_3, and the angle between P_3 and P_2 will be 60° because of the condition given in the question.

Intensity of light after falling on P_2, $I''' = I''\cos^2(\theta)$

$$= \frac{3I_0}{8}\cos^2(60°) = \frac{3I_0}{32}$$

110. $\ell\ I_{max} = I_1 + I_2 + 2\sqrt{I_1\ I_2}$

Here $I_1 = I$ and $I_2 = I + \delta I$

$$\therefore I_{max} = I + I + I\delta + 2\sqrt{I(I+\delta I)}$$

$$\approx I + I + 2\sqrt{I^2} \qquad [\therefore\ I + \delta I = I]$$

$$\approx 2I + 2I \approx 4I$$

$\because I_{max} = 4I$ and $I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2}$

$$= I + (I + \delta I) - 2\sqrt{I(I+\delta I)}$$

$$= I + I + \delta I - 2\sqrt{I^2 + I\delta I} = 2I + \delta I - 2\left[I^2\left(I + \frac{\delta I}{I}\right)\right]^{\frac{1}{2}}$$

$$= 2I + \delta I - 2\ I\left(I + \frac{\delta I}{I}\right)^{\frac{1}{2}}$$

Using Binomial Expansion

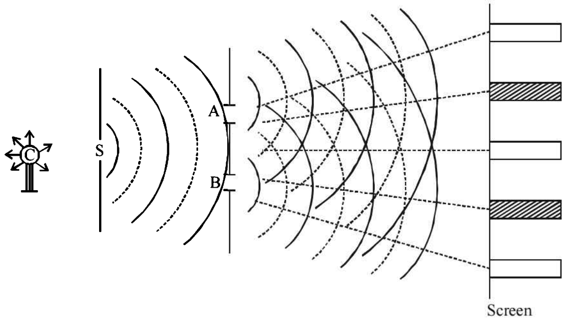
$$\therefore\ I_{min} = 2I + \delta I - 2I\left(1 + \frac{1}{2}\frac{\delta I}{I} + \frac{\frac{1}{2}\left(\frac{1}{2} - 1\right)}{2} \cdot \frac{\delta I^2}{I^2} + ...\right)$$

Neglecting δI^3 higher powers of δI

$$I_{min} = 2I + \delta I - 2I - 2I.\frac{1}{2}\frac{\delta I}{I} - 2I\frac{\frac{1}{2}\left(-\frac{1}{2}\right)}{2} \cdot \frac{\delta I^2}{I^2}$$

$$I_{min} = \delta I - \delta I + \frac{1}{4} \cdot \frac{\delta I^2}{I} \qquad \therefore\ I_{min} = \frac{\delta I^2}{4I}$$

111. There is a narrow slit illuminated by a monochromatic source of light. Two fine slits A and B (about 0.5 mm apart) are placed equidistant from the source (S). A screen is placed at a suitable distance from the slits.



Supoose the phase difference between two waves arising from slits A and B is ϕ. Then,

$y_1 = a\cos\omega t$ and $y_2 = a\cos(\omega t + \phi)$.

Therefore the resultant displacent

$$y = y_1 + y_2 = a\cos\omega t + a\cos(\omega t + \phi)$$

$$y = 2a\cos\frac{\phi}{2}.\cos(\omega t + \frac{\phi}{2})$$

The amplitude of the resultant displacent

$$R = 2a\cos\left(\frac{\phi}{2}\right)$$

As, intensity $\propto$ (amplitude)^2

$I_0 \propto a^2$ or $I \propto R^2$

$\therefore$ Resultant intensity, $I = 4I_0\cos^2\left(\frac{\phi}{2}\right)$

112. Einsteins equation gives

$K_{max} = h\nu - \phi_0$ ..... (i)

K_{max} = maximum k.E of electron emitted

$h\nu$ = energy of incident photon

ϕ_0 = work function

By definition of stopping potential, $eV_0 = K_{max}$

$$\Rightarrow \quad eV_0 = h\nu - \phi_0 \Rightarrow V_0 = \left(\frac{h}{e}\right)\nu - \frac{\phi_0}{e}$$

113. $p_c = |p_A| + |p_B| = \frac{h}{\lambda_A} + \frac{h}{\lambda_B} = \frac{h}{\lambda_c} = \frac{h}{\lambda_c}$ if $p_A, p_B > 0$

or $p_A, p_B < 0$ or $\lambda_c = \frac{\lambda_A \lambda_B}{\lambda_A + \lambda_B}$

If $p_A > 0, p_B < 0$ or $p_A < 0, p_B > 0$

$$p_c = h\frac{\lambda_B - \lambda_A}{|\lambda_A.\lambda_B|} = \frac{h}{\lambda_c}, \quad \lambda_c = \frac{\lambda_B.\lambda_A}{|\lambda_A - \lambda_B|}.$$

114. Kinetic energy, $K = \frac{p^2}{2m}$

p = momentum
m = mass and
k = kinetic energy

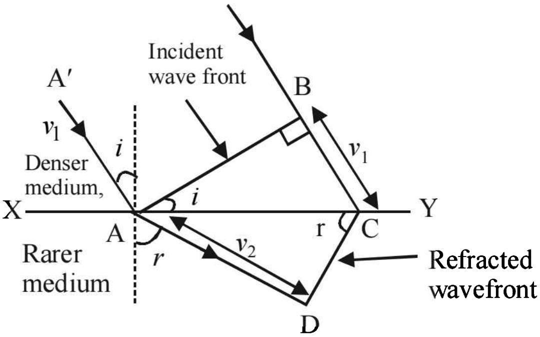
$\Rightarrow \quad p = \sqrt{2mK}$

de-Broglie wavelength, $\lambda = \frac{h}{p}$

where, $p = \sqrt{2mK}$

Therefore, de-broglie wavelength $\lambda = \frac{h}{\sqrt{2mK}}$

115. Let XY be the surface separating the denser medium and the rarer medium. Let:
v_1 = Speed of lightwave in the denser medium
v_2 = Speed of light wave in the rarer medium



Let us consider a plane wavefront AB. Let this wavefront incident on the interface at an angle of incidence i.
Let t be the time taken by the wavefront to travel the distance BC in denser medium.
$\Rightarrow \quad BC = v_1 t$
To determine the shape of refracted wavefront, we will draw a sphere of radius v_2t from point A in the rarer medium. Let CD represent a tangent plane drawn from point C onto the sphere.
Now, $\quad AD = v_2 t$
Here, CD would represent the refracted wavefront. Considering the triangles ABC and ADC, we get

$$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC}$$

$$\sin r = \frac{AD}{AC} = \frac{v_2 t}{AC}$$

$$\Rightarrow \quad \frac{\sin r}{\sin i} = \frac{v_2}{v_1} \qquad \text{....(1)}$$

Since $r > i$, the speed of light in the rarer medium (v_2) will be greater than the speed of light in the denser medium (v_1).

Now, $\mu_1 = \frac{c}{v_1}$; $\mu_2 = \frac{c}{v_2}$

where

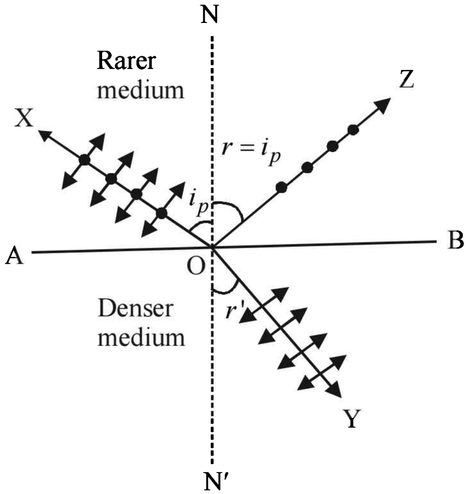
μ_1= Refractive index of denser medium

μ_2= Refractive index of rarer medium

Further, (1) can be written as $\mu_1 \sin i = \mu_2 \sin r$

This is the Snell's law of refraction.

116. Let us consider that an unpolarised light is incident along XO at an angle i_p (angle of polarisation) on the interface AB, separating air, a rarer medium, from a denser medium of refractive index μ.



It has been experimentally observed that when unpolarised light is incident at polarising angle, the reflected components along OZ and OY are mutually perpendicular to each other. So, we have

$\angle ZOB + \angle BOY = 90°$

$\Rightarrow (90° - i_p) + (90° - r') = 90°$

$\Rightarrow \quad 90° - i_p = r'$

By Snell's law, $\mu = \frac{\sin i_p}{\sin r'}$

$$\therefore \quad \mu = \frac{\sin i_p}{\sin(90° - i_p)} = \tan i_p$$

This gives us the required expression for Brewster's law.

117. From the lens maker formula, we have

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Let f_1 anf f_2 be the focal lengths of the two mediums. Then,

$$\frac{1}{f_1} = (\mu_1 - 1)\left[\frac{1}{R} - \left(-\frac{1}{R}\right)\right] \Rightarrow \frac{1}{f_1} = (\mu_1 - 1)\left(\frac{2}{R}\right)$$

$$\frac{1}{f_2} = (\mu_2 - 1)\left[\left(-\frac{1}{R}\right) - \frac{1}{\infty}\right] \Rightarrow \frac{1}{f_2} = (\mu_2 - 1)\left(-\frac{1}{R}\right)$$

(a) If f_{eq} is the equivalent focal length of the combination, then

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\Rightarrow \quad \frac{1}{f_{eq}} = \frac{2(\mu_1 - 1)}{R} - \frac{(\mu_2 - 1)}{R} \Rightarrow \frac{1}{f_{eq}} = \frac{2\mu_1 - \mu_2 - 1}{R}$$

$$\Rightarrow \quad f_{eq} = \frac{R}{2\mu_1 - \mu_2 - 1}$$

(b) For the combination to behave as a diverging lens, $f_{eq} < 0$

$$\Rightarrow \quad \frac{R}{2\mu_1 - \mu_2 - 1} < 0$$

$$\Rightarrow \quad 2\mu_1 - \mu_2 - 1 < 0$$

$$\Rightarrow \quad \mu_1 < \frac{(\mu_2 + 1)}{2}$$

which is the required condition

118. The mirror equation or formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

For concave mirror $f < 0$, as object always placed on the left side of mirror, so $u < 0$. According to question, $f < u < 2f$ (Object lies between f and $2f$)

$$\frac{1}{2f} > \frac{1}{u} > \frac{1}{f} \text{ or } -\frac{1}{2f} < -\frac{1}{u} < -\frac{1}{f}$$

Add $\frac{1}{f}$ on both sides, we get

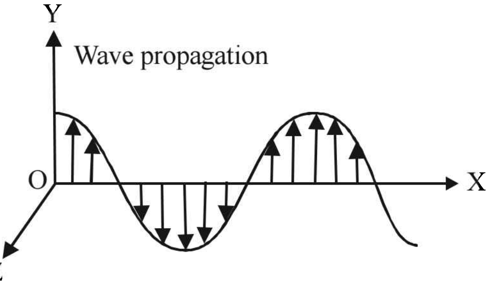
$$\frac{1}{f}-\frac{1}{2f}<\frac{1}{f}-\frac{1}{u}<0 \qquad \dots \text{(i)}$$

From mirror formula, $\frac{1}{f}-\frac{1}{u}=\frac{1}{v}$, So from eq. (i), we get

$$\frac{1}{f}-\frac{1}{2f}<\frac{1}{v}\Rightarrow\frac{1}{2f}<\frac{1}{v} \text{ or } v>2f$$

As, f is negative, $2f$ is also negative and hence v will be also negative. So the image formed is real and image lies beyond $2f$.

119. Linearly polarised light is the light wave in which the vibration of electric field vectors are confined in one plane and parallel to one direction.



The intensity of transmitted light becomes maximum when the inserted polaroid and analyser (the polaroid which receive light that is transmitted by inserted polaroid) have axis parallel to each other.

120. According to the photoelectric equation.

$$K_{\text{max}} = \frac{1}{2}mv_{\text{max}}^{2} = hv - \phi_o$$

$$K_{\text{max}} = \frac{hc}{\lambda_1}-\phi_0 \quad \dots\dots\dots \text{(i)}$$

Let the maximum kinetic energy for the wavelength of the incident λ_2 be K_{max}

$$K_{\text{max}}=\frac{hc}{\lambda_2}-\phi_0 \quad \dots\dots\text{(ii)}$$

From equations (i) and (ii) we have

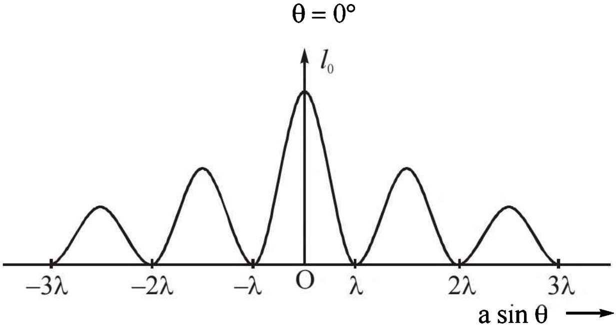
$$\frac{hc}{\lambda_2}-\phi_0 = 2\left(\frac{hc}{\lambda_1}-\phi_0\right)$$

$$\Rightarrow \phi_0 = hc\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right) \Rightarrow \quad h\nu_0 = hc\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$\Rightarrow \frac{c}{\lambda_0} = c\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right) \Rightarrow \frac{1}{\lambda_0} = \left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$\Rightarrow \lambda_0 = \frac{\lambda_1 \lambda_2}{2\lambda_2 - \lambda_1}$$

121. For central bright fringe,



For first dark fringe,

$$a \sin\theta = \pm\lambda \quad \text{or} \quad \sin\theta = \pm\frac{\lambda}{a}$$

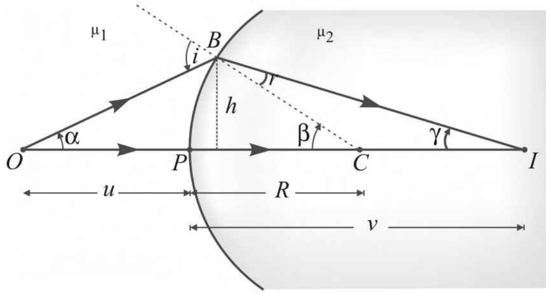
If θ is small, then $\sin\theta \approx \theta$

So, $\quad \theta = \pm\frac{\lambda}{a}$

So, the half angular width of central maximum is

$$\theta \approx \sin\theta = \frac{\lambda}{a}$$

122. Consider a spherical surface of radius R. The refractive indexes at left and right of the surface are μ_1 and μ_2 respectively.



Let an object O be placed at a distance u from pole P of the surface in a medium of refractive index μ_1. Ray OP, incident normally, passes into the second medium without deviation. Ray OB, making an angle α with the principal axis, is incident at an angle i with the normal and is refracted at an angle r. These rays intersect at I at a distance v to the right of pole P. Thus I is the real image of the object O.

From the triangles OBC and IBC, we have

$$i = \alpha + \beta$$

and $$\beta = r + \gamma \text{ or } r = \beta - \gamma$$

From Snell's law

$$\frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}$$

or $\mu_1 \sin i = \mu_2 \sin r$

For small angle of incidence i, we can write

$$\sin i \simeq i \text{ and } \sin r \simeq r$$

Thus $$\mu_1 i = \mu_2 r$$

or $$\mu_1 (\alpha + \beta) = \mu_2 (\beta - r) \qquad ...(i)$$

As i is small, and so α, β and γ are also small. Thus

$$(\alpha + \beta) = \tan\alpha + \tan\beta$$

$$= \frac{h}{-u} + \frac{h}{+R}$$

and $$(\beta - \gamma) = \frac{h}{R} - \frac{h}{v}$$

On substituting these values in equation (i), we have

$$\mu_1 \left[\frac{h}{-u} + \frac{h}{+R}\right] = \mu_2 \left[\frac{h}{R} - \frac{h}{v}\right]$$

After simplifying, we get

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

123. When angle of deviation is minimum, the prism is said to be placed in the minimum deviation position.

There is only one angle of incidence for which the angle of deviation is minimum.

When $\delta = \delta_m$ [prism in minimum deviation position]

$e = i$ and $r_2 = r_1 = r$ ......(1)

$\therefore r_1 + r_2 = A$

From (i), we get

$r = r = A$

$$r = \frac{A}{2}$$

Also, we have $A + \delta = i + e$

Substituting $\delta = \delta_m$ and $e = i$,

$$A+\delta_m = i+i \Rightarrow i=\frac{(A+\delta_m)}{2}$$

$$\therefore \mu = \frac{\sin i}{\sin r}$$

$$\therefore \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

This is the expression for refractive index (μ) of the prism in terms of angle of minimum deviation (δ_m) and angle of prism (A).

124. According to law of Malus, when a beam of completely plane polarised light is incident on an analyser at an angle, θ, resultant intensity of light (I) transmitted from the analyser

$I \propto \cos^2\theta$.

or, $I = I_o \cos^2\theta$ ...(i)

when $\theta = 0°$ or $\theta = 180°$(polarizer and analyzer parallel)

$\cos\theta = \pm 1$

$\therefore \quad I = I_0$ ...(ii)

when $\theta = 90°$ $\cos\theta = \cos 90° = 0$

$\therefore \quad I = 0$ ...(iii)

In unpolarised light, vibrations are probable in all the directions in a plane perpendicular to the direction of propagation.

$\therefore$ θ can have any value from 0 and 2π

$$\therefore \left[\cos^2\theta\right]av = \frac{1}{2\pi}\int_0^{2\pi}\cos^2\theta\, d\theta = \frac{1}{2\pi}\int_0^{2\pi}\frac{(1+\cos 2\theta)}{2}d\theta$$

$$= \frac{1}{2\pi\times 2}\left[0+\frac{\sin 2\theta}{2}\right]_0^{2\pi} = \frac{1}{2}$$

Therefore from malus law, expression

$$I = I_0\cos^2\theta = I_0 \times \frac{1}{2} = \frac{I_0}{2}$$

$$\therefore I = \frac{I_0}{2}$$

125. When a photon of energy 'hv' falls on a metal surface then,

(i) a part of energy is used to overcome the surface barrier and come out of the metal surface i.e., work function and is expressed as $\phi_o = hv_o$

and (ii) the remaining part of energy is used in giving a velocity 'v' to the emitted photoelectron and is equal to the maximum kinetic energy of photo electrons i.e., $KE_{max} = \left(\frac{1}{2} mv_{max}^2\right)$

According to the law of conservation of energy,

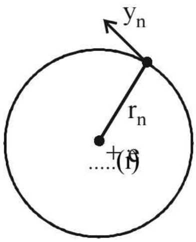
$$h\nu = \phi_o + \frac{1}{2} mv_{max}^2 = h\nu_o + \frac{1}{2} mv_{max}^2$$

$$\therefore \frac{1}{2} mv_{max}^2 = KE_{max} = h\nu - h\nu_o = h(\nu - \nu_o)$$

or $KE_{max} = h\nu - \phi_o$ ....(i)

126. Let there be an electron of mass m carrying a charge 'e' revolving around the nucleus of hydrogen atom carrying a charge +e.

Let r_n be the radius of the orbit and v_n be the speed of the electron in that orbit. The centripetal force required to revolve the electron is provided by the electrostatic force between the electron and the nucleus.



$$\therefore \quad k.\frac{e^2}{r_n^2} = \frac{mv_n^2}{r_n}$$

$$\therefore \quad r_n = \frac{ke^2}{mv_n^2}$$

Also, $mv_n^2 = \dfrac{ke^2}{r_n}$

According to Bohr's angular momentum postulate

$$mv_n r_n = \frac{nh}{2\pi}$$

$$\therefore \quad v_n = \frac{nh}{2\pi\, m\, r_n}$$

Putting this value of v_n in eq. (i), we have

$$r_n = \frac{ke^2}{mn^2h^2}.4\pi^2m^2r_n^2$$

or, $$r_n = \frac{n^2h^2}{4\pi^2ke^2m} \quad \text{..... (ii)}$$

$\therefore$ KE of the electron

$$\frac{1}{2}mv_n^2 = \frac{1}{2}\frac{ke^2}{r_n} = \frac{1}{2}\frac{ke^2}{2n^2h^2}.4\pi^2ke^2m$$

or $$KE = \frac{2\pi^2k^2e^4m}{n^2h^2}$$

(ii) **Potential energy :** Potential energy between the two charges q_1 and q_2 separated by a distance r is

$$PE = k\,.\frac{q_1 q_2}{r}, \text{ where } k = \frac{1}{4\pi \epsilon_0}$$

q_1 (charge of electron) = –e
q_2 (charge of hydrogen nucleus) = +e
$r = r_n$

$$\therefore \text{ PE of the electron } = -\frac{ke^2}{r_n} = \frac{-ke^2}{n^2h^2}4\pi^2kme^2$$

$$= -\frac{4\pi^2k^2me^4}{n^2h^2}$$

127. In H-atom an electron (–e) revolves around nucleus (+e) under lectrostatic force of attraction given by,

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{e\times e}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

This is the centripetal force of electron

$$\therefore \quad F_e = F_c \Rightarrow \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$\Rightarrow mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

Put $v = \frac{nh}{2\pi mr}$ (Bohr's quantisation condition)

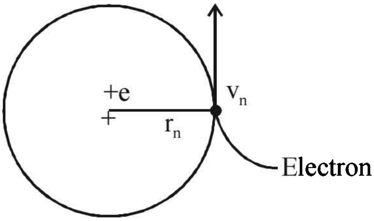
$$\text{We get, } m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$\Rightarrow r = 4\pi\varepsilon_0\frac{n^2h^2}{4\pi^2me^2}$$

From above expression, $r \propto n^2$

∴ Radii of successive orbits increases in the proportion n^2 i.e., 1 : 4 : 9, hence we can say that the orbits are not equally spaced but widen as we go from inner to outer orbits.

128. Let an electron of mass m, carrying a charge e revolving around the nucleus of hydrogen atom carrying a charge +e. Let r_n be the radius of the orbit and v_n is the speed of the electron in that orbit. The necessary centripetal force to revolve the electron is provided by the electrostatic force between the electron and hydrogen nucleus.



$$\therefore \quad k\frac{e^2}{r_n^2} = m\frac{v_n^2}{r_n}, \text{ where } k = \frac{1}{4\pi \epsilon_0}$$

$$\therefore \quad r_n = \frac{ke^2}{mv_n^2} \qquad \text{...(i)}$$

$$\text{or,} \quad mv_n^2 = \frac{ke^2}{r_n} \qquad \text{...(ii)}$$

According to Bohr's postulate

$$mv_n r_n = \frac{nh}{2\pi}$$

$$v_n = \frac{nh}{2\pi m r_n} \qquad \text{...(iii)}$$

Putting the value of v_n from (iii) into (i), we have

$$r_n = \frac{ke^2}{m.n^2h^2} 4\pi^2 m^2 r_n^2$$

$$\text{or} \quad r_n = \frac{n^2h^2}{4\pi^2 ke^2 m} \qquad \text{....(iv)}$$

KE of the electron

$$= \frac{1}{2}mv_n^2 = \frac{1}{2}\frac{ke^2}{r_n}$$

$$= \frac{1}{2}\frac{ke^2}{n^2h^2}.4\pi^2 kme^2 = \frac{2\pi^2k^2me^4}{n^2h^2} \qquad \text{....(v)}$$

Potential energy of the electron

$$PE = -\frac{kq_1q_2}{r} = -\frac{k.e.e}{r_n} = -\frac{ke^2}{r_n}$$

$$= \frac{-ke^2}{n^2h^2} 4\pi^2 ke^2 m$$

$$PE = \frac{-4\pi^2k^2e^4m}{n^2h^2}$$

∴ Total energy of the electron

$$= \frac{2\pi^2k^2me^4}{n^2h^2} - \frac{4\pi k^2me^4}{n^2h^2}$$

or, $$E_n = \frac{-2\pi^2k^2me^4}{n^2h^2}$$

If E_{ni} and E_{nf} are the energies of the electron for which $n = n_i$ and n_f

∴ $$E_{ni} = \frac{-2\pi^2k^2me^4}{n_i^2h^2}$$

and $$E_{nf} = \frac{-2\pi^2k^2me^4}{n_f^2h^2}$$

If $h\nu$ is the energy of the photon when the electron jumps from $n = n_i$ to $n = n_f$, then

$$h\nu = \frac{2\pi^2k^2me^4}{h^2n_f^2} + \frac{-2\pi^2k^2me^4}{h^2n_i^2}$$

$$\Rightarrow \quad h\nu = \frac{2\pi^2k^2me^4}{h^2}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

or, $$\nu = \frac{2\pi^2k^2me^4}{h^3}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

This is the required expression for the frequency of emitted radiation.

129. We know, radius of orbit, $r = 4\pi\varepsilon_0 \dfrac{n^2h^2}{4\pi^2me^2}$

Now, Bohr's quantisation condition gives,

$$mvr = \frac{nh}{2\pi} \text{ or } v = \frac{nh}{2\pi mr}$$

Put value of r, we get

$$v = \frac{nh}{2\pi m}\left(\frac{1}{4\pi\varepsilon_0}\frac{4\pi^2me^2}{n^2h^2}\right) = \frac{1}{4\pi\varepsilon_0}\frac{2\pi e^2}{nh} \Rightarrow v \propto \frac{1}{n}$$

130. **Radioactive decay law :** The rate of disintegration of radioactive sample at any instant is directly proportional to the number of undisintegrated nuclei present in the sample at that instant

$$\because \quad \frac{dN}{dt} = -\lambda N$$

where λ = decay constant
N = number of undisintegrated nuclei in the sample of radioactive substance.

$$\text{or} \quad \frac{dN}{N} = -\lambda dt$$

Integrating both sides, we get,

$$\int \frac{dN}{N} = -\lambda \int dt$$

$$\ln N = -\lambda t + C$$

At t = 0, N = N_0 = number of undisintegrated nuclei present in the sample, initially

$$\ln N_0 = -\lambda \times 0 + C$$

$$\Rightarrow \quad C = \ln N_0 \Rightarrow \ln N = -\lambda t + \ln N_0$$

$$\Rightarrow \ln N - \ln N_0 = -\lambda t$$

$$\ln \frac{N}{N_0} = -\lambda t$$

$$\Rightarrow \quad \log_e \frac{N}{N_0} = -\lambda t \Rightarrow \frac{N}{N_0} = e^{\lambda t}$$

$$\text{or} \quad N = N_0 e^{-\lambda t}$$

131. If, F_c – centripetal force required to keep a revolving electron in orbit

F_e – electrostatic force of attraction between the revolving electron and the nucleus then, for a dynamically stable orbit in a hydrogen atom, where Z = 1,

$$F_c = F_e$$

$$\frac{mv^2}{r} = \frac{(e)(e)}{4\pi\varepsilon_0 r^2} \quad \text{...(i)}$$

$$r = \frac{e^2}{4\pi\varepsilon_0 mv^2} \quad \text{...(ii)}$$

K.E. of electron in the orbit,

$$K = \frac{1}{2}mv^2$$

From equation (i),

$$K = \frac{e^2}{8\pi\varepsilon_0 r}$$

Potential energy of electron in orbit,

$$U = \frac{(e)(-e)}{4\pi\varepsilon_0 r} = \frac{-e^2}{4\pi\varepsilon_0 r}$$

Negative sign indicates that revolving electron is bound to the positive nucleus.

∴ Total energy of electron in hydrogen atom

$$E = K + U = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{e^2}{4\pi\varepsilon_0 r}$$

$$E = -\frac{e^2}{8\pi\varepsilon_0 r}$$

Therefore, total energy of electrons in orbit of hydrogen atom is negative. Hence, the electron bound to the nucleus i.e., the electron is not free to leave the orbit around the nucleus.

132. Relation between decay constant and half life of a radioactive substance:

The number of atoms at any instant in a radioactive sample is given by

$$N = N_0\, e^{-\lambda t}$$

N = total number of atoms at any instant

N_0 = number of atoms in radioactive substance at $t = 0$

When t = T (Where T is the half life of the sample)

$$N = \frac{N_0}{2}$$

$$\Rightarrow \quad \frac{N_0}{2} = N_0 e^{-\lambda T} \quad \Rightarrow e^{\lambda T} = 2$$

Taking log on both the sides, we get

$\lambda T = \log_e 2 = 2.303 \log_{10} 2$

$$\Rightarrow \quad T = \frac{2.303 \log_{10} 2}{\lambda} \quad \Rightarrow \quad T = \frac{0.693}{\lambda}$$

133. The de-Broglie wavelength of a particle is given by

$$\lambda \propto \frac{1}{\sqrt{mq}}$$

If m_p and q are mass and charge of a proton respectively, and m_α and $2q$ are mass and charge of a alpha particle respectively. Then, According to question

$\lambda_p = \lambda_\alpha$

(i) For accelerating potential,

$$\lambda = \frac{12.27}{\sqrt{V}}$$

$$\lambda_p = \frac{12.27}{\sqrt{V_p}} \quad \text{or } V_p = \left(\frac{12.27}{\lambda_p}\right)^2$$

$$\text{and } \lambda_\alpha = \frac{12.27}{\sqrt{v_\alpha}} \quad \text{or } V_\alpha = \left(\frac{12.27}{\lambda_\alpha}\right)^2$$

$$\text{Now, } \frac{V_p}{V_\alpha} = \frac{(12.27/\lambda_p)^2}{(12.27/\lambda_\alpha)^2}$$

$$\frac{V_p}{V_\alpha} = \left(\frac{\lambda\alpha}{\lambda p}\right)^2 \qquad (\because \lambda_p = \lambda_\alpha)$$

$V_p : V_\alpha = 1.$

(ii) For, speed

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\text{Now, } \lambda_p = \frac{h}{m_p v_p} \quad \text{or} = v_p = \frac{h}{m_p \lambda_p}$$

$$\text{and } \lambda_\alpha = \frac{h}{m_\alpha v_\alpha} \quad \text{or } v_\alpha = \frac{h}{m_\alpha \lambda_\alpha}$$

$$\frac{v_p}{v_\alpha} = \frac{h/m_p\lambda_p}{h/m_\alpha\lambda_\alpha}$$

$$\frac{v_p}{v_\alpha} = \frac{m_p\lambda_p}{m_p v_p} \qquad (\because \lambda_p = \lambda_\alpha \text{ and } m_\alpha = 4m_p)$$

$$\Rightarrow \quad \frac{v_p}{v_\alpha} = \frac{4m_p}{m_p}$$

$v_p : v_\alpha = 4 : 1$

134. Electron revolves in a stable orbit, the centripetal force is provided by electrostatic force of attraction acting on it, due to positive charges in the nucleus.

$$\text{Hence, } \frac{mv_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0}.\frac{e^2}{r_n^2} \Rightarrow v_n^2 = \frac{e^2}{4\pi\varepsilon_0 m r_n} \qquad \text{...(i)}$$

and from Bohr's quantum condition, we have

$$mv_n r_n = \frac{nh}{2\pi} \text{ or } v_n = \frac{nh}{2\pi m r_n} \qquad \text{...(ii)}$$

Squaring Eq (ii) and then equating it with Eq. (i), we get

$$\frac{n^2h^2}{4\pi^2m^2r_n^2} = \frac{e^2}{4\pi\varepsilon_0 m r_n}$$

$$\Rightarrow \quad r_n = \frac{n^2h^2}{4\pi^2m^2} \times \frac{4\pi\varepsilon_0 m}{e^2} = \frac{\varepsilon_0 h^2}{\pi m e^2}.n^2$$

135. Density of nuclear matter is the ratio of mass of nucleus and its volume.

If m is average mass of a nucleon and A is the mass number of element, then mass of nucleus = mA. If R is the nuclear radii, then

$$\text{Volume of nucleus} = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi(R_0A^{1/3})^3 = \frac{4}{3}\pi R_0^3 A$$

$$\text{As density of nuclear matter} = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$$

$$\therefore \ \rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} \quad \text{or} \quad \rho = \frac{3m}{4\pi R_0^3}$$

Thus, the density of nucleus is a constant, independent of A, for all nuclei.

136. The Rydberg formula of the spectra of hydrogen atom, is given by

$$\bar{\nu}_1 = \frac{1}{\lambda_1} = R\left(\frac{1}{n_2^2} - \frac{1}{n_3^2}\right) \qquad ....(1)$$

$$\bar{\nu}_2 = \frac{1}{\lambda_2} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad ....(2)$$

$$\bar{\nu}_3 = \frac{1}{\lambda_3} = R\left(\frac{1}{n_1^2} - \frac{1}{n_3^2}\right) \qquad ....(3)$$

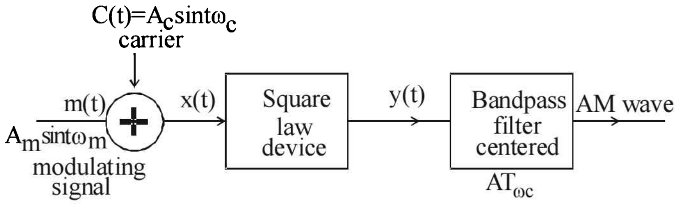
Where R - Rydberg Constant

Adding 1 and 2, we get

$$\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = R\left(\frac{1}{n_1^2} - \frac{1}{n_3^2}\right) = \frac{1}{\lambda_3}$$

This is the required relation between the three wavelengths λ_1, λ_2 & λ_3.

137.



Amplitude modulation can be done using a square law device. The modulating signal $A_m \sin\omega_n t$ is added to the carrier signal $A_c \sin \omega_c t$ to produce a signal

$x(t) = A_m \sin \omega_n t + A_c \sin\omega_c t$ and passed through a square law device which produces a non linear output of the form.

$y(t) = Bx(t) + Cx^2(t)$ Where B and C are constants

Thus, $y(t) = BA_m \sin \omega_m t + BA_c \sin\omega_c t + C$

$$(A_m^2 \sin^2 \omega_m t + A_c^2 \sin^2 \omega_c t + 2A_m A_c \sin \omega_m t \sin \omega_c t)$$

using $(A + B)^2 = A^2 + B^2 + 2AB)$

Use $\sin^2 A = \frac{1 - \cos 2A}{2}$ and

$\sin A \sin B = \frac{1}{2}[\cos A - B) - \cos(A + B)]$

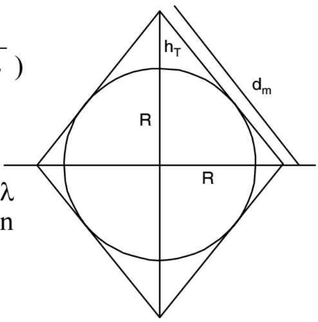
We get,

$$y(t) = BA_m \sin\omega_m t + BA_c \sin\omega_c t + \frac{c(A_m^2 + A_c^2)}{2} - \frac{CA_m^2}{2}\cos 2\omega_m t - \frac{CA_c^2}{2}\cos 2\omega_c t + CA_m A_c \cos(\omega_c - \omega_m)t - CA_m A_c \text{Cos}(\omega_c + \omega_m)t$$

Here $\frac{C(A_m^2 + A_c^2)}{2}$ is a d.c term.

and ω_m, $2\omega_m$, $2\omega_c$, $\omega_m + \omega_c$, $\omega_c - \omega_m$ are sinusoidal frequencies, when passed through a band pass filter, dc and $2\omega_m$, $2\omega_c$ parts are rejected, ω_m, $\omega_m + \omega_c$, $\omega_c - \omega_m$ parts are transmitted as AM wave.

138. $d_m^2 = 2(R + h_T)^2$



$8Rh_T = 2(R + h_T)^2$ $(\because d_m = 2\sqrt{2Rh_T})$

$4Rh_T = R^2 + h_T^2 + 2Rh_T$

$(R - h_T)^2 = 0$

$R = h_T$

Since space wave frequency is used, $\lambda << h_T$, hence only tower height is taken to consideration.

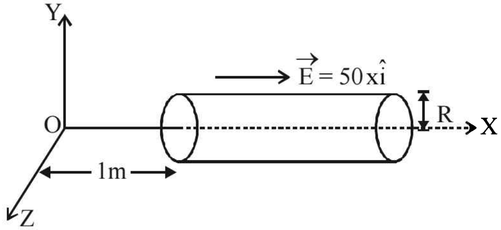
□□□

CHAPTER 8

How will you get the solution of numericals based on formula ......?

(A) *Electrostatics*

1. A uniformly charged conducting sphere of 2.5 m in diameter has a surface charge density of 100 μ C/m^2. Calculate the
   (i) charge on the sphere
   (ii) total electric flux passing through the sphere **[Delhi 2008]**
2. A dipole is present in an electrostatic field of magnitude 10^6 N/C. If the work done in rotating it, from its position of stable equilibrium to its position of unstable equilibrium, 2×10^{-23} J, find the magnitude of the dipole moment of this dipole. **[All India 2010C]**
3. Two identical metallic spherical shells *A* and *B* having charges + 4 Q and – 10 Q are kept a certain distance apart. A third identical uncharged sphere *C* is first placed in contact with sphere A and then with sphere *B*, then spheres A and B are brought in contact and then separated. Find the charge on the spheres A and B. **[All India 2011C]**
4. A given charge situated at a distance from an electric dipole in the end on position, experiences a force F. If the distance of charge is doubled, what will the force acting on the charge?
5. Calculate the amount of work done in turning an electric dipole of dipole moment 3×10^{-8} C-m from its position of unstable equilibrium to the position of stable equilibrium, in a uniform electric field of intensity 10^3 N/C. **[Foreign 2011]**
6. A hollow cyindrical box of length 1 m and area of cross-section 25 cm^2 is placed in a three dimensional coordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 50\,x\hat{i}$, where E is in NC^{-1} and x is in metres. Find : **[Delhi 2013]**
   (i) Net flux through the cylinder
   (ii) Charge enclosed by the cylinder



7. Two charges of magnitudes +4Q and –Q are located at point (a, 0) and (–3a, 0) respectively. What is the electric flux due to these charges through a sphere of radius '2a' with its centre at the origin? **[All India 2013]**

8. A hollow cylindrical box of length 0.5 m and area of cross-section 20 cm^2 is placed in a three dimensional coordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 20x\,\hat{i}$, where E is in NC^{-1} and x is in metres. Find : **[Delhi 2013]**
   (i) Net flux through the cylinder
   (ii) Charge enclosed in the cylinder

9. Two charges of magnitudes –3Q and +2Q are located at points (a, 0) and (4a, 0) respectively. What is the electric flux due to these charges through a sphere of radius '5a' with its centre at the origin? **[All India 2013]**

10. Calculate the electric field due to a dipole of length 10 cm and consisting of ± 100 μC charges at a point 20 cm from each charge (equatorial point).

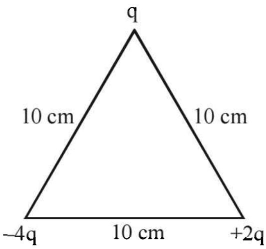
11. Given a uniform electric field $\vec{E} = 2 \times 10^3 \hat{i}$ N/C, find the flux of this field through a square of side 20 cm, whose plane is parallel to the *y–z* plane. What would be the flux through the same square, if the plane makes an angle of 30° with the *x*-axis ? **[Delhi 2014]**

12. An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has charge ± 8 nC **[Delhi 2014]**

13. Given a uniform electric field $\vec{E} = 4\times10^3\ \hat{i}$ N/C. Find the flux of this field through a square of 5 cm on a side whose plane is parallel to the Y-Z plane. What would be the flux through the same square if the plane makes a 30° angle with the x-axis? **[Delhi 2014]**

14. A 500 mC charge is at the centre of a square of side 10 cm. Find the work done in moving a charge of 10 mC between two diagonally opposite points on the square. **[Delhi 2008]**

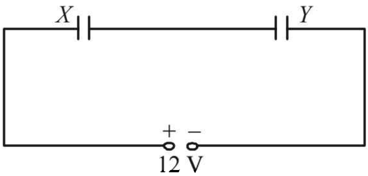
15. Calculate the work done to dissociate the system of three charges placed on the vertices of a triangle as shown.
Here $q = 1.6 \times 10^{-10}$C **[Delhi 2008]**



16. Calculate the potential at a point 9 cm away from a charge 4×10^{-7} C. Hence obtain the work done in bringing a charge of 2×10^{-9} C from infinity to that point.

17. Two charges $+q$ and $-q$ are located at points A (0, 0, – 2) and B (0, 0, 2) respectively. How much work will be done in moving a test charge from point P (4, 0, 0) to Q (– 5, 0, 0)? **[Delhi 2009]**

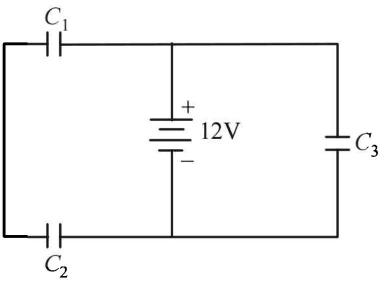
18. Two parallel plate capacitor, X and Y, have the same area of plates and same separation between them. X has air between the plates while Y contains a dielectric medium of $\in_r = 4$.



(i) Calculate capacitance of each capacitor if equivalent capacitance of the combination is 4 μF.
(ii) Calculate the potential difference between the plates of X and Y.
(iii) What is the ratio of electrostatic energy stored in X and Y?

[Delhi 2009]

19. Three idential capacitors C_1, C_2, and C_3 of capacitance μF each are connected to a 12 V battery as shown. **[Delhi 2009]**



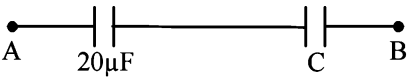
Find:

(i) charge on each capacitor

(ii) equivalent capacitance of the network

(iii) energy stored in the network of capacitors

20. The eqiuvalent capacitance of the combition of two capacitors between A and B in the given figure is $4\ \mu F$.



(i) Calculate capacitance of the capacitor C.

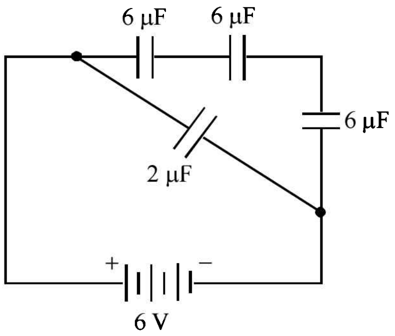
(ii) Calculate charge on each capacitor if a 12 V battery is connected across terminals A and B.

(iii) What will be the potential drop across each capacitor?

[Delhi 2009C]

21. A capacitor of 200 pF is charged by a 300 V battery. The battery is then disconnected and the charge capacitor is connected to another uncharged capacitor of 100 pF. Calculate the difference between the final energy stored in the combined system and the initial energy stored in the single capacitor. **[All India 2010, Foreign 2012]**

22. Four capacitors of values 6 μF, 6μF, 6 μF and 2 μF are connected to a 6V battery as shown in the figure. Determine.

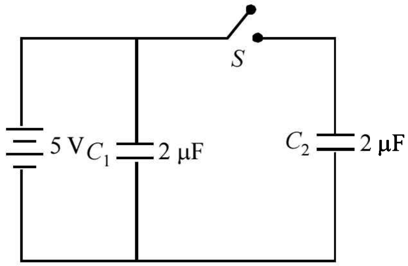


(i) Equivalent capacitance of the network.

(ii) The charge on each capacitor. **[Delhi 2010C]**

23. Figure shows two identical capacitors C_1 and C_2, each of $2\ \mu F$ capacitance, connected to a battery of 5V. Initially switch 'S' is closed. After some time S is left open and dielectric slabs of dielectric constant $K = 5$ are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and

(ii) potential difference between the plates of the capacitors be affected after the slabs are inserted? **[Delhi 2011]**



24. A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 360 μC. When potential across the capacitor is reduced by 120 V, the charge stored in it becomes 120 μC.

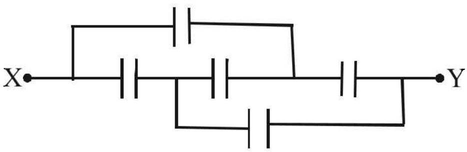
(i) Calculate the potential V and the unknown capacitance C.

(ii) What will be the charge stored in the capacitor, if the voltage applied had increased by 120 V? **[Delhi 2013]**

25. A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 300 μC. When potential across the capacitor is reduced by 100 V, the charge stored in it becomes 100 μC. Calculate the potential V and the unknown capacitance. What will be the charge stored in the capacitor if the voltage applied had increased by 100 V? **[Delhi 2013]**

26. Calculate the amount of work done to dissociate a system of three charges 1 μC, 1 μC and – 4 μC placed on the vertices of an equilateral triangle of side 10 cm. **[All India 2013C]**

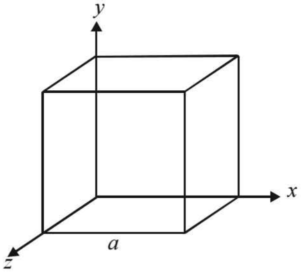
27. Find the equivalent capacitance of the network shown in the figure, when each capacitor is of 1 μF. When the ends X and Y are connected to a 6 V battery, find out (i) the charge and (ii) the energy stored in the network. **[All India 2015]**



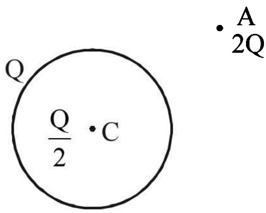
28. What is the electric flux through a cube of side 1cm which enclosed an electric dipole? **[Delhi 2015]**

29. Two capacitors of unknown capacitances C_1 and C_2 are connected first in series and then in parallel across a battery of 100 V. If the energy stored in the two combinations is 0.045 J and 0.25 J respectively, determine the value of C_1 and C_2. Also calculate the charge on each capacitor in parallel combination. **[Delhi 2015]**

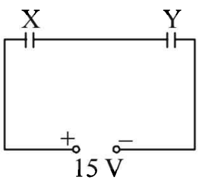
30. (a) Given the electric field in the region $\vec{E} = 2x\hat{i}$, find the net electric flux through the cube and the charge enclosed by it



(b) A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge $\frac{Q}{2}$ is placed at its centre C and an other charge +2Q is placed outside the shell at a distance x from the centre as shown in the figure. Find (i) the force on the charge at the centre of shell and at the point A, (ii) the electric flux through the shell. **[Delhi 2015]**



31. Two parallel plate capacitors X and Y have the same area of plates and same separation between them. X has air between the plates while Y contains a dielectric medium of $\varepsilon_r = 4$.



(i) Calculate capacitance of each capacitor if equivalent capacitance of the combination is 4 μF.

(ii) Calculate the potential difference between the plates of X and Y.

(iii) Estimate the ratio of electrostatic energy stored in X and Y.

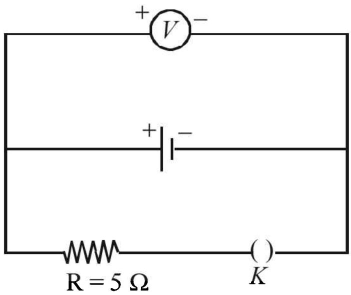
[Delhi 2016]

(B) Current Electricity

32. Two conducting wires *X* and *Y* of same diameter but different materials are joined in series across a battery. If the number density of electrons in *X* is twice that in *Y*, find the ratio of drift velocity of electrons in the two wires. **[All India 2010]**

33. The reading on a high resistance voltmeter, when a cell is connected across it, is 2.2 V. When the terminals of the cell are also connected to a resistance of 5Ω as shown in the circuit, the voltmeter reading drops to 1.8 V. Find the internal resistance of the cell.

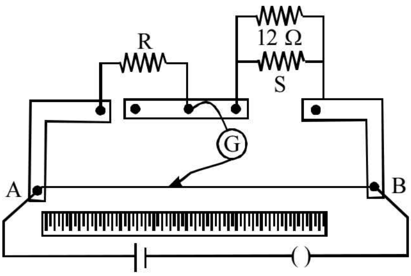
[All India 2010]



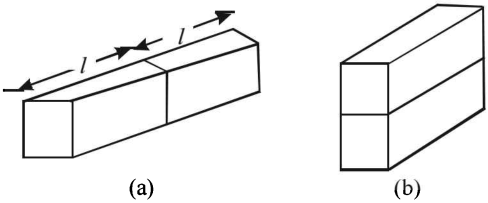
34. In a meter bridge, two unknown resistances R and S when connected in the two gaps, give a null point at 40 cm from one end. What is the ratio of R and S? **[Delhi 2010]**

35. In a meter bridge, the null point is found at a distance of 40 cm from A. If a resistance of 12 Ω is connected in parallel with S, the null point occurs at 50.0 cm from *A*. Determine the values of *R* and *S*.

[Delhi 2010]



36. Two identical slabs, of a given metal, are joined together, in two different ways, as shown in figures (a) and (b). What is the ratio of the resistances of these two combinations? **[Delhi 2010C]**



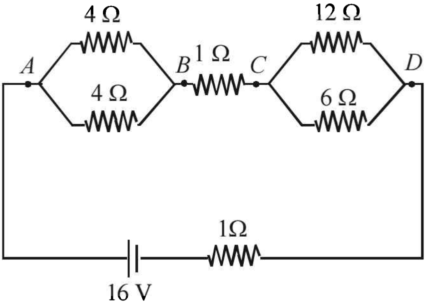
37. The sequence of coloured bands in two carbon resistors R_1 and R_2 is

(i) brown, green, blue and

(ii) orange, black, green

Find the ratio of their resistances. **[Delhi 2010C]**

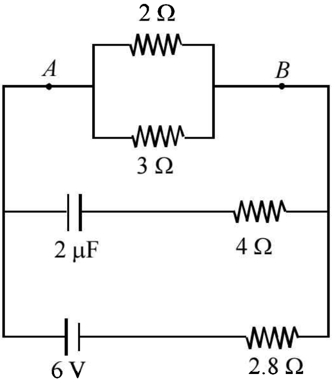
38. A network of resistors is connected to a 16 V battery of internal resistance 1 Ω as shown in the figure.



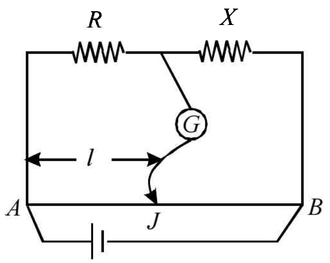
(i) Compute the equivalent resistance of the network.

(ii) Obtain the voltage drops V_{AB} and V_{CD}. **[Foreign 2010]**

39. Calculate the steady current through the 2Ω resistor in the circuit shown. **[Foreign 2010]**



40. In the meter bridge experiment, balance point was observed at J with $AJ = l$.



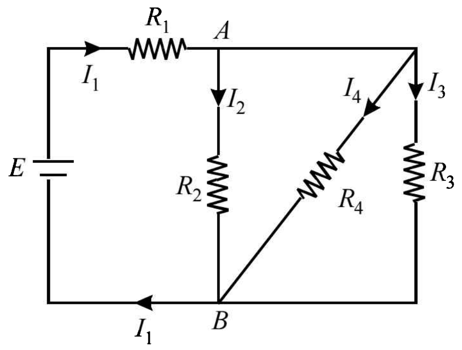
(i) If the values of R and X were doubled and then interchanged, what would be the new position of balance point?

(ii) If the galvanometer and battery are interchanged at the balanced position, how will the balance point get affected?

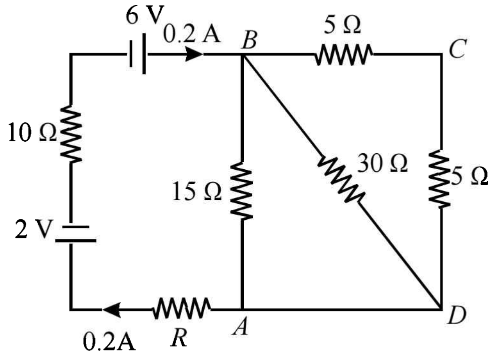
[All India 2011]

41. You are required to select a carbon resistor of resistance 47 kΩ $\pm$ 10% from a large collection. What should be the sequence of colour bands used to code it? **[Delhi 2011]**

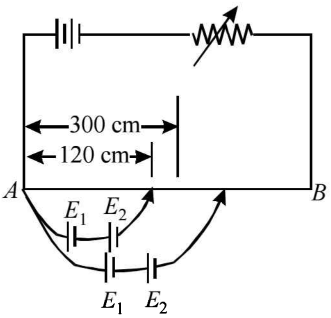
42 In the circuit shown, $R_1 = 4\Omega$, $R_2 = R_3 = 15\Omega$, $R_4 = 30\Omega$ and $E = 10$ V. Calculate the equivalent resistance of the circuit and the current in each resistor. **[Delhi 2011]**



43. Calculate the value of the resistance R in the circuit shown in the figure so that the current in the circuit is 0.2 A. What would be the potential difference between points A and B? **[All India 2012]**



44. In the figure, a long uniform potentiometer wire AB is having a constant potential gradient along its length. The null points for the two primary cells of emfs E_1 and E_2 connected in the manner shown, are obtained at a distance of 120 cm and 300 cm from the end A. **[Delhi 2012]**



Find

(i) E_1/E_2 and

(ii) position of null point for the cell E_1.

45. A conductor of length l is connected to a DC source of potential V. If the length of the conductor is tripled by gradually stretching it, keeping V constant, how will

(i) drift speed of electrons and

(ii) resistance of the conductor be affected? Justify your answer. **[Foreign 2012]**

46. A light bulb is rated at 120 W for a 240 V ac supply. Calculate the resistance of the bulb. **[All India 2013]**

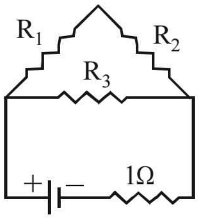
47. A light bulb is rated at 125 W for a 250 V ac supply. Calculate the resistance of the bulb. **[All India 2013]**

48. A battery of emf E and internal resistance r when connected across an external resistance of 12 Ω produces a current of 0.5 A.

When connected across a resistance of 25 ohm it produces a current of 0.25 A. Determine the (i) emf and (ii) internal resistance of the cell. **[All India 2013C]**

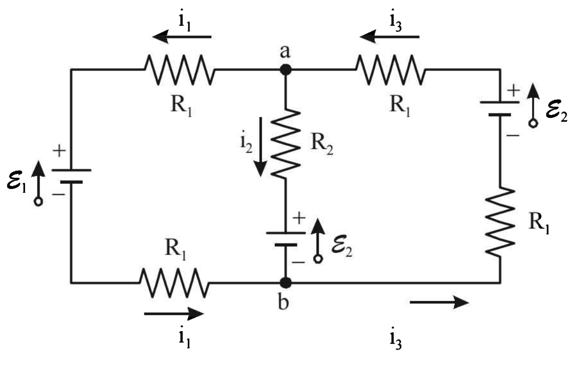
49. The potential difference across the terminals of a battery is 10 V when there is a current of 3A in the battery from the negative to the positive terminal. When the current is 2A in the reverse direction, the potential difference become 15 V. What is the internal resistance of the battery ?

50. A uniform wire of resistance 12 Ω is cut into three pieces so that the ratio of the resistances $R_1 : R_2 : R_3 = 1 : 2 : 3$ and the three pieces are connected to form a triangle across which a cell of emf 8 V and internal resistance 1 Ω is connected as shown. Calculate the current through each part of the circuit.
[All India 2013C, Delhi 2013C]



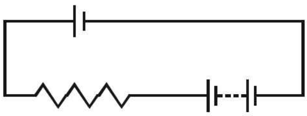
51. An ammeter of resistance 0.80 Ω can measure current upto 1.0 A.
(i) What must be the value of shunt resistance to enable the ammeter to measure current upto 5.0 A?
(ii) What is the combined resistance of the ammeter and the shunt?
[Delhi 2013]

52. The figure shows a circuit whose elements have the following values:
$\mathcal{E}_1 = 3.0$ V, $\mathcal{E}_2 = 6.0$ V,
$R_1 = 2.0\,\Omega$, $R_2 = 4.0\,\Omega$.



The three batteries are ideal batteries. Find the magnitude and direction of the current in each of the three branches.

53. A 5V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 39 Ω as shown in the figure. Find the value of the current. **[Delhi2013]**



54. A heating element is marked 210 V, 630 W. Find the resistance of the element when connected to a 210V dc source. **[Delhi 2013]**

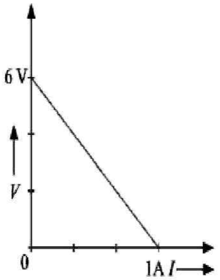
55. An ammeter of resistance 0.6 Ω can measure current upto 1.0 A. Calculate (i) the shunt resistance required to enable the ammeter to measure current upto 5.0A (ii) the combined resistance of the ammeter and the shunt. **[Delhi 2013]**

56. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. **[All India 2014]**

57. A potentiometer wire of length 1.0 m has a resistance of 15 Ω. It is connected to a 5 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 60 cm. **[Delhi 2014]**

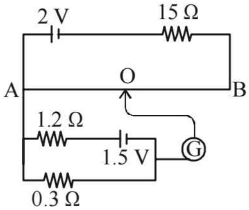
58. It is found that when R = 4 Ω, the current is 1 A and when R is increased to 9 Ω, the current reduces to 0.5 A. Find the values of the emf E and internal resistance r. **[Delhi 2015]**

59. The plot of the variation of potential difference across a combination of three identical cells in series, versus current is shown below. What is the emf and internal resistance of each cell ? **[All India 2016]**

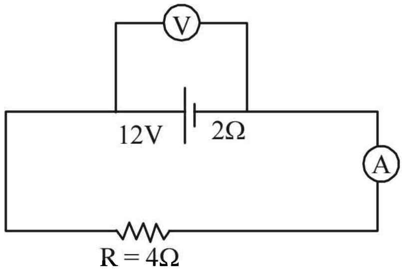


60. Two cells of emfs 1.5 V and 2.0 V having internal resistances 0.2 W and 0.3 W respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell. **[Delhi 2016]**

61. In the following potentiometer circuit AB is a uniform wire of length 1 m and resistance 10 Ω. Calculate the potential gradient along the wire and balance length AO (=l) **[Delhi 2016]**



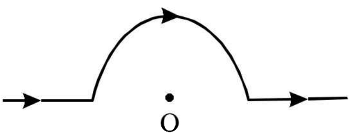
62. In the figure shown, an ammeter A and a resistor of 4 W are connected to the terminals of the source. The emf of the source is 12V having an internal resistance of 2W. Calculate the voltmeter and ammeter readings. **[All India 2017]**



(C) Magnetism

63. A straight wire carrying a current of 12 A is bent into a semi-circular arc of radius 2.0 cm as shown. What is the magnetic field B at O due to

(a) straight segments,



(b) semicircular arc? **[Foreign 2010]**

64. A galvanometer coil of 50Ω resistance shows full scale deflection for a current of 5 mA. How will you convert this galvanometer into a voltmeter of range 0 to 15 V? **[Foreign 2011]**

65. A wire AB is carrying a steady current of 12A and is lying on the table. Another wire CD carrying 5A is held directly above AB at a height of 1 mm. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB.

[Take the value of $g = 10\ ms^{-2}$] **[All India 2013]**

66. A wire AB is carrying a steady current of 6 A and is lying on the table. Another wire CD carrying 4A is held directly above AB at a height of 1 mm. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB.
[Take the value of $g = 10\ ms^{-2}$] **[All India 2013]**

67. A Rowland ring of mean radius 15 cm has 3500 turns of wire wound on a ferromagnetic core of relative permeability 800. What is the magnetic field B in the core for a magnetising current of 1.2A ?

68. A coil of 'N' turns and radius 'R' caries a current 'I'. It is unwound and rewound to make a square coil of side 'a' having same number of turns (N). Kepping the current 'I' same, find the ratio of the magnetic moments of the square coil and the circular coil.

69. The coil area of a galvanometer is $25 \times 10^{-4}\ m^2$. It consists of 150 turns of a wire and is in a magnetic field of 0.15 T. The restoring torque constant of the suspension fibre is 10^{-6} N m per degree. Assuming the magnetic field to be radial, calculate the maximum current that can be measured by the galvanometer, if the scale can accommodate 30° deflection. **[All India 2013C]**

70. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip down at 60° with the horizontal. The horizontal components of the earth's magnetic field at the place is known to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place. **[Delhi 2011]**

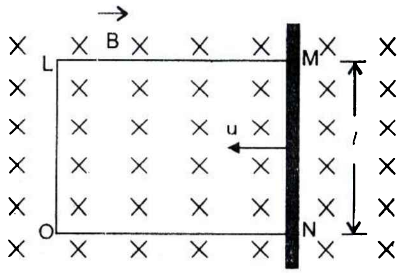
71. The vertical component of the earth's magnetic field at a given place in $\sqrt{3}$ times its horizontal component. If total intensity of earth's magnetic field at the place is 0.4 G find the value of :
(i) angle of dip
(ii) the horizontal component of earth's magnetic field.

72. Current in a circuit falls steadily from 2.0 A to 0.0 A in 10 ms. If an average emf of 200 V is induced, calculate the self-inductance of the circuit. **[Foreign 2011]**

73. A rod PQ of length 0.5 m completes a circuit which is placed with its plane normal to a uniform magnetic field $\vec{B}$ of 0.15 T, as shown. If the resistance of rod is 3Ω, what will be the force required to move the rod with a constant velocity of 2 m/s ?

74. A rectangular conductor LMNO is placed in a uniform magentic field at 0.5 T. The field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20 cm is moved towards left with a velocity of 10 ms^{-1}, calculate the emf inducted in the arm. Given the resistance of the arm to be 5Ω (assuming that other arms are of negligible resistance) find the value of the current in the arm.

[All India 2013]



75. (a) A wheel with 10 metallic spokes each 0.5 m long is rotated with a speed of 120 rev/min in a plane normal to the Earth's magnetic field at the place. If the magnitude of the field is 0.4 G, what is the induced emf between the axle and the rim of the wheel?

(b) A circular coil having 20 turns, each of radius 8 cm, is rotating about its vertical diameter with an angular speed of 50 radians s^{-1} in a uniform horizontal magnetic field of magnitude 30 mT. Obtain the maximum, average and r.m.s. values of the emf induced in the coil.

If the coil forms a closed loop of resistance 10 Ω, how much power is dissipated as heat in it?

76. A wheel with 8 metallic spokes each 50 cm long is rotated with a speed of 120 rev/min. in a plane normal to the horizontal component of the Earth's magnetic field. The earth's magnetic field at the place is 0.4 G and the angle of dip is 60°. Calculate the emf induced between the axle and the rim of the wheel. How will the value of emf be affected if the number of spokes were increased? **[All India 2013]**

77. The Earth's magnetic field at the Equator is approximately 0.4 G. Estimate the Earth's magnetic dipole moment. Given : Radius of the Earth = 6400 km. **[All India 2015]**

78. A horizontal conducting rod 10 m long extending form east to west is falling with a speed 5.0 ms^{-1} at right angles to the horizontal component of the Earth's magnetic field, 0.3×10^{-4} Wb m^{-2}. Find the instantaneous value of the emf induced in the rod.

[All India 2017]

(D) EMI, Alternating Current and EM waves

79 An inductor of unknown value, a capacitor of 100 mF and a resistor of 10 Ω are connected in series to a 200 V, 50 Hz a.c. source. It is found that the power factor of the circuit is unity. Calculate the inductance of the inductor and the current amplitude. **[Delhi 2008]**

80. A series L-C-R circuit is connected to a 220V variable frequency AC supply. If $L = 20$ mH, $C = (800/\pi^2)$ μF and $R = 110\ \Omega$ then find

(i) the frequency of the source, for which average power absorbed by the circuit is maximum.

(ii) the value of maximum current amplitude. **[Delhi 2010C]**

81. A resistor of 400 Ω, a inductor of $\frac{5}{\pi}$ H and a capacitor of $\frac{50}{\pi}$ μF are connected in series across a source of alternating voltage of $140 \sin 100\pi t$ *V*. Find the voltage (rms) across the resistor, the inductor and the capacitor. **[Foreign 2010]**

82. An electrical device draws 2kW power from AC mains (voltage 223V (rms) $= \sqrt{50,000}$ V). The current differs (lags) in phase by $\phi \left(\tan\phi = \frac{-3}{4} \right)$ as compared to voltage.

Find (i) R, (ii) $X_C - X_L$, and (iii) I_M. Another device has twice the values for R, X_C and X_L. How are the answers affected?

83. A step-down transformer operated on a 2.5 kV line. It supplies a load with 20 A. The ratio of the primary winding to the secondary is 10 : 1. If the transformer is 90% efficient, calculate

(i) the power output (ii) the voltage and

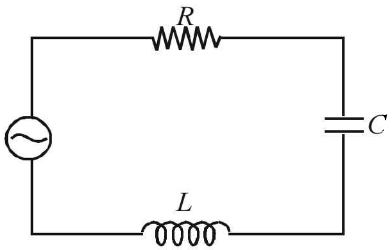
(iii) the current in the secondary. **[Foreign 2010]**

84. An alternating voltage given by $V = 140 \sin 314t$ is connected across a pure resistor of 50 Ω. Find

(i) the frequency of the source

(ii) the rms current through the resistor **[All India 2012]**

85. The figure shows a series *L-C-R* circuit with $L = 10.0$ H, $C = 40$ μF and $R = 60\ \Omega$ connected to a variable frequency source of 240 V. Calculate.



(i) the angular frequency of the source which drives the circuit at resonance.

(ii) the current at the resonating frequency.

(iii) the rms potential drop across the inductor at resonance.

[Delhi 2012]

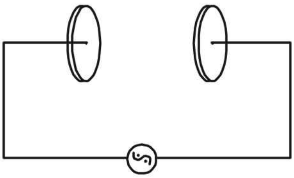
86. 1MW power is to be delivered from a power station to a town 10 km away. One uses a pair of Cu wires of radius 0.5 cm for this purpose. Calculate the fraction of ohmic losses to power transmitted if

(i) power is transmitted at 220V. Comment on the feasibility of doing this.

(ii) a step-up transformer is used to boost the voltage to 11000 V, power transmitted, then a step-down transformer is used to bring voltage to 220 V. ($\rho_{Cu} = 1.7 \times 10^{-8}$ SI unit)

87. You are given a 2μF parallel plate capacitor. How would you establish an instantaneous displacement current of 1mA in the space between its plates?

88. A parallel plate capacitor made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V a.c. supply with an angular frequency of 300 rad. s^{-1}.



(a) What is the r.m.s. value of the conduction current?

(b) Is the conduction current equal to the displacement current?

(c) Determine the magnitude of B at a point 3.0 cm from the axis between the plates.

89. A capacitor of unknown capacitance, a resistor of 100 Ω and an inductor of self-inductance $L = (4/\pi^2)$ henry are in series connected to an ac source of 200 V and 50 Hz. Calculate the value of the capacitance and the current that flows in the circuit when the current is in phase with the voltage. **[All India 2013C]**

90. How much current is drawn by the primary of a transformer connected to 220 V supply when it delivers power to a 110V – 550 W refrigerator?

[All India 2016]

91. A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s. what is the change of flux linkage with the other coil? **[Delhi 2016]**

92. The primary coil of an ideal step up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are respectively 220 V and 1100 W. Calculte
(a) Number of turns in secondary (b) Current in primary
(c) Voltage across secondary (d) Current in secondary
(e) Power in secondary **[Delhi 2016]**

(E) Optics

93. A ray of light passing through an equilateral triangular glass prism from air undergoes minimum deviation when angle of incidence is 3/4th of the angle of prism. Calculate the speed of light in the prism. **[Delhi 2008]**

94. A converging lens of refractive index 1.5 is kept in a liquid medium having same refractive index. What would be the focal length of the lens in this medium? **[Delhi 2008]**

95. Calculate the distance of an object of height h from a concave mirror of focal length 10 cm, so as to obtain a real image of magnification. **[Delhi 2008]**

96. An astronomical telescope uses two lenses of powers 10 D and 1 D. What is its magnifying power in normal adjustment? **[All India 2010]**

97. An object of 3 cm height is placed at a distance of 60 cm from a convex mirror of focal-length 30 cm. Find the nature, position and size of the image formed. **[All India 2010]**

98. A convex lens is used to obtain a magnified image of an object on a screen 10 cm from the lens. If the magnification is 19, find the focal-length of the lens. **[All India 2010]**

99. Two thin lenses of power $+6D$ and $-2D$ are in contact. What is the focal length of the combination? **[All India 2010]**

100. A lens of refractive index 1.45 disappears when immersed in a liquid. What is the value of refractive index of the liquid? **[Delhi 2010]**

101. Find the radius of curvature of convex surface of a plano-convex lens, whose focal length is 0.3 m and the refractive index of the material of the lens is 1.5. **[Delhi 2010]**

102. A biconvex lens has a focal length 2/3 times the radius of curvature of either surface. Calculate the refractive index of lens material. **[Delhi 2010]**

103. Calculate the speed of light in a medium whose critical angle is 30°. **[Delhi 2010]**

104. The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. If focal length of the lens is 12 cm, find the refractive index of the material of the lens. **[Delhi 2010]**

105. A convex lens has 20 cm focal length in air. What is its focal length in water? (Refractive index of air-water = 1.33, refractive index of air-glass = 1.5). **[Foreign 2010]**

106. A converging lens has a focal length of 20 cm in air. It is made of a material of refractive index 1.6. It is immersed in a liquid of refractive index 1.3. Calculate its new focal-length. **[All India 2011]**

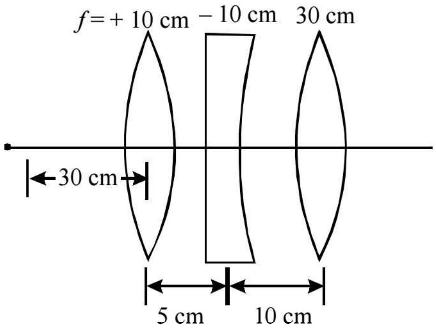
107. A compound microscope uses an objective lens of focal length 4 cm and eyepiece lens of focal length 10 cm. An object is placed at 6 cm from the objective lens. Calculate the magnifying power of the compound microscope. Also calculate the length of the microscope. **[All India 2011]**

108. A giant reflecting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece lens of focal length 1.0 cm is used, find the angular magnification of the telescope.
If this telescope is used to view the moon, what is the diameter of the image of the moon formed by the objective lens? The diameter of the moon is 3.42×10^6 m and the radius of the lunar orbit is 3.8×10^8 m. **[All India 2011]**

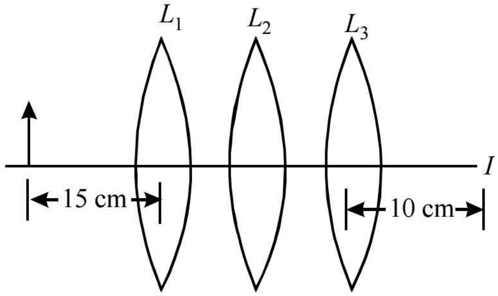
109. Two convex lenses of focal length 20 cm and 1 cm constitute a telescope. The telescope is focused on a point which is 1 m away from the objective. Calculate the magnification produced and the length of the tube, if the final image is formed at a distance, 25 cm from the eyepiece. **[Delhi 2011C]**

110. The objective of an astronomical telescope has a diameter of 150 mm and a focal length of 4.00 m. The eyepiece has a focal length of 25.00 mm. Calculate the magnifying and resolving power of telescope. ($\lambda = 6000$Å for yellow colour). **[Delhi 2011C]**

111. Find the position of the image of the object O formed by the lens combination given in the figure. **[Foreign 2011]**



112. You are given three lenses L_1, L_2 and L_3 each of focal length 10 cm. An object is kept at 15 cm in front of L_1, as shown. The final real image is formed at the focus I of L_3. Find the separation between L_1 and L_2, L_2 and L_3. **[All India 2012]**



113. For the same value of angle of incidence, the angles of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which medium would the velocity of light be minimum? **[All India 2012]**

114. The focal lengths of the objective and eyepiece of a microscope are 1.25 cm and 5 cm respectively. Find the position of the object relative to the objective in order to obtain an angular magnification of 30 in normal adjustment. **[Delhi 2012]**

115. A convex lens of focal length f_1 is kept on contact with a concave lens of focal length f_2. Find the focal length of the combination. **[All India 2013]**

116. (a) A small telescope has an objective lens of focal length 140 cm and an eyepiece of focal length 5.0 cm. Find the magnifying powr of the telescope for viewing distant obejcts when:
(i) the telescope is in normal adjsutment and
(ii) the final image is formed at the least distance of distinct vision.
(b) Also, find the separation between the objective and the eyepiece. **[All India 2013C]**

117. An equiconvex lens of focal length 15 cm is cut into two equal halves in thickness. What is the focal length of each half?

118. A ray of light passes through an equilateral prism in such a way that the angle of incidence is equal to the angle of emergence and each of these angles is 3/4th the angle of the prism. Determine the (i) angle of deviation and (ii) the refractive index of the prism. **[All India 2013C]**

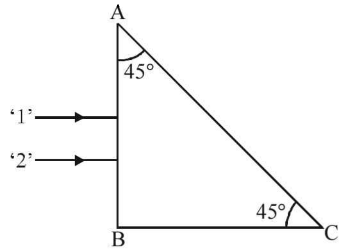
119. A convex lens of focal length 25 cm is placed coaxially in contact with a concave lens of focal length 20 cm. Determine the power of the combination. **[Delhi 2013]**

120. A convex lens of focal length 30 cm is placed coaxially in contact with a concave lens of focal length 40 cm. Determine the power of the combination. Will the system be converging or diverging in nature? **[Delhi 2013]**

121. A small bulb (assumed to be a point source) is placed at the bottom of a tank containing water to a depth of 60 cm. Find out the area of the surface of water through which light from the bulb, can emerge. Take the value of the refractive index of water to be 4/3. **[Delhi 2013C]**

122. A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason. **[All India, 2014]**

123. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering the prism. **[All India, 2014]**



124. What is the value of the critical angle for a material of refractive index $\sqrt{3}$?

125. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm apart. A point object lies 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the image by the combination. Determine the nature and position of the image formed. **[All India, 2014]**

126. A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens? **[Delhi 2014]**

127. The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focussed on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye piece. **[Delhi 2014]**

128. If the angle between the pass axis of polarizer and the analyser is 45°, write the ratio of the intensities of original light and the transmitted light after passing through the analyser. **[Delhi 2009]**

129. In Young's double slit experiment, the two slits 0.15 mm apart are illuminated by monochromatic light of wavelength 450 nm. The screen is 1.0 m away from the slits. Find the distance of the second
(a) bright fringe,
(b) dark fringe from the central maximum. **[All India 2010]**

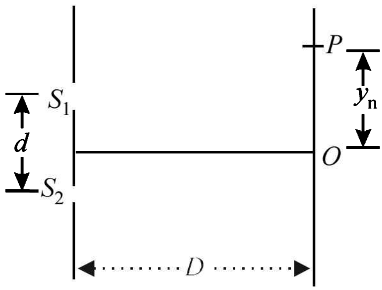
130. A beam of light, consisting of two wavelengths 560 nm and 420 nm, is used to obtain interference fringes in a Young's double slit experiment. Find the least distance from the central maximum, where the bright frings, due to both the wavelengths coincide. The distance between the two slits is 4.0 mm and the screen is at a distance of 1.0 m from the slits. **[Delhi 2010C]**

131. Yellow light ($\lambda = 6000$ Å) illuminates a single slit of width 1×10^{-4} m. Calculate the distance between two dark lines on either side to the central maximum, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit. **[All India 2011C]**

132. Between two polaroids placed in crossed position, a third polaroid is introduced. The axis of the third polaroid makes an angle of 30° with the axis of the first polaroid. Find intensity of transmitted light from the system assuming I_0 to be the intensity of polarized light obtained from the first polaroid. **[All India 2011C]**

133. Light passes through two polaroids P_1 and P_2 with pass axis of P_2 making an angle θ with the pass axis of P_1. For what value of θ is the intensity of emergent light zero? **[Foreign 2011]**

134. The intensity at the central maxima (O) in a Young's double slit experiment is I_0. If the distance OP equals one-third of fringe width of the pattern, show that the intensity at point P would be $I_0/4$.
[Foreign 2011]



135. Two polaroids, A and B are kept in crossed position. How should a third polaroid, C be placed between them so that the intensity of polarized light transmitted by polaroid, B reduces to 1/8th of the intensity of unpolarized light incident on A? **[All India 2012]**

136. Calculate the wavelength of light in glass if the frequency of light is 6×10^{14} Hz and the refractive index of glass is 1.5

137. A parallel beam of light of 450 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.5 m away. It is observed that the first minimum is at a distance of 3 mm from the centre of the screen. Calculate the width of the slit. **[All India 2013]**

138. Two wavelengths of sodium light 590 nm and 596 nm are used, in turn, to study the diffraction taking place due to a single slit of aperture 1×10^{-4} m. The distance between the slit and the screen is 1.8 m. Calculate the separation between the position of the first maxima of the diffraction pattern obtained in the two cases.

[All India 2013C, Delhi 2013]

139. The human eye has an approximate angular resolution of $\phi = 5.8 \times 10^{-4}$ rad and a typical photoprinter prints a minimum of 300 dpi (dots per inch, 1 inch = 2.54 cm). At what minimal distance *z* should a printed page be held so that one does not see the individual dots.

140. An α-particle and a proton are accelerated from rest by the same potential. Find the ratio of their de-Broglie wavelengths.

[All India 2010]

141. The ratio between the de-Broglie wavelengths associated with protons, accelerated through a potential of 512 V and α-particles, accelerated through a potential of x volt, is found to be one. Find the value of x. **[Delhi 2010C]**

142 Find the ratio of the de-Broglie wavelength, associated with

(i) protons, accelerated through a potential of 128 V and

(ii) α-particles, accelerated through a potential of 64 V.

[Delhi 2010C]

143. Two metals A and B have work function 2eV and 6eV respectively which of these will emit radiation when irradiated by light of wavelength 400 nm?

144. What is momentum of photon of wavelength 0.01Å?

145. A particle is moving three times as far as an electron. The ratio of the de-Broglie wavelength of the particle to that of the electron is 1.813×10^{-4}. Calculate the particle's mass and identify the particle.

[All India 2011C]

146. An electron and a photon each have a wavelength 1.00. Find

(i) their momenta,

(ii) the energy of the photon and

(iii) the kinetic energy of electron **[All India 2011C]**

147. An electron microscope uses electrons accelerated by a voltage of 50 kV. Determine the de-Broglie wavelength associated with the electrons. Taking other factors, such as numerical aperture etc. to be same, how does the resolving power of an electron microscope compare with that of an optical microscope which used yellow light? **[All India 2014]**

148. Monochromatic light of frequency 5.0×10^{14} Hz is produced by a laser. The power emitted is 3.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source. **[Delhi 2014]**

149. Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source. **[Delhi 2014]**

150. The equivalent wavelength of a moving electron has the same value as that of a photon of energy 6×10^{-17} J. Calculate the momentum of the electron. **[All India 2015]**

151. A ray of light passes through an equilateral glass prism such that the angle of incidence is equal to the angle of emergence and each of these angles is equal to 3/4 of angle of prism. Find the angle of deviation. **[All India 2015]**

152. A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65. What is the nature of the lens? **[Delhi 2015]**

153. Answer the following questions :

(a) In a double slit experiment using light of wavelength 600 nm, the angular width of the fringe formed on a distant screen is 0.1°. Find the spacing between the two slits.

(b) Light of wavelength 5000 Å propagating in air gets partly reflected from the surface of water. How will the wavelengths and frequencies of the reflected and refracted light be affected? **[Delhi 2015]**

154. (i) A giant refracting telescope has an objective lens of focal length 15 m. If an eye piece of focal length 1.0 cm is used, what is the angular magnification of the telescope?

(ii) If this telescope is used to view the moon, what is the diameter of the image of the moon formed by the objective lens? The diameter of the moon is 3.48×10^6 m and the radius of lunar orbit is 3.8×10^8 m. **[Delhi 2015]**

155. What is the value of refractive index of a medium of polarising angle 60° ? **[All India 2016]**

156. Light from a point source in air falls on a convex spherical glass surface of refractive index 1.5 and radius of curvature 20 cm. The distance of light source from the glass surface is 100 cm. At what position is the image formed? **[All India 2016]**

157. Calculate the distance of an object of height h from a concave mirror of radius of curvature 20, so as to obtain real image of magnification 2. Find the location of image also. **[Delhi 2016]**

158. (a) Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light.

(b) A double convex lens is made of a glass of refractive index 1.55 with both faces of the same radius of curvature. Find the radius of curvature required, if the focal length is 20 cm.

[All India 2017]

159. A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}$th of the angle of prism. Calculate the speed of light in the prism.

[All India 2017]

(F) Atoms and Nuclei

160. The radius of innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. What is the radius of orbit in the second excited state?

[Delhi 2010]

161. The electron in a given Bohr orbit has a total energy of – 1.5 eV. Calculate its

(i) kinetic energy

(ii) potential energy

(iii) wavelength of radiation emitted, when this electron makes a transition to the ground state. **[Delhi 2011, 2011C]**

162. The electron in hydrogen atom is initially in the third excited state. What is the maximum number of spectral lines which can be emitted when it finally moves to the ground state? **[Delhi 2012]**

163. The ground state energy of hydrogen atom is – 13.6 eV. If an electron makes a transition from an energy level – 0.85 eV to – 1.51 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does this wavelength belong? **[All India 2012]**

164. The electron in the hydrogen atom passes from the n = 4 energy level to n = 1 level. What is the maximum number of photons that can be emitted? and minimum number?

165. Given that the Bohr radius of hydrogen atom is 5.3×10^{-11} m. Determine its radius in the first excited state and calculate the total energy in this state. **[Delhi 2013C]**

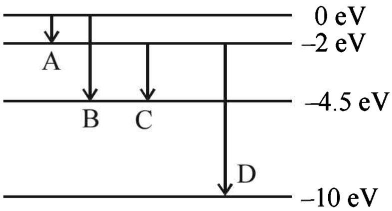
166. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited?

Calculate the wavelengths of the first member of Lyman and first member of Balmer series. **[Delhi 2014]**

167. A 12.9 eV beam of electronic is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited ?

Calculate the wavelength of the first member of Paschen series and first member of Balmer series. **[Delhi 2014]**

168. The energy levels of an atom are as shown in figure. Which of these transitions will result in emission of photon of wavelength 275 nm?



169. A nucleus $^{23}_{10}\text{Na}$ undergoes β^-decay and becomes $^{23}_{11}\text{Na}$. Calculate the maximum kinetic energy of electrons emitted assuming that the daughter nucleus and anti -neutrino carry negligible kinetic energy.

[mass of $^{23}_{10}\text{Na}$ = 22.994466 u; mass of $^{23}_{11}\text{Na}$ = 22.989770 u; $1\,u = 931.5\ \text{MeV}/c^2$] **[Delhi 2008]**

170. Findout the binding energy per nucleon of an α – particle in MeV $m_p = 1.00728$ u, $m_n = 1.00867$ u, $m_\alpha = 4.00\,150$ u.

171. Two nuclei have mass numbers in the ratio 2 : 5. What is the ratio of their nuclear densities ? **[Delhi 2009]**

172. A radioactive nucleus 'A' undergoes a series of decays according to the following scheme :

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

The mass number and atomic number of A are 190 and 75 respectively. What are these numbers for A_4 ? **[Delhi 2009]**

173. A heavy nucleus X of mass number 240 and binding energy per nuclean 7.6 MeV is splited, into two fragments Y and Z of mass numbers 110 and 130. The binding energy of nucleons in Y and Z is 8.5 MeV per nucleon. Calculate the energy, released per fission in MeV. **[Delhi 2010]**

174. A nucleus of mass number 225 splits into two fresh nuclei having mass numbers in the ratio 3 : 2. If the nuclear radius is $R = 1.1 \times 10^{-15} A^{1/3}$ m, find the radii of the new nuclei.

175. In a given sample, two radio isotopes, A and B, are initially present in the ratio of 1 : 4. The half-lives of A and B are 100 yr and 50 yr respectively. Find the time after which the amounts of *A* and *B* become equal. **[Foreign 2012]**

176. The number of nuclei of a given radioactive sample at time $t = 0$ and $t = T$ are N_0 and N_0/n respectively. Obtain an expression for the half-life ($T_{½}$) of the nucleus in terms of *n* and T. **[Delhi 2013C]**

177. Calculate the energy release in MeV in the deuterium- tritium fusion reaction : **[Delhi 2015]**

$$^2_1H + ^3_1H \longrightarrow ^4_2He + n$$

Using the data :

$$m(^2_1H) = 2.014102u$$

$$m(^3_1H) = 3.016049u$$

$$m(^4_2He) = 4.002603u$$

$$m_n = 1.008665\,u$$

$$1u = 931.5\,MeV/c^2$$

178. Calculate the de-Broglie wavelength of the electron orbitting in the n = 2 state of hydrogen atom. **[All India 2016]**

179. Calculate the shortest wavelength of the spectral lines emitted in Balmer series.
[Given Rydberg constant, $R = 10^7\ m^{-1}$] **[All India 2016]**

180. A nucleus with mass number A = 240 and BE/A = 7.6 MeV breaks into two fragments each of A = 120 with BE/A = 8.5 MeV. Calculate the released energy. **[Delhi 2016]**

181. Calculate the energy in fusion reaction.

$$^2_1H + ^2_1H \rightarrow ^3_2He + n, \text{ where BE of } ^2_1H = 2.23\ MeV$$
$$\text{and of } ^3_2He = 7.73\ MeV$$

[Delhi 2016]

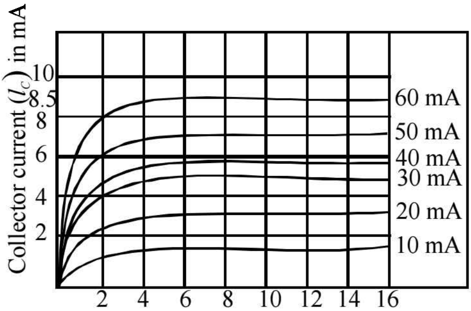
182. A 12.5 eV electron beam is used to excite a gaseous hydrogen atom at room temperature. Determine the wavelengths and the corresponding series of the lines emitted. **[All India 2017]**

(G) Electronics and Communication systems

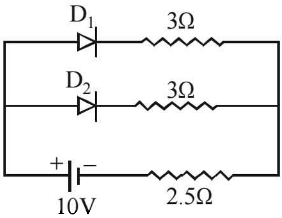
183. The typical output characteristics (I_C versus V_{CE}) of an n-p-n transistor in CE configuration, is shown in the figure. Calculate.

(a) the output resistance r_0 and

(b) the current amplification factor β_{AC}. **[Foreign 2010]**



184. Assuming that the two diodes D_1 and D_2 used in the electric circuit shown in the figure are ideal, find out the value of the current flowing through 2.5Ω resistor. **[Delhi 2013C]**



185. Consider the circuit arrangement shown in Fig. (a) for studying input and output characteristics of npn transistor in CE configuration.

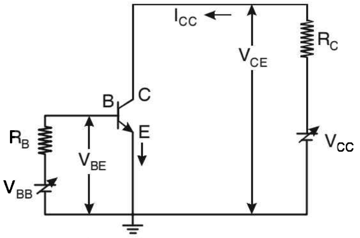


Fig. (a)

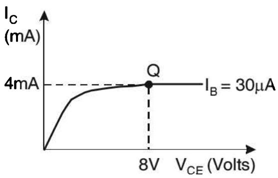


Fig. (b)

Select the values of R_B and R_C for a transitor whose V_{BE} = 0.7 V, so that the transistor is operating at point Q as shown in the characteristics shown in Fig. (b).

Given that the input impedance of the transistor is very small and $V_{CC} = V_{BB} = 16$ V, also find the voltage gain and power gain of circuit making appropriate assumptions.

186. Suppose a 'n'-type wafer is creatd by doping Si crystal having 5×10^{28} atoms/m^3 with 1ppm concentration of As. On the surface 200 ppm Boron is added to create 'P' region in this wafer. Considering $n_i = 1.5 \times 10^{16}\ \text{m}^{-3}$,
Calculate the densities of the charge carries in the n and p regions.

187. A transmitting antenna at the top of a tower has a height of 36 m and the height of the receiving antenna is 49 m. What is maximum distance between them, for satisfactory communication in the LOS mode? **[Delhi 2008]**

188. By what percentage will the transmission range of a TV tower be affected when the height of the tower is increased by 21% ? **[Delhi 2009]**

189. A carrier wave, $c(t) = Ac \sin \omega_c t$, is amplitude modulated by a modulating signal, $m(t) = A_m \sin \omega_m t$. The maximum and minimum amplitudes of the resulting AM wave are found to be 16 V and 4 V respectively. Calculate the modulation index. **[Delhi 2010]**

190. A TV tower is 80 m tall. Calculate the maximum disance upto which the signals transmitted from the tower can be recieved. **[Delhi 2010]**

191. A carrier wave of peak voltage 18 V is used to transmit a message signal. Calculate the peak voltage of the modulating signal in order to have a modulation index of 50%. **[Delhi 2012]**

192. A transmitting antenna at the top of a tower has a height of 45 m and the height of the receiving antenna is 80 m. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4×10^6 m) **[All India 2013]**

193. A transmitting antenna at the top of a tower has a height of 45 m and the receiving antenna is on the ground. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4×10^6 m) **[All India 2013]**

194. A 50 MHz sky wave takes 4.04 ms to reach a receiver via re-transmission from a satellite 600 km above earth's surface. Assuming re-transmission time by satellite negligible, find the distance between source and receiver. If communication between the two was to be done by Line of sight (LOS) method, what should size and placement of receiving and transmitting antenna be?

195. (i) The intensity of a light pulse travelling along a communication channel decreases exponentially with distance x according to the relation $I = I_o e^{-\alpha x}$, where I_o is the intensity at $x = 0$ and α is the attenuation constant.

Show that the intensity reduces by 75 per cent after a distance of $\left(\frac{\ln 4}{\alpha}\right)$

(ii) Attenuation of a signal can be expressed in decibel (dB) according to the relation dB = $10 \log_{10}\left(\frac{I}{I_o}\right)$. What is the attenuation in dB/km for an optical fibre in which the intensity falls by 50 per cent over a distance of 50 km?

196. A carrier wave of frequency 1.5 MHz and amplitude 50 V is modulated by a sinusoidal wave of frequency 10 kHz producing 50% modulation. Calculate the amplitude of A.M. wave and frequencies of the side bands produced. **[Delhi 2013C]**

197. For a CE-transistor amplifier, the audio signal voltage across the collector resistance of 2kΩ is 2V. Suppose the current amplification factor of the transistor is 100, find the input signal voltage and base current, if the base resistance is 1 kΩ. **[All India 2016]**

198. The frequencies of two side bands in an AM wave are 640 kHz and 660 kHz respectively. Find the frequencies of carrier and modulating signal. What is the bandwidth required for amplitude modulation? **[All India 2017]**

SOLUTIONS

1. Given, diameter, D = 2.5 m

$\therefore$ radius R = 1.25 m

$\sigma = 100\,\mu\ C/m^2 = 100' \ 10^{-6} C/m^2$

(i) Charge on the sphere

$$q = (4\pi R^2).\sigma = 4 \times 3.14 \times (1.25)^2 \times (100 \times 10^{-6})$$

$$= 1.96 \times 10^{-3} C$$

(ii) Total electric flux passing through the sphere,

$$\phi_E = \frac{q}{\varepsilon_0} = \frac{1.96 \times 10^{-3}}{8.85 \times 10^{-12}} = 2.2 \times 10^8 NC^{-1}m^2$$

2. Electric field intensity $E = 10^6$ N/C

Work done $(W) = 2 \times 10^{-23} J$

Work done in rotating the dipole from stable equilibrium position to unstable equilibrium position.

$$W = pE(\cos 0° - \cos 180°) = 2pE$$

$\therefore$ Dipole moment, $p = \frac{W}{2E} = \frac{2 \times 10^{-23}}{2 \times 10^6} = 10^{-29}$ cm

3. When C and A are placed in contact, charge of A equally divides in two spheres. Therefore charge on each A and C = + 2Q

Now, C is placed in contact with B, then charge on each B and C becomes

$$\frac{2Q + (-10Q)}{2} = -4Q$$

When A and B are placed in contact then charge on each, A and B becomes

$$\frac{2Q + (-4Q)}{2} = -Q$$

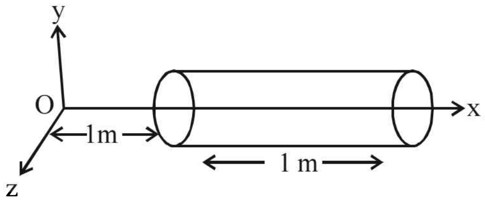
4. For an electric dipole, $F \propto \frac{1}{r^3}$

$\therefore$ New force, $F^1 = \frac{F}{2^3} = \frac{F}{8}$.

5. For unstable equilibrium, the angle between p and E is $\theta_1 = 180°$.
For stable equilibrium $\theta_2 = 0°$
Required work done

$W = pE(\cos\theta_1 - \cos\theta_2)$
$= 3 \times 10^{-8} \times 10^3 (\cos 180° - \cos 0°)$
$= -6 \times 10^{-5}$ J

6. (i) From question, it is clear that the electric field $\vec{E} = 50\, x\hat{i}$ is directed along the x-axis. Hence, there is no electric flux through the curved surface.



Electric field on the left face of the cylinder,

$E = 50\, \hat{i} \quad (\because x = 1\text{ m})$

$\therefore$ Electric flux through this face

$\phi_1 = \oint \vec{E} \cdot \vec{ds} = -E \times A$

$= 50 \times 25 \times 10^{-4}\, m^2 \quad (\because A = 25\text{ cm}^2)$

$= -0.125\ NC^{-1}\, m^2$

Electric flux through the other face

$\phi_2 = E \times A \quad (\because E = 50 \times \hat{i},\ x = 2\text{ m})$

$= 100 \times 25 \times 10^{-4}$

$= 0.25\ NC^{-1}\, m^2$

Net flux through the cylinder $= \phi_1 + \phi_2$

$= 0.25 - 0.125\ NC^{-1} m^2$

$= 0.125\ NC^{-1}\, m^2$

(ii) Let q be the charge enclosed by the cylinder.
According to Gauss's theorem

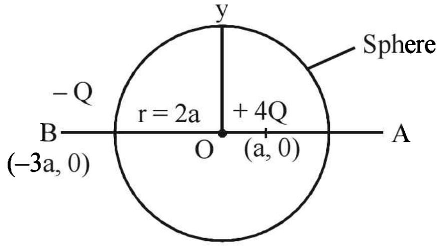
$\phi = \dfrac{q}{\epsilon_0}$

$\therefore \quad q = \phi\, \epsilon_0$

$= 0.125 \times 8.854 \times 10^{-12}$ C

$= 1.11 \times 10^{-12}$ C

7. It is clear that the sphere of radius 2a encloses the charge +4Q only

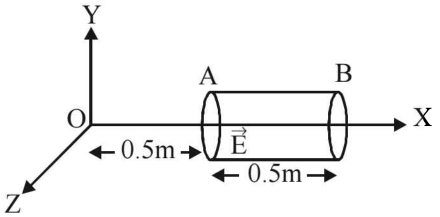


Therefore, electric flux

$$\phi = \oint \vec{E} \cdot \vec{ds} = \frac{1}{\epsilon_0} \cdot 4Q = \frac{4Q}{\epsilon_0}$$

8. (i) Given : $\vec{E} = 20x\,\hat{i}$

$A = 20\ cm^2 = 20 \times 10^{-4}\ m^2$



Since the electric field $\vec{E} = 20x\,\hat{i}$ is directed along the x-axis, there is no any flux across curved surface.

Flux through the face A of the cylinder

$$\phi_1 = \oint \vec{E} \cdot \vec{ds}$$
$$= Es \cos 180^\circ$$
$$= 20 \times 0.5 \times (-1) \times 20 \times 10^{-4}$$
$$= -200 \times 10^{-4} = -2 \times 10^{-2}\ NC^{-1}\ m^2$$

Flux through the face B of the cylinder

$$\phi_2 = \oint \vec{E} \cdot \vec{ds}$$
$$= EA \cos \theta = 20 \times 20 \times 10^{-4} \times 1$$
$$= 400 \times 10^{-4} = 4 \times 10^{-2}\ NC^{-1}\ m^2$$

Therefore net flux through the cylinder

$$\phi = \phi_1 + \phi_2$$
$$= 4 \times 10^{-2} - 2 \times 10^{-2}$$
$$= 2 \times 10^{-2}\ NC^{-1}\ m^2$$

(ii) According to Gauss's theorem

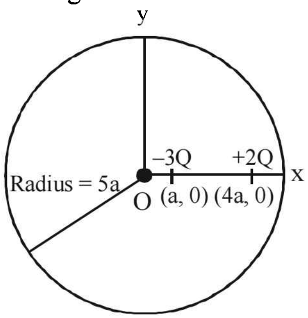
$$\phi = \int \vec{E} . \vec{ds} = \frac{Q}{\epsilon_0} \quad \text{or,} \quad 2 \times 10^{-2} = \frac{Q}{\epsilon_0}$$

or, $Q = 2 \times 10^{-2} \times 8.854 \times 10^{-12}$

$= 1.7708 \times 10^{-13}$ C

Hence the charge enclosed by the cylinder is 1.7708×10^{-13} C

9. If we draw a spherical surface of radius 5a, it will enclose both the charges as shown in figure.



∴ Net charge enclosed by the spherical surface is $-3Q + 2Q = -Q$

∴ By Gauss's theorem, electric flux

$$\phi = \oint \vec{E} . \vec{ds} = \frac{1}{\epsilon_0}(-Q) = -\frac{Q}{\epsilon_0}$$

10. $$E = \frac{kp}{(r^2 + a^2)^{3/2}}$$

$$= \frac{9 \times 10^9 \times 100 \times 10^{-6} \times 0.1}{(0.2)^3} = 1.125 \times 10^7 \text{ N/C.}$$

11. When the plane is parallel to the *y-z* plane:

$\phi = \vec{E} . \vec{A}$

Here: $\vec{E} = 2 \times 10^3 \hat{i}$ N/C

$\vec{A} = (20 \text{ cm})^2 \hat{i} = 4 \times 10^{-2} \hat{i}$ m^2

∴ $\phi = (2 \times 10^3 \hat{i}).(4 \times 10^{-2} \hat{i})$

⇒ $\phi = 80$ NC^{-1}m^2

When the plane makes a 30° angle with the x-axis, the area vector makes a 60° angle with the x-axis.

$$\phi = \vec{E}\cdot\vec{A} \quad \Rightarrow \quad \phi = EA\cos\theta$$

$$\Rightarrow \quad \phi = (2\times 10^3)(4\times 10^{-2})\cos 60° \quad \Rightarrow \quad \phi = 80/2$$

$$\Rightarrow \quad \phi = 40\,NC^{-1}m^2$$

12. Torque on a dipole which is placed in an uniform electric field (E) is given by,

$$\tau = PE\sin\theta = (ql)\,E\sin\theta \qquad ...(1)$$

Here, l is the length of the dipole, Q is the charge and E is the electric field.

Potential energy,

$$U = -PE\cos\theta = -(ql)\,E\cos\theta \qquad ...(2)$$

Dividing (2) by (1), $\dfrac{\tau}{U} = \dfrac{qlE\sin\theta}{-qlE\cos\theta} = -\tan\theta$

$$\Rightarrow U = \frac{-\tau}{\tan\theta} \qquad \Rightarrow U = \frac{-\tau}{\tan 60°}$$

$$\Rightarrow U = \frac{-4\sqrt{3}}{\sqrt{3}} \qquad \Rightarrow U = -4J$$

13. When the plane is parallel to the y-z plane:

Electric flux, $\phi = \dfrac{\vec{E}}{\vec{A}}$

Here: $\vec{E} = 4\times 10^3\,\hat{i}$ N/C

$\vec{A} = (5\text{ cm})^2\,\hat{i} = 0.25\times 10^{-2}\,\hat{i}\ m^2$

$\therefore\ \phi = (4\times 10^3\,\hat{i}).(25\times 10^{-4}\,\hat{i})$

$\Rightarrow \phi = 10\,NC^{-1}m^2$

When the plane makes a 30° angle with x-axis, the area vector makes a 60° angle with the x-axis.

$$\phi = \frac{\vec{E}}{\vec{A}} \quad \Rightarrow \quad \phi = EA\cos\theta$$

$$\Rightarrow \phi = (4\times 10^3)\,(25\times 10^{-4})\cos 60° \quad \Rightarrow \quad \phi = \frac{10}{2}$$

$$\Rightarrow \phi = 5\,NC^{-1}m^2$$

14. Work done is zero because the potential difference between two diagonally opposite points of a square with a 500 μC charge at the centre is zero.

15. Potential energy of the system

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{q(2q)}{r} + \frac{(+2q)(-4q)}{r} + \frac{(-4q)(q)}{r}\right]$$

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{q^2}{r}[2-8-4]$$

$$= 9\times10^9 \times \frac{(1.6\times10^{-10})^2}{0.1}\times(-10) = -2.304\times10^{-8} \text{ joule}$$

Hence, the work done required to dissociate the system of three charges,

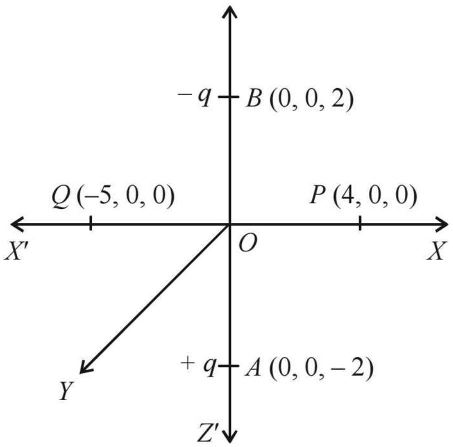
$$W = U = 2.304\times10^{-8}\,\text{J}.$$

16. $$V = \frac{kq}{r} = \frac{9' \ 10^{9}' \ 4' \ 10^{-7}}{0.09} = 4' \ 10^{4}\ \text{V}.$$

Work done = Charge × potential

$$= 2\times10^{-9}\times4\times10^{4} = 8\times10^{-5}\,\text{J}.$$

17.



Potential at point *P*,

$$V_1 = \frac{-q}{4\pi\varepsilon_0}\frac{1}{\sqrt{(4-0)^2+0+(2-0)^2}} + \frac{-q}{4\pi\varepsilon_0}\frac{1}{\sqrt{(4-0)^2+0+(2-0)^2}} = 0.$$

Potential at Point Q,

$$V_2 = \frac{-q}{4\pi\varepsilon_0} \cdot \frac{1}{\sqrt{(-5-0)^2 + 0 + (2-0)^2}} + \frac{q}{4\pi\varepsilon_0} \cdot \frac{1}{\sqrt{(-5-0)^2 + 0 + (-2-0)^2}} = 0.$$

Thus, work done in moving a test charge from points P to Q,

$$W = q(V_2 - V_1)$$
$$= q(0-0)$$
$$= 0.$$

18. (i) Capacitance of the parallel plate capacitor is given by,

$$C = \frac{\varepsilon_0 A}{d} \quad \therefore \quad X = \frac{\varepsilon_0 A}{d}$$

$$Y = \frac{\varepsilon_r \, \varepsilon_0 A}{d} = \frac{4\varepsilon_0 A}{d}$$

or, $Y = 4X$

Now, X and Y are in series combination and their equivalent capacitance is $4\mu F$.

$$\therefore \quad \frac{1}{4} = \frac{1}{X} + \frac{1}{Y} = \frac{1}{X} + \frac{1}{4X}$$

or, $\frac{1}{4} = \frac{5}{4X}$

or, $X = 5\mu F.$

$$Y = 4 \times 5 = 20\ \mu F.$$

(ii) Total charge, $Q = CV$

$$= 4 \times 10^{-6} \times 12$$
$$= 48 \times 10^{-6}\,\text{C}.$$

$\therefore$ Potential difference between the plates of capacitor

$$X = \frac{Q}{C} = \frac{48 \times 10^{-6}}{5 \times 10^{-6}} = 9.6\ V.$$

Potential difference between the plates of capacitor

$$Y = \frac{Q}{C} = \frac{48 \times 10^{-6}}{20 \times 10^{-6}} = 2.4\ V.$$

(iii) Energy stored = $\frac{1}{2}CV^2$

$\therefore$ The ratio of electrostatic energy stored in X and Y.

$$= \frac{\frac{1}{2}C_1V_1^2}{\frac{1}{2}C_2V_2^2} = \frac{(5\times10^{-6})(9.6)^2}{(20\times10^{-6})(2.4)^2}$$

$$= \frac{1}{4}\times\left(\frac{4}{1}\right)^2 = \frac{16}{4} = \frac{4}{1} = 4:1.$$

19. (i) Here $V = 12$ V and $C_1 = C_2 = C_3 = 6\,\mu F = 6\times10^{-6}\,F$.

Charge on capacitor C_3 is

$q_3 = C_3 V = 6\times10^{-6}\times12 = 72\times10^{-6} = 72\,\mu C$.

Since capacitor C_1 and C_3 are in series

$\therefore$ Equivalent capacitance

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C_s} = \frac{1}{6} + \frac{1}{6} = \frac{2}{6} = \frac{1}{3}$$

$\therefore$ $C_s = 3\,\mu F$

Charges on capacitor C_1 and C_2 is

$$q = C_S V = 3\times10^{-6}\times12 = 36\times10^{-6} = 36\,\mu C$$

$\therefore$ Charge on each capacitor C_1 and C_2 is $36\,\mu C$.

(ii) Since C_1 and C_2 are in series

$\therefore$ Equivalent capacitance $C_S = 3\,\mu F$

Now C_3 and C_S are in parallel

$\therefore$ Equivalent capacitance $C = C_3 + C_S = 6 + 3 = 9\,\mu F$

(iii) Energy stored $= \frac{1}{2}CV^2$

$$= \frac{1}{2}\times9\times10^{-6}\times(12)^2$$

$$= \frac{1}{2}\times9\times10^{-6}\times144 = 648\times10^{-6}$$

$= 6.48\times10^{-4}$ J.

20. (i) $\because$ 20 μF and C are in series

$\therefore \quad \frac{1}{4} = \frac{1}{20} + \frac{1}{C}$

$\Rightarrow \quad \frac{1}{4} - \frac{1}{20} = \frac{1}{C} \Rightarrow \frac{5-1}{20} = \frac{1}{C} \Rightarrow \frac{4}{20} = \frac{1}{C}$

$\therefore \quad C = 5\ \mu F.$

(ii) $\because\ q = CV$, $q = 4 \times 10^{-6} \times 12 = 48 \times 10^{-6} = 48\ \mu C.$

(iii) $V_1 = \frac{q}{C_1} = \frac{48 \times 10^{-6}}{20 \times 10^{-6}} = 2.4\ V$

$V_2 = \frac{q}{C_2} = \frac{48 \times 10^{-6}}{5 \times 10^{-6}} = 9.6\ V$

$\therefore$ Potential drop across 20 μF capacitor $= 2.4$ V

And potential drop across 5 μF capacitor $= 9.6$ V.

21. Given, $C = 200\ \text{pF} = 200 \times 10^{-12}$ F.

$V = 300$ V

The energy (initial) stored by the capacitor is

$$U_i = \frac{1}{2}CV^2$$

$$= \frac{1}{2} \times 200 \times 10^{-12} \times 300^2 = 9 \times 10^{-6}\ \text{J}$$

The charge on the capacitor when charged through 300 V battery is

$Q = CV$

$= 200 \times 10^{-12} \times 300 = 6 \times 10^{-8}$ C

When two capacitors are connected, let V' be the common potential difference. By charge conservation, charge would distribute but total charge would remain constant.

Thus, $Q = q + q'$

As potential difference is same,

Therefore $\frac{q}{C} = \frac{q'}{C'}$

$\frac{q}{200} = \frac{q'}{100}$

$q = 2q'$

Thus, $Q = 2q' + q' = 3q'$

So, $q' = \frac{Q}{3} = \frac{60 \text{ nC}}{3} = 20 \text{ nC}$

and $q = 2q' = 40$ nC

Thus, final energy $U_f = \frac{q^2}{2C} + \frac{q'^2}{2C'}$

$$= \frac{1}{2} \times \frac{\left(40 \times 10^{-9}\right)^2}{200 \times 10^{-12}} + \frac{1}{2} \times \frac{\left(20 \times 10^{-9}\right)^2}{100 \times 10^{-12}}$$

$= 4 \times 10^{-6} + 2 \times 10^{-6} = 6 \times 10^{-6}$ J

Difference in energy = final energy – initial energy

$= U_f - U_i$

$= 6 \times 10^{-6} - 9 \times 10^{-6} = -3 \times 10^{-6}$

22. (i) All capacitors of 6 μF are in series then equivalent capacitance

$$\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

or, $C' = \frac{C}{n} = \frac{6\mu F}{3} = 2\mu F$

C′ and 2μF capacitors are in parallel combination.
Equivalent capacitance

$C_{eq.} = C' + 2\mu F = 2\mu F + 2\mu F = 4\mu F$

(ii) Since, C' and 2μF are in parallel combination, therefore same potential difference 6V is applied on them.

Charge on C'

$q' = C'V = (2\mu F) \times 6V = 12\mu C$

The charge across the each capacitor of 6 μF capacitor is same and equal to charge across the combination i.e., 12 μC.
Charge on 2μF capacitor

$q = CV = (2\mu F)(6V) = 12\mu C$

23. Two identical capacitors C_1 and C_2 gets fully charged with 5V battery initially.

So, the charge and potential difference on both capacitors becomes

$q = CV$

$= 2 \times 10^{-6} \times 5\text{V} = 10\ \mu\text{C}$

and $V = 5$V

On introduction of dielectric medium of $K = 5$.

For C_1 (Continue to be connected with battery) potential difference of $C_1, (V') = 5V$

Capacitance of $C_1' = KC = 5 \times 2\mu F = 10\ \mu F$

Charge $q' = C'V' = (10\ \mu F)(5\ V) = 50\ \mu C$

For C_2 (Disconnected with battery)

Charge $q' = q = 10\ \mu C$

Potential difference

$$V' = \frac{V}{K} = \frac{5}{5} = 1\ V$$

24. (i) Charge stored in the capacitor $Q = CV$

From question,

$Q = CV = 360 \times 10^{-6}$ ...(i)

$C(V - 120) = 120 \times 10^{-6}$ ...(ii)

Dividing eq. (i) by (ii)

$$\frac{V}{V-120} = 3 \quad \Rightarrow \quad V = 3V - 360$$

$$\Rightarrow\ 2V = 360 \qquad \therefore \quad V = 180V$$

Voltage V of the capacitor is 180 V

and unknown capacitance $C = \dfrac{Q}{V}$

$$= \frac{360 \times 10^{-6}}{180} = 2 \times 10^{-6} F$$

(ii) When the voltage across the capacitor increases by 120 V, the new voltage will be $180V + 120V = 300V$

Therefore, new charge stored in the capacitor

$Q' = CV' = 300 \times 2 \times 10^{-6} = 600\ \mu C$

25. Let C farad be the capacity of the unknown capacitor. Charge stored in the capacitor

$Q = C \times V = 300 \times 10^{-6}$ ...(i)

When the potential is reduced by 100 volts, the new potential will be $(V - 100)$ volts and charge

$= C \times (V - 100) = 100 \times 10^{-6}$ ...(ii)

Dividing eq. (i) by (ii), we have

$$\frac{V}{V-100} = \frac{300}{100} = 3$$

or $V = 3V - 300$

$\therefore$ $V = 150$ volt

Putting this value in eq. (i), we have

$C \times 150 = 300 \times 10^{-6}$

$\therefore$ $C = 2 \times 10^{-6} F$

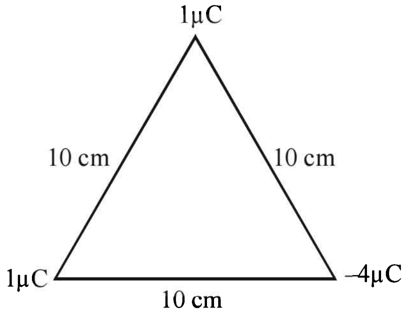
When the voltage is increased by 100 volts, the new voltage will be

$$150\,V + 100\,V = 250\,V$$

$\therefore$ New charge $\quad Q' = CV$

$$= 2 \times 10^{-6} \times 250\,C = 500\,\mu C$$

26. Work done (w) = change in electrostatic potential energy $(U_f - U_i)$



$$U_i = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right)$$

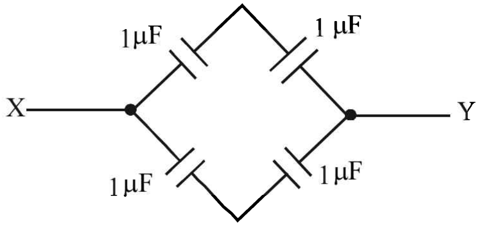
$$= 9 \times 10^9\left(\frac{1\times 1}{0.1} + \frac{1\times -4}{0.1} + \frac{1\times -4}{0.1}\right) \times 10^{-12}$$

$$U_i = 9 \times 10^{10}(1 - 4 - 4) \times 10^{-12} = -0.63\,J$$

$$U_f = 0$$

Hence, $W = U_f - U_i = 0 - (-0.63) = 0.63\,J$

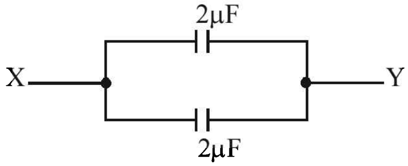
27. The equivalent circuit is given below.



There are two capacitors in one branch in series. So, the equivalent capacitance of one branch will be

$$\frac{1}{1} + \frac{1}{1} = 2\mu F$$

The arrangement will be further reduced as



Now, both the capacitors are in parallel, so the equivalent capacitance will be

$2 + 2 = 4\mu F$

(i) Voltage, V = 6 V

The charge in the network is given by q = CV

Now, $q = 4 \times 10^{-6} \times 6$

$= 24 \times 10^{-6}$ C = 24 μC

(ii) The energy stored in the network is given by

$$E = \frac{1}{2}CV^2 = \frac{1}{2} \times 4 \times 10^{-6} \times (6)^2$$

$$= \frac{1}{2} \times 4 \times 36 \times 10^{-6} = 72 \times 10^{-6} \text{ J} = 72 \text{ μJ}$$

28. According to the Gauss's law of electrostatics, electric flux through a closed surface is given by

$$\phi_E = \oint \vec{E}.\,\vec{ds} = \frac{Q}{\varepsilon_o} \text{ ....(i)}$$

Here,

E = electrostatic field

Q = total charge enclosed by the surface

ε_0 = absolute electric permittivity of free space

In the given case, cube encloses an electric dipole. Therefore the total charge enclosed by the cube is zero. i.e. Q = 0

Therefore, from (i), we have

$$\phi_E = \oint \vec{E}.\,\vec{ds} = \frac{0}{\varepsilon_o} = 0.$$

29. When the capacitors are connected in parallel, Equivalent capacitance $C_p = C_1 + C_2$

The energy stored in the combination of the capacitor, $E_p = \frac{1}{2} C_p V^2$

$$\Rightarrow \quad E_p = \frac{1}{2}(C_1 + C_2)(100)^2 = 0.25J$$

$\Rightarrow \quad (C_1 + C_2) = 5 \times 10^{-5}$ ....(i)

When the capacitors are connected in series Equivalent capacitance $C_s = \frac{C_1 C_2}{C_1 + C_2}$

The energy stored in the combination of the capacitors

$$E_s = \frac{1}{2} C_s V^2$$

$$\Rightarrow \quad C_s = \frac{1}{2}\frac{C_1 C_2}{C_1 + C_2}(100)^2 = 0.045J$$

$$\Rightarrow \quad \frac{1}{2}\frac{C_1 C_2}{5\times10^{-5}}(100)^2 = 0.045J$$

$\Rightarrow \quad C_1 C_2 = 0.045 \times 10^{-4} \times 5 \times 10^{-5} \times 2$
$= 4.5 \times 10^{-10}$

$\Rightarrow$ Now, $(C_1 - C_2)^2 = (C_1 + C_2)^2 - 4C_1C_2$

$\Rightarrow \quad (C_1 - C_2)^2 = 25 \times 10^{-10} - 4\times 4.5 \times 10^{-10}$
$= 7 \times 10^{-10}$

$\Rightarrow \quad C_1 - C_2 = \sqrt{7\times10^{-10}}$

$\Rightarrow \quad C_1 - C_2 = 2.64 \times 10^{-5}$ ..... (ii)

By solving equations (i) and (ii)

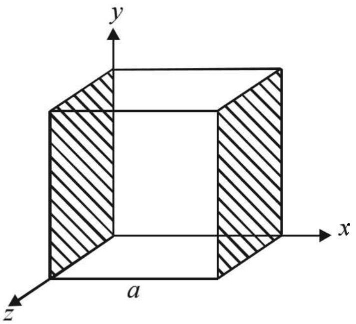
$C_1 = 35$ μF and $C_2 = 15$ μF

When the capacitors are connected in parallel, the charge on each of them can be obtained as follows:

$Q_1 = C_1V = 35 \times 10^{-6} \times 100 = 35 \times 10^{-4}$ C

$Q_2 = C_2V = 15 \times 10^{-6} \times 100 = 15 \times 10^{-4}$ C

30. (a) The electric field has only x component, for faces normal to x direction, the angle between E and Δs is $\pm\frac{\pi}{2}$. Therefore, the flux is separately zero for each face of the cube except the two shaded ones.



The magnitude of the electric field at the left face is $E_L = 0$ (As x = 0 at the left face)

The magnitude of the electric field at the right face is $E_R = 2a$ (As $x = a$ at the right face)

Their corresponding fluxes are

$$\phi_L = \vec{E}_L . \Delta\vec{S} = 0$$

$$\phi_R = \vec{E}_L . \Delta\vec{S} = E_R \Delta S \cos\theta = E_R \Delta S \ (\because \theta = 0°)$$

$$\Rightarrow \phi_R = E_R a^2$$

Net flux (ϕ) through the cube = $\phi_L + \phi_R = 0 + E_R a^2 = E_R a^2$

$\phi = 2a(a^2) = 2a^3$

From, Gauss's law

$$\phi = \frac{q}{\varepsilon_0} \Rightarrow q = \phi\varepsilon_0$$

$$\therefore \quad q = 2a^3\varepsilon_0$$

(b) (i) The metallic spherical shell of radius R carries a charge Q on its surface, So electric field inside a spherical shell is zero thus, the force experienced by the charge at the centre of the shell C will also be zero.

$$\because \quad \vec{F}_C = q\vec{E}$$

$$\because \quad \vec{F}_C = 0$$

At point A,

$$|\vec{F}_A| = 2Q\left(\frac{1}{4\pi\varepsilon_0} . \frac{3Q/2}{x^2}\right) = \frac{3Q^2}{4\pi\varepsilon_0 x^2} \text{, away from shell}$$

(ii) Electric flux through the shell

$$\phi = \frac{1}{\varepsilon_0} \text{ x magnitude of the charge enclosed by the shell}$$

$$\phi = \frac{1}{\varepsilon_0} \times \frac{Q}{2} = \frac{Q}{2\varepsilon_0}$$

31. (i) The capacitance of a parallel-plate capacitor having same area of plates and same seperation between them

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

$$C_Y = \frac{\varepsilon_0 4A}{d} \text{ and } C_X = \frac{\varepsilon_0 A}{d}$$

Thus,

$$C_Y = 4C_X \qquad ...(1)$$

$$C_{eq} = \frac{C_X C_Y}{C_X + C_Y} = 4\mu F \qquad ...(2)$$

Solving eqn (1) and (2) we get

$$\Rightarrow C_x = 5\mu F$$

$$\Rightarrow C_Y = 20\mu F$$

(ii) The potential difference between plates X and Y can be calculated as follows:

$$Q = CV$$

$$C_X V_X = C_Y V_Y \quad \frac{V_X}{V_Y} = \frac{C_Y}{C_X} = 4$$

$$V_X = 4V_Y \qquad ...(3)$$

From given circuit, $V_Y + V_X = 15V$ ...(4)

Solving eqs. (3) and (4) we get

$V_Y = 3V$ and $V_X = 12V$

(iii) The ratio of electrostatic energies can be calculated as follows:

Energy stored in a capacitor

$$E = \frac{Q^2}{2C} \text{ i.e. } E \propto \frac{1}{C}$$

Hence $\frac{E_X}{E_Y} = \frac{C_Y}{C_X} = 4$

32. Given that number density in X

$= 2 \times$ number density in Y

$n_x = 2n_y$

As current is common for the entire circuit

i.e., $I = n_X A_X e(v_d)_X = n_Y A_Y e(v_d)_Y$

As, $A_X = A_Y$

$$\therefore \frac{(v_d)_X}{(v_d)_Y} = \frac{n_Y}{n_X} = \frac{n_Y}{2n_Y} = \frac{1}{2}$$

33. When resistance of 5Ω is not connected in the circuit then voltmeter shows emf of cell

$(E) = 2.2$ V

The terminal voltage across cell when 5Ω resistance (R) connected across it (V) = 1.8 V

Let internal resistance = r

As we know, $r = R\left(\frac{E}{V} - 1\right)$

$$\therefore r = 5\left(\frac{2.2}{1.8} - 1\right) = 5 \times \frac{0.4}{1.8} = \frac{2}{1.8} = \frac{10}{9}\Omega$$

34. Null point is obtained at 40 cm from one end.

$l = 40$ cm,

$\therefore \quad 100 - l = 60$ cm

For meter bridge we know,

$$\frac{R}{S} = \frac{l}{(100 - l)} = \frac{40}{60} = \frac{2}{3}$$

$\therefore \quad R : S = 2 : 3$

35. Applying the condition of balanced Wheatstone bridge,

$$\frac{R}{S} = \frac{l}{100 - l} = \frac{40}{100 - 40} = \frac{40}{60} = \frac{2}{3}$$

$$\frac{R}{S} = \frac{2}{3} \qquad \text{...(i)}$$

The equivalent resistance of 12Ω and 5Ω in parallel is $\frac{12S}{12 + S}\Omega$

Again, applying the balanced wheatstone bridge condition

$$\frac{R}{\left(\frac{12S}{12+S}\right)}=\frac{50}{50}=1$$

$$\Rightarrow \quad R=\frac{12S}{12+S} \qquad \text{...(ii)}$$

From eqs. (i) and (ii)

$$\frac{2}{3}S=\frac{12S}{12+S}$$

$$12+S=18 \qquad \therefore\ S=6\,\Omega$$

$$R=\frac{2}{3}S=\frac{2}{3}\times 6=4\Omega$$

36. Let each conductor is of resistance R.

Case I: According to fig. (a) the resistances are connected in series combination, so resistance

$$R_1=R+R=2R$$

Case II: According to fig. (b), the resistances are connected in parallel combination, so equivalent resistance

$$\frac{1}{R_2}=\frac{1}{R}+\frac{1}{R} \quad \Rightarrow \quad R_2=\frac{R}{2}$$

Ratio of the equivalent resistance in two combinations is

$$\frac{R_1}{R_2}=\frac{2R}{(R/2)}=4$$

37. According to colour codes, resistance of two wires are

(i) $R_1=15\times 10^6\,\Omega$

(ii) $R_2=30\times 10^5\,\Omega$

$\therefore$ Ratio of resistances,

$$\frac{R_1}{R_2}=\frac{15\times 10^6}{30\times 10^5}=5$$

38. (i) 4Ω and 4Ω are in parallel combination.

$\therefore$ Equivalent resistance $R_{AB} = \frac{4}{2} = 2\Omega$

Similarly, equivalent resistor of $12\ \Omega$ and $6\ \Omega$ resistor

$$\frac{1}{R_{CD}} = \frac{1}{12} + \frac{1}{6} = \frac{1}{4\Omega} \Rightarrow R_{CD} = 4\Omega$$

Now, 2Ω, 4Ω, 1Ω, and 1Ω are in series combination.

$\therefore$ Equivalent resistance of the network

$R_{eq} = 2\Omega + 1\Omega + 4\Omega + 1\Omega = 8\Omega$

(ii) Current drawn from the battery

$$I = \frac{V}{R} = \frac{16}{8} = 2A$$

This current will flow from A to B and C to D. So, the potential difference between AB and CD is

$V_{AB} = IR_{AB} = 2 \times 2 = 4V$

and $V_{CD} = IR_{CD} = 2 \times 4 = 8V$

39. In DC circuit, capacitor offers infinite resistance. Therefore, no current flows through capacitor and through 4Ω resistance.

$\therefore$ Effective resistance between A and B

$$R_{AB} = \frac{2 \times 3}{2+3} = 1.2\Omega$$

Total resistance of the circuit $= 1.2 + 2.8 = 4\ \Omega$.

Current drawn from the cell

$$I = \frac{V}{R} = \frac{6}{4} = 1.5A$$

$\therefore$ Potential difference between A and B

$$V_{AB} = IR_{AB} = 1.5 \times 1.2 = 1.80\,V$$

Current through 2Ω resistance

$$I' = \frac{V_{AB}}{2\Omega} = \frac{1.8}{2} = 0.9A$$

40. (i) The balanced condition state

$$\frac{R}{X} = \frac{l}{(100-l)} \Rightarrow \frac{X}{R} = \frac{100-l}{l}$$

when X and R both are doubled then

$$\frac{2X}{2R} = \frac{X}{R} = \frac{100-l}{l}$$

balancing point would be at $(100 - l)$ cm

(ii) On changing the position of galvanometer and battery, the meter bridge continue to be balanced and hence no change occur in the balance point.

41. Given, resistance $= 47k\Omega \pm 10\%$

$$= 47 \times 10^3 \Omega \pm 10\%$$

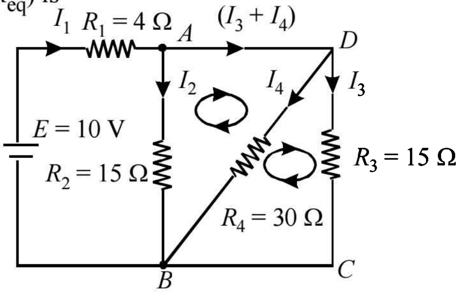
Ist colour band should be yellow as code for it is 4

IInd colour band should be violet as code for it is 7

IIIrd colour band should be orange as code for it is 3 (multiplier)

IVth colour band should be gold because tolerance is $\pm 10\%$

42. According to figure 15Ω, 30Ω and 15Ω are in parallel, their equivalent resistance (R_{eq}) is



$$\frac{1}{R_{eq}} = \frac{1}{15} + \frac{1}{30} + \frac{1}{15}$$

$$= \frac{2+1+2}{30} = \frac{5}{30}$$

$$= \frac{1}{6}$$

$$R_{eq} = 6\Omega$$

Now, R_{eq} ($= 6\Omega$) and 4Ω are in series their equivalent resistance

$$R'_{eq} = R_{eq} + 4\Omega$$

$$= 6\Omega + 4\Omega = 10\Omega$$

By junction rule at A

$$I_1 = I_2 + I_3 + I_4 \qquad \text{...(i)}$$

Applying Kirchhoff's second rule

(i) In mesh *ADB*

$$-I_4 \times 30 + 15 I_2 = 0$$

$$I_2 = 2I_4 \quad \Rightarrow \quad I_4 = \frac{I_2}{2}$$

(ii) In mesh *BDC*,

$$\Rightarrow \quad 30 I_4 - 15 I_3 = 0$$

$$\Rightarrow \quad I_3 = 2I_4 \quad \Rightarrow \quad I_4 = \frac{I_3}{2}$$

(iii) In mesh *ABE* (Containing battery)

$$-4I_1 - 15I_2 + 10 = 0$$

$$4I_1 + 15I_2 = 10 \qquad \text{...(ii)}$$

(iv) In mesh $ABCD$,

$$-15I_2 + 15I_3 = 0 \quad \therefore \quad I_2 = I_3$$

$$I_1 = I_2 + I_2 + \frac{I_2}{2}$$

$$I_1 = \frac{5}{2} I_2$$

From Eq. (ii),

$$4\left(\frac{5}{2} I_2\right) + 15I_2 = 10 \quad \Rightarrow \quad I_2 = \frac{10}{25} A = \frac{2}{5} A = I_3$$

$$\Rightarrow \quad I_2 = I_3 = \frac{2}{5} A$$

$$I_4 = \frac{I_2}{2} = \frac{1}{5} A \quad \therefore \quad I_1 = \frac{5}{2} I_2$$

$$= \frac{5}{2} \times \frac{2}{5} = 1\text{A}$$

43. **For BCD,** equivalent resistance

$$R_1 = 5\Omega + 5\Omega = 10\Omega$$

Across BA, equivalent resistance R_2

$$\frac{1}{R_2} = \frac{1}{10} + \frac{1}{30} + \frac{1}{15} = \frac{3+1+2}{30} = \frac{6}{30} = \frac{1}{5}$$

$$\Rightarrow R_2 = 5\Omega$$

Potential difference

$$V_{BA} = I \times R_2$$
$$= 0.2 \times 5 = \text{IV}$$

$$\therefore \quad V_{AB} = -1\text{V}$$

44. (i) Let potential gradient be k.

$$\because E_1 - E_2 = k \times 120 \qquad \text{...(i)}$$

[Cells are connected in opposite order]

$$E_1 + E_2 = k \times 300 \qquad \text{...(ii)}$$

[Cells are connected in supporting order]

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{k \times 300}{k \times 120} = \frac{5}{2}$$

Now, applying componendo and dividendo

$$\frac{(E_1+E_2)+(E_1-E_2)}{(E_1+E_2)-(E_1-E_2)}=\frac{5+2}{5-2}$$

$$\frac{E_1}{E_2}=\frac{7}{3}$$

(ii) $\because \frac{E_1}{E_2}=\frac{7}{3} \quad \therefore \quad E_2=\frac{3}{7}E_1$

From Eq. (i)

$$E_1-\frac{3}{7}E_1=k\times 120 \quad \Rightarrow \quad \frac{4}{7}E_1=k\times 120$$

$$E_1=k\times 120\times\frac{7}{4}=k\times 210$$

Thus the null point for E_1 is obtained at 210 cm.

45. The potential V = constant

Length of the conductor, $l'=3l$

(i) Drift speed of electrons $v_d=\frac{V}{nel\rho} \quad \therefore \; v_d \propto \frac{1}{l}$

So, when length is tripled, drift velocity gets one-third.

(ii) Resistance of the conductor is given as

$$R=\rho\frac{l}{A}$$

As volume remains same,

$$\therefore \quad A_1l_1=A_2l_2$$

$$A_1l=A_2(3l) \quad \therefore \quad A_2=\frac{A_1}{3}$$

i.e., when length is tripled area of cross-section is reduced to $\frac{A}{3}$.

Hence, $R=\rho\frac{l'}{A'}=\rho\frac{3l}{\frac{A}{3}}$

$$=9\rho\frac{l}{A}=9R$$

Thus, new resistance will be 9 times of its original value.

46. Given : P = 120 W, V = 240 V, R = ?
We know that

$$P = \frac{V^2}{R}$$

or $$R = \frac{V^2}{P} = \frac{240 \times 240}{120} = 480\ \Omega$$

47. Given : P = 125 W, V = 250 V, R = ?

We know that

$$R = \frac{V^2}{P} = \frac{250 \times 250}{125} = 500\ \Omega$$

48. Given : $I_1 = 0.5$ A, $R_1 = 12$ ohm, $I_2 = 0.25$ A,
$R_2 = 25$ ohm, E = ? and r = ?

From formula, $I = \frac{E}{(R+r)}$ or $E = I(R+r)$

$= 0.5 \times (12 + r) = 0.25 \times (25 + r)$
Solving we get, r = 1 ohm
and emf, $E = 0.5\,(12 + 1) = 6.5$ V

49. $E - 3r = 10$ ....(i)
$E + 2r = 15$ ....(ii)

solving these two equations, we get, $r = 1\ \Omega$

50. Given : $R_1 : R_2 : R_3 = 1 : 2 : 3$
and $R_1 + R_2 + R_3 = 12\ \Omega$
The three resistance are

$$R_1 = \frac{1}{6} \times 12 = 2\Omega,\ R_2 = \frac{2}{6} \times 12 = 4\Omega \text{ and}$$

$$R_3 = \frac{3}{6} \times 12 = 6\Omega$$

Resistance R_1 and R_2 are connected in series
$\therefore\ R = R_1 + R_2 = 2 + 4 = 6\Omega$
This resistance R and R_3 are connected in parallel,

$\therefore$ Net resistance $R_P = \frac{RR_3}{R + R_3} = \frac{6 \times 6}{6 + 6} = 3\Omega$

Again R_P and the internal resistance of the cell (r) are connected in series, therfore, net resistance of the circuit
$R_N = R_P + r = 3 + 1 = 4\Omega$
Hence, current in the circuit
$I = V/R_N = 8/4 = 2$ A
From the circuit, it is clear that I/2 (= 1A) through resistors R_1, R_2 and I/2 (=1A) through resistor R_3

51. Given : $G = 0.80\,\Omega, I_g = 1.0\,A$
$I = 5.0\,A, S = ?$
From formula

(i) $$S = \frac{GI_g}{I - I_g} = \frac{0.8 \times 1}{5 - 1} = 0.2\,\Omega$$

(ii) Combined resistance of the ammeter and shunt(R)

$$\frac{1}{R} = \frac{1}{G} + \frac{1}{S} \text{ or } R = \frac{G \times S}{G + S}$$

$$= \frac{0.8 \times 0.2}{0.8 + 0.2} = 0.16\,\Omega$$

52. To simplify this circuit, we apply the Kirchhoff's junction and loop rules.
Using arbitrarily chosen directions for the currents as shown in figure we apply the junction rule at point a by writing

$$i_3 = i_1 + i_2. \qquad ...(i)$$

We next apply the loop rule to any two of the three loops of the circuit. We first arbitrarily choose the left-hand loop, arbitrarily start at point a, and arbitrarily traverse the loop in the counterclockwise direction, obtaining

$$-i_1R_1 - \mathcal{E}_1 - i_1R_1 + \mathcal{E}_2 + i_2R_2 = 0.$$

Substituting the given data and simplifying yield

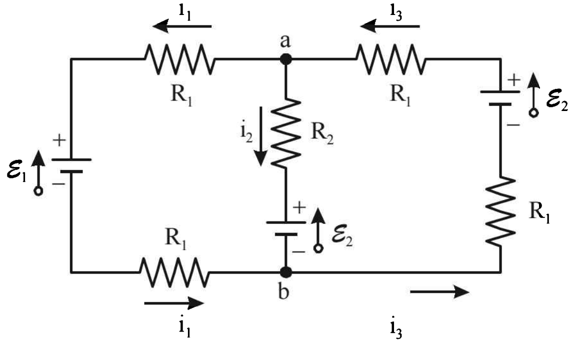
$$i_1(4.0\Omega) - i_2(4.0\Omega) = 3.0V. \qquad ...(ii)$$

For our second application of the loop rule, we arbitrarily choose to traverse the right-hand loop clockwise from point a, finding

$$+ i_3R_1 - \mathcal{E}_2 + i_3R_1 + \mathcal{E}_2 + i_2R_2 = 0.$$

Substituting the given data and simplifying yield

$$i_2(4.0\Omega) + i_3(4.0\Omega) = 0 \qquad ...(iii)$$



Using equation (i) eliminate i_3 from equation (iii) and simplifying gives us

$$i_1(4.0\Omega)+i_2(8.0\Omega)=0 \qquad ...(iv)$$

$$i_2=-0.25A.$$

Using equations (ii) and (iv), we find

(The minus sign shows that our arbitrary choice of direction for i_2 in Figure is wrong; i_2 should point up through $\mathcal{E}_2$ and R_2.)

Substituting $i_2=-0.25$ A into equations (iv) and solving for i_1 then give us

$$i_1=0.50A.$$

With equation (i) we then find that

$$i_3=i_1+i_2=0.25A.$$

The positive answers we obtained for i_1 and i_3 that our choices of directions for these currents are correct. We can now correct the direction for i_2 and write its magnitude as $I_2=0.25$ A

53. It is clear that the cell and the battery send current in the opposite directions.

$\therefore$ Net emf in the circuit $=200-5=195$V

Hence, current in the circuit

$$i=\frac{V}{R}=\frac{195}{39}=5A$$

54. Given : $V=210$ V, $P=630$ W, $R=?$

As we know

$$R=\frac{V^2}{P}=\frac{210\times 210}{630}=70\ \Omega$$

55. (i) Given : $G=0.6\ \Omega$, $I_g=1.0$ A, $I=5$A, $S=?$

We know that

$$S=\frac{GI_g}{I-I_g}=\frac{0.6\times 1}{5-1}=\frac{0.6}{4}=0.15\Omega$$

$\therefore$ Required shunt resistance $=0.15\ \Omega$

(ii) Since the ammeter and shunt are in parallel, their combined resistance

$$R_C=\frac{G\times S}{G+S}=\frac{0.6\times 0.15}{0.6+0.15}$$

$$=\frac{0.6\times 0.15}{0.75}=0.12\ \Omega$$

56. Drift velocity,

$$V_d = \frac{I}{neA}$$

where, I is the current, n is charge density, e is charge of electron and A is cross-section area.

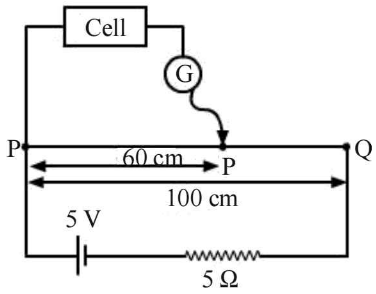
$$V_d = \frac{1.5}{9\times10^{28}\times1.6\times10^{-19}\times1.0\times10^{-7}}$$

$$V_d = \frac{1.5}{14.4\times10^{2}}$$

$V_d = 10.4 \times 10^{-4}$ m/s

57. Total resistance of the circuit,

$R = (R_{AB} + 5)\ \Omega = 20\ \Omega$



Current in the circuit, $i = \frac{V}{R} = \frac{5}{20}$ A

$\therefore$ Voltage across PQ, $V_{PQ} = i.R_{PQ} = 3.75$ V

The emf of the cell connected as above is given by:

$$e = \frac{l}{L}V_o$$

Here balance point is at,

$l = 60$ cm

Total length of wire PQ = L = 1 m = 100 cm

$$\therefore e = \frac{60}{100}(3.75) = 2.25 \text{ V}$$

58. When R = 4Ω and I = 1A

We know that, Terminal voltage, $V = E - Ir$

So, we have, $V = IR = 4 = E - Ir$

or $E - Ir = 4$ ..... (i)

When, R′ = 9Ω and $I' = 0.5$ A

$V = IR = 0.5 \times 9 = E - 0.5r$

or, $E - 0.5r = 4.5$ ..... (ii)

By solving eq^n (i) and eq^n (ii), we get

$r = 1\Omega$ and $E = 5V$

59. Let E and r be the EMF and internal resistance of all cells respectively and internal resistance of each cell respectively as cells are identical. As we know, according to the definition of the terminal potential difference,

$V = E - Ir$ ... (i)

E is the EMF and r is the total internal resistance of the circuit.

From eqn (i) when

$I = 0 \Rightarrow V = E$

From the graph we can see, E = 6 V

As there are three cells

$\therefore \quad E = 3 \times e = 6\,v \Rightarrow e = 2\,V$

And, when, V = 0

$$E = Ir \quad \Rightarrow \quad r = \frac{E}{I} = \frac{6}{1} = 6\Omega$$

As the cells are connected in series, so internal resistance of each cell.

$$= \frac{r}{3} = \frac{6}{3} = 2\Omega$$

60. Given: $E_1 = 1.5V; E_2 = 2V; r_1 = 0.2\Omega$ and $r_2 = 0.3\Omega$

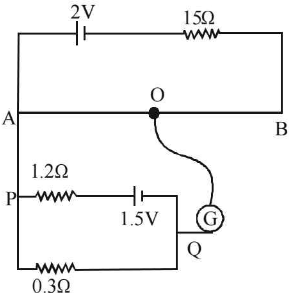
The effective emf of two cells connected in parallel can be calculated as follows:

$$E_{eff} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} = \frac{1.5 \times 0.3 + 2.0 \times 0.2}{0.5} = 1.7\,V$$

The effective resistance can be calculated as follows:

$$R_{eff} = \frac{r_1 r_2}{r_1 + r_2} = \frac{0.2 \times 0.3}{0.5} = 0.12\Omega$$

61. (ii) For the given potentiometer circuit



$$\text{Current, } I = \frac{V}{R} = \frac{2}{15+10} = \frac{2}{25}A$$

$$V_{AB} = I \times 10 = \frac{2}{25} \times 10 = 0.8V$$

Potential gradient, $K = \frac{V_{AB}}{L} = \frac{0.8}{1} = 0.8 Vm^{-1}$

Current I in the lower branch, $I = \frac{1.5}{1.2+0.3} = 1A$

Terminal potential between P and Q

$$V_{PQ} = 1 \times 0.3 = 0.3V$$

Balancing length $V_{PQ} = Kl$

or, $0.3 = 0.8l \Rightarrow l = \frac{0.3}{0.8} m = 0.375m$

62. Given : emf of cell /source E 12 V

Internal resistance $r = 2\,\Omega$

External resistance $R = 4\,\Omega$

Current $I = \frac{E}{R+r} = \frac{12}{4+2} = \frac{12}{6} = 2\,A$

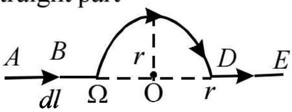
Using $V = E - Ir$

$V = 12 - (2 \times 2) = 8\,V$

Thus, reading of the ammeter will be 2 A and of the voltmeter will be 8V.

63. (a) Magnetic field due to straight part

$$B = \int \frac{\mu_0}{4\pi} \frac{Idl \times r}{r^3}$$



For point O, dl and r for each element of the straight segments AB and DE are parallel. Therefore, $dl \times r = 0$. Hence, magnetic field due to straight segments is zero.

(b) Magnetic field at the centre due to circular point

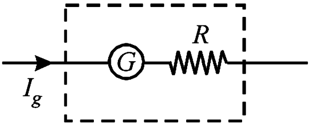
$$= \frac{\text{Magnetic field at the centre of circular coil}}{2}$$

$$B = \frac{1}{2}\left(\frac{\mu_0 I}{2r}\right) = \frac{\mu_0 i}{4r} \qquad [\because \text{ Here, coil is half}]$$

$$\Rightarrow B = \frac{\mu_0 I}{4r} = \frac{(4\pi \times 10^{-7}) \times 12}{4 \times 2 \times 10^{-2}}$$

$$= 6\pi \times 10^{-5} T$$

64. Given: $G = 50\Omega, I_g = 5\times10^{-3} A, V = 15V$



Voltmeter

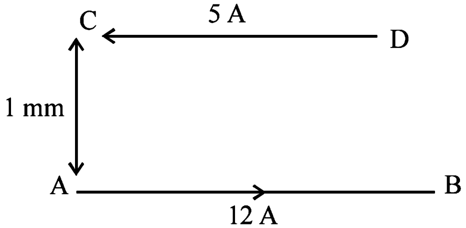
$\because V = I_g(G+R)$

$\Rightarrow \quad R = \frac{V}{I_g} - G = \frac{15}{5\times10^{-3}} - 50$

$R = 2950\,\Omega$

A resistance R = 2950 Ω is to be connected in series with the galvanometer to convert it into a desired voltmeter.

65. **Given :** $r = 1\text{ mm} = 1\times10^{-3}\text{ m}, i_1 = 12A, i_2 = 5A$



Since the wire CD is supported in air, the force of repulsion between the wire should be just equal to the weight of the wire.

Force of repulsion per unit length between the two wires

$$\frac{dF}{dl} = \frac{\mu_0}{4\pi}\cdot\frac{2i_1i_2}{r}\,Nm^{-1}$$

Let m kg be the mass per unit length of the wire CD

Downward force on a unit length

$= mg = m\times10\,Nm^{-1}$

$\Rightarrow \quad m\times10 = \frac{dF}{dl} = \frac{\mu_0}{4\pi}\cdot\frac{2i_1i_2}{r}$

or, $\quad m\times10 = \frac{10^{-7}\times2\times5\times12}{10^{-3}}$

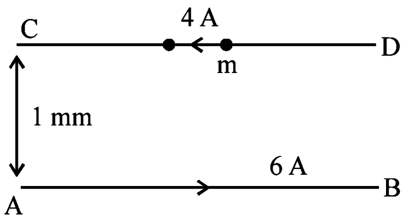
$\therefore \quad m = 12\times10^{-4}\,kg/m$

The current in the wire CD is in a direction opposite to that of AB.

66. Given : $r = 1\text{ mm} = 10^{-3}\text{ m}$

$i_1 = 6A, i_2 = 4A$

Mass per unit length of the wire CD, m = ?



To support the wire CD the weight of its unit length must be equal to the force of repulsion on the wire per unit length.

i.e. $$mg = \frac{dF}{dl} = \frac{\mu_0}{4\pi} \cdot \frac{2i_1i_2}{r}$$

or, $$m = \frac{1}{g}\frac{dF}{dl} = \frac{1}{g} \times \frac{\mu_0}{4\pi} \cdot \frac{2i_1i_2}{r}$$

$$= \frac{1}{10} \times \frac{10^{-7} \times 2 \times 6 \times 4}{10^{-3}}$$

$$= 48 \times 10^{-5} = 4.8 \times 10^{-4}\text{ kg m}^{-1}$$

The direction of current in wire CD must be opposite to that in wire AB.

67. Here, $r = 15\text{ cm} = 15 \times 10^{-2}\text{ m}, N = 3500, \mu_r = 800, I = 1.2\text{ A}, B = ?$

Number of turns/length, $$n = \frac{N}{2\pi r} = \frac{3500}{2\pi \times 15 \times 10^{-2}}$$

Also, $$B = \mu_0 \mu_r n I$$

$$= 4\pi \times 10^{-7} \times 800 \times \frac{3500 \times 1.2}{2\pi \times 15 \times 10^{-2}}$$

$$= 4.48\text{ T}$$

68. The magnetic moment of a current loop

$$M = nIA$$

For the circular loop $M_C = NI\pi R^2$ ... (i)

When the coil is unwound and rewound to make a square coil, then

$2\pi R = 4a$ or $a = \pi R/2$

Hence, magnetic moment of the square coil

$M_S = NIa^2 = NI(\pi R/2)^2 = NI\pi 2R^2/4$ ... (ii)

From eqs. (i) and (ii)

$$\frac{M_S}{M_C} = \frac{NI\pi^2R^2/4}{NI\pi R^2} = \frac{\pi}{4}$$

69. Given :

$A = 25 \times 10^{-4}\ m^2,\ n = 150$

$B = 0.15\ T,\ C = 10^{-6}\ Nm$

$\theta = 30° \quad I = ?$

From the expression

$$I = \frac{c\theta}{nBA} = \frac{10^{-6} \times 30}{150 \times 0.15 \times 25 \times 10^{-4}} = 5.3mA$$

70. Horizontal component of earth's magnetic field, $H = 0.4\ G$

Angle of dip, $\delta = 60° = \frac{\pi}{3}$

As we know, $H = B_e \cos\delta$

$$\Rightarrow \quad B_e = \frac{H}{\cos\delta} = \frac{0.4G}{\cos 60°} = 0.8\ G$$

71. Here $V = \sqrt{3}$ H and $B = 0.4$ G

(i) $\tan\delta = \frac{V}{H}$

$\tan\delta = \frac{\sqrt{3}H}{H} = \sqrt{3}$

$\tan\delta = \tan 60° \Rightarrow \delta = 60°$

$\therefore$ Angle of dip $= 60°$

(ii) Horizontal component of earth's magnetic field

$H = B\cos\delta = 0.4\cos 60° = 0.4 \times ½$

$= 0.2\ G$

72. As, $\Delta I = -2\ A$

$\Delta t = 10 \times 10^{-3}\ s$

$V = 200\ V$

As we know, $e = -L\frac{\Delta I}{\Delta t} \quad \therefore \quad 200 = -L\left(\frac{-2}{10 \times 10^{-3}}\right)$

or, $200 = L \times 2 \times 10^2$

$\therefore \quad L = 1H$

73. The force required to move the rod with a constant velocity is

$$F = \frac{B^2 l^2 v}{R} = \frac{(0.15)^2 \times (0.5)^2 \times 2}{3} N$$

$= 3.75 \times 10^{-3}$ N

74. Given, B = 0.5 T, l = 20 cm = 0.2 m and resistance of arm, R = 5Ω

Induced emf $e = BlV$

$= 0.5 \times 0.2 \times 10$ V

or $e = 1.0$ V

Current through this conductor

$$i = \frac{e}{R} = \frac{1V}{5\Omega} = 0.2 \text{ A}$$

75. (a) Given, for wheel,

n = 10, r = 0.5 m, v = 120 rev/min = 2 rev/sec.

$B = 0.4 G = 0.4 \times 10^{-4}$ T, E = ?

Area of wheel = πr^2 and Area swept by each spoke per sec, $A = \pi r^2 v$

Magnetic flux cut by each spoke per sec,

$\phi = BA = B\pi r^2 v$

i.e. $\frac{d\phi}{dt} = B\pi r^2 v$

By relation, induced emf,

$$E = \frac{d\phi}{dt} = B\pi r^2 v$$

$$= \frac{0.4 \times 10^{-4} \times 22 \times 0.5 \times 0.5 \times 2}{7}$$

$$= \frac{4 \times 22 \times 5 \times 5 \times 2 \times 10^{-7}}{7}$$

$$= \frac{4400}{7} \times 10^{-7} = \frac{44}{7} \times 10^{-5}$$

$= 6.286 \times 10^{-5}$ V.

Since all spokes are in parallel, total e.m.f. induced will be same as due to one spoke.

(b) Here, number of turns, N = 20

radius, $r = 8 \text{ cm} = 8 \times 10^{-2}$ m

angular speed, $\omega = 50$ radian s^{-1}

magnetic field, $B = 30 \text{ mT} = 30 \times 10^{-3}$ T

$\therefore$ Area of coil, $A = \pi r^2$
$= 3.14 \times (8 \times 10^{-2})^2 = 3.14 \times 64 \times 10^{-4}$
$= 200.96 \times 10^{-4} = 2.0 \times 10^{-2}$ m

(i) Maximum emf of the coil,
$e_{max} = NBA\,\omega = 20 \times 30 \times 10^{-3} \times 2 \times 10^{-2} \times 50$
$= 60000 \times 10^{-5} = 0.6$ V

(ii) $e_{rms} = \dfrac{e_0}{\sqrt{2}} = \dfrac{0.6}{1.414} = 0.42$ V

(iii) average emf of the coil $e_{average} = 0$
Now, R = 10 Ω

(iv) $\therefore$ Power dissipated $= \dfrac{e_{rms}^2}{R} = \dfrac{(0.42)^2}{10}$

$$= \frac{0.1764}{10} = 0.01764 \text{ watt}$$

76. Given : Length of each spoke = 50 cm = 0.5 m

$$\omega = \frac{120}{60} = 2 \text{ rps}$$

$= 2 \times 2\pi = 4\pi$ radian s^{-1}
$B = 0.4$ G
$\delta = 60°$

Horizontal component of Earth's magnetic field
$B_H = B\cos\delta = 0.4 \times \cos 60° = 0.2$ G

Now, $e = \dfrac{1}{2} B_H \omega l^2$

$= \dfrac{1}{2} \times 0.2 \times 4\pi \times 0.5 \times 0.5$ V

$= 0.314$ V

The emf will be uneffected by the increase in the number of spokes because they are in parallel.

77. Here, d = R = Radius of the Earth
Given : B = 0.4G = 0.4×10^{-4} T

$\dfrac{\mu_0}{4\pi} = 10^{-7}$ Wb A^{-1} m^{-1}

$d = 6400$ km $= 6.4 \times 10^6$ m

$\therefore \quad M = \dfrac{4\pi B d^3}{\mu_0}$

$\Rightarrow \quad M = \dfrac{(0.4\times10^{-4})(6.4\times10^{6})^3}{10^{-7}} \Rightarrow \quad M = 1.05 \times 10^{23}\ \text{Am}^2$

78. Here, speed, $V = 5\ \text{ms}^{-1}$ length of conducting rod, $l = 10$ m and magnetic field, $B = 0.3 \times 10^{-4}\ wb/\text{m}^2$

emf induced in the rod $\varepsilon = Blv$

$\therefore\ \varepsilon = 0.3 \times 10^{-4} \times 10 \times 5 = 1.5 \times 10^{-3}\ \text{V} = 1.5\ \text{mV}$

79. The power factor of the circuit is unity at the resonance.

$\therefore X_C = X_L$

$\dfrac{1}{2\pi\nu C} = 2\pi\nu L$

$\therefore L = \dfrac{1}{4\pi^2\nu^2 C} = \dfrac{1}{4\times(3.14)^2\times(50)^2\text{s}^{-1}\times100\times10^{-6}\text{F}}$

$= \dfrac{1}{9.8596} = 0.1014\ \text{H} \quad = 101.42\ \text{mH}$

$V = 200\text{V}$ (given)

$\therefore$ Peak voltage of the source

$V_m = \sqrt{2}V = \sqrt{2}\,(200)$ volt

At resonance, the current amplitude is

$I_m = \dfrac{V_m}{R} = \dfrac{\sqrt{2}\times200}{10} = \sqrt{2}.(20) = 28.28\ \text{A}$

80. Given, $V_{rms} = 220$ V, $L = 20$ mH $= 2 \times 10^{-2}$ H, $R = 110\ \Omega$,

$C = \dfrac{800}{\pi^2}\mu F = \dfrac{800}{\pi^2}\times10^{-6}\,F$

(i) Average power observed by L-C-R series AC circuit is maximum when circuit is in resonance.

$\therefore$ Resonant frequency,

$\omega_0 = \dfrac{1}{\sqrt{LC}} \quad \Rightarrow \quad \nu_0 = \dfrac{1}{2\pi\sqrt{LC}}$

$$V_0 = \frac{1}{2\pi\sqrt{2\times10^{-2}\times\frac{800}{\pi^2}\times10^{-6}}}$$

$$= \frac{1000}{2\times4} = 125\ \text{s}^{-1} \quad v_0 = 125\ \text{s}^{-1}$$

(ii) As, $I_{rms} = \frac{V_{rms}}{Z} = \frac{220}{110} = 2\text{A}$

$Z = R = 110\Omega$

$I_{\text{rms}} = 2\text{A}$

∴ maximum current amplitude,

$I_0 = I_{\text{rms}}\sqrt{2} = 2\sqrt{2}\text{A}$

81. Applied voltage, $V = 140\sin 100\pi t$

$C = \frac{50}{\pi}\mu F = \frac{50}{4}\times10^{-6}\text{F}$, $L = \frac{5}{\pi}H$, $R = 400\Omega$

Comparing with $V = V_0 \sin\omega t$,

$V_0 = 140\text{V}, \omega = 100\pi$

Inductive reactance, $X_L = \omega L$

or, $100\pi\times\frac{5}{\pi} = 500\Omega$

Capacitive reactance, $X_C = \frac{1}{\omega C}$

$$= \frac{1}{100\pi\times\frac{50}{\pi}\times10^{-6}} = 200\Omega$$

Impedance of the circuit,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{(400)^2 + (500-200)^2}$$

$$= \sqrt{1600+900} = 500\Omega$$

Maximum current in the circuit, $I_0 = \frac{V_0}{Z} = \frac{140}{500}$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{140}{500\times\sqrt{2}} = 0.2\text{A}$$

V_{rms} across resister R, $V_R = I_{rms}R$

$= 0.2 \times 400 = 800\text{ V}$

V_{rms} across inductor, $V_L = I_{rms}X_L$

$= 0.2 \times 500 = 100\text{ V}$

V_{rms} across capacitor, $V_C = I_{rms} \times X_C$

$= 0.2 \times 200 = 40\text{ V}$

82. Power $P = \frac{V^2}{Z} \Rightarrow \frac{50.000}{2000} = 25 = Z$

$Z^2 = R^2 + (X_C - X_L)^2 = 625$

$\tan\phi = \frac{X_C - X_L}{R} = -\frac{3}{4}$

$625 = R^2 + \left(-\frac{3}{4}R\right)^2 = \frac{25}{16}$

$R^2 = 400 \Rightarrow R = 20\,\Omega$

$X_C - X_L = -15\Omega$

$I = \frac{V}{Z} = \frac{223}{25} \simeq 9\text{A}.$

$I_M = \sqrt{2} \times 9 = 12.6\text{ A}.$

If R, X_C, X_L are all doubled, $\tan\phi$ does not change.

Z is doubled, current is halfed.

Power drawn is halfed.

83. Input voltage, $V_p = 2.5 \times 10^3\text{ V}$

Input current, $I_p = 20\text{ A}$

Also, $\frac{N_p}{N_s} = \frac{10}{1}$

$\Rightarrow \frac{N_s}{N_p} = \frac{1}{10}$ ...(i)

Percentage efficiency $= \frac{\text{Output power}}{\text{Input power}} \times 100$

$\Rightarrow \frac{90}{100} = \frac{\text{Output power}}{V_p I_p}$

(i) Output power $= \frac{90}{100} \times (V_p I_p)$

$= \frac{90}{100} \times (2.5 \times 10^3) \times (20\text{A}) = 4.5 \times 10^4\text{ W}$

(ii) $\because \dfrac{V_s}{V_p} = \dfrac{N_s}{N_p} \quad \Rightarrow \quad V_s = \dfrac{N_s}{N_p} \times V_p$

Voltage $V_s = \dfrac{1}{10} \times 2.5 \times 10^3 \text{ V} = 250\text{V}$

(iii) $V_s I_s = 4.5 \times 10^4 \text{ W}$

Current $I_s = \dfrac{4.5 \times 10^4}{V_s} = \dfrac{4.5 \times 10^4}{250} = 180 \text{ A}$

84. Given, $V = 140 \sin 314t$, $R = 50\,\Omega$

(i) Comparing it with $V = V_0 \sin \omega t$

$\omega = 314$ rad/s

i.e., $2\pi v = 314$ $[\because \omega = 2\pi v]$

$\Rightarrow \quad v = \dfrac{314}{2\pi}$

$= \dfrac{31400}{2 \times 314} = 50 \text{ Hz}$

Frequency of AC, $v = 50$ Hz

(ii) As, $I_{rms} = \dfrac{V_{rms}}{R}$ and $V_{rms} = \dfrac{V_0}{\sqrt{2}}$

Here, $V_0 = 140$ V

$\Rightarrow \quad V_{rms} = \dfrac{140}{\sqrt{2}} \times \dfrac{\sqrt{2}}{\sqrt{2}} = 70\sqrt{2}\text{V}$

$\therefore \; I_{rms} = \dfrac{70\sqrt{5}}{R} = \dfrac{70\sqrt{5}}{50} = 1.9\text{A}$ or 2A

85. Given : $L = 10$ H, $C = 40\,\mu$F,

$R = 60\,\Omega$, $V_{rms} = 240$ V

(i) Resonating angular frequency,

$\omega_C = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{10 \times 40 \times 10^{-6}}}$

$\dfrac{1}{20 \times 10^{-3}} = 50$

$\omega_C = 50$ rad/s

(ii) Current at resonating frequency,

$I_{rms} = \dfrac{V_{rms}}{Z} = \dfrac{V_{rms}}{R}$ $(\because$ At resonance $Z = R)$

$$= \frac{240}{60} = 4\text{A}$$

$I_{\text{rms}} = 4\text{A}$

(iii) Inductive reactance, $X_L = \omega L$

At resonance,

$X_L = \omega_0 L = 50 \times 10 = 500\Omega$

Potential drop across inductor,

$V_{\text{rms}} = I_{\text{rms}} \times X_L$

$= 4 \times 500$

$V_{\text{rms}} = 2000 \text{ V}$

86. (i) Resistance of Cu wires, R

$$= \rho \frac{l}{A} = \frac{1.7 \times 10^{-8} \times 20000}{\pi \left(\frac{1}{2}\right)^2 \times 10^{-4}} = 4\Omega$$

I at 220 V: $VI = 10^6$ W; $I = \frac{10^6}{220} = 0.45 \times 10^4$ A

RI^2 = Power loss

$= 4 \times (0.45)^2 \times 10^8$ W

$> 10^6$ W

This method cannot be used for transmission

(ii) $V' I' = 10^6 \text{ W} = 11000 I'$

$$I' = \frac{1}{1.1} \times 10^2$$

$$RI'^2 = \frac{1}{1.21} \times 4 \times 10^4 = 3.3 \times 10^4 \text{ W}$$

Fraction of power loss

$$= \frac{3.3 \times 10^4}{10^6} = 3.3\%$$

87. $i_D = C\frac{dV}{dt}$; $\quad 1 \times 10^{-3} = 2 \times 10^{-6} \frac{dV}{dt}$

$$\frac{dV}{dt} = \frac{1}{2} \times 10^3 = 5 \times 10 \text{V/s}$$

88. Here, R = 6.0 cm, C = 100 pF = 100×10^{-12} F, ω = 300 rad . s^{-1},
E_{rms} = 230 V

(a) $$I_{rms} = \frac{E_{rms}}{X_c} = \frac{E_{rms}}{\frac{1}{\omega C}} = E_{rms} \times \omega C$$

∴ $$I_{rms} = 230 \times 300 \times 100 \times 10^{-12}$$

(b) Yes, I = I_D, whether I is a steady d.c. or a.c.
This is shown below

$$I_D = \epsilon_0 \frac{d(\phi_E)}{dt} = \epsilon_0 \frac{d}{dt}(EA) \qquad (\because \ \phi_E = EA)$$

or $$I_D = \epsilon_0 A \frac{dE}{dt} = \epsilon_0 A \frac{d}{dt}\left(\frac{Q}{\epsilon_0 A}\right) \quad \left(\because E = \frac{\sigma}{\epsilon_0} = \frac{Q}{\epsilon_0 A}\right)$$

or $$I_D = \epsilon_0 A \times \frac{1}{\epsilon_0 A}\frac{dQ}{dt} = \frac{dQ}{dt} = I.$$

(c) We know, $$B = \frac{\mu_0}{2\pi}\frac{r}{R^2} I_D$$

The formula is valid even if I_D is oscillating.

As I_D = I, therefore $$B = \frac{\mu_0 r I}{2\pi R^2}$$

If I = I_0, the maximum value of current, then
Amplitude of B = max. value of

$$B = \frac{\mu_0 r I_0}{2\pi R^2} = \frac{\mu_0 r \sqrt{2} I_{rms}}{2\pi R^2} \qquad (\because \ I_0 = \sqrt{2} \ I_{rms})$$

$$= \frac{4\pi \times 10^{-7} \times 0.03 \times \sqrt{2} \times 6.9 \times 10^{-6}}{2 \times 3.14 \times (0.06)^2}$$

$= 1.63 \times 10^{-11}$ T.

89. Given : R = 100 Ω, L = $4/\pi^2$, I = ? C = ?
Current is in phase with the voltage, therefore, the circuit is in series resonance. In series resonance Z = R
Hence, current I = V/Z = V/R = 200/100 = 2A

Also, $f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$

or $C = \frac{1}{4\pi^2 Lf^2} = \frac{\pi^2}{4\pi^2 \times 4 \times (50)^2}$

$= 2.5 \times 10^{-5}\,F = 25\mu F$

90. Given, $V_s = 110V, P = 550\,W, V_p = 220\,V, I_p = ?$

Power, $P = V_P I_P$

$\therefore \quad I_P = \frac{P}{V_P} = \frac{550}{220} = 2.5A$

91. As we know that, induced emf

$e = -M\frac{dI}{dt}$ where M - mutual inductance

$e = -1.5 \times \frac{20-0}{0.5} = -60V$

So, the flux linked with the other coil is given by

$\Delta\phi = e \times \Delta t = -60 \times 0.5 = -30\,Wb$

92. (ii) (a) Number of turns in secondary coil is given by

$\frac{N_S}{N_P} = n \Rightarrow \frac{N_S}{100} = 100 \Rightarrow N_S = 10,000$

(b) Current in primary is given by

$I_P V_P = P \Rightarrow I_P = \frac{1100}{220} = 5A$

(c) Voltage across secondary is given by $\frac{V_S}{V_P} = \frac{N_S}{N_P} = n$

$\Rightarrow V_S = 100 \times 220 = 22,000V$

(d) Current in secondary is given by

$V_S I_S = P \Rightarrow I_S = \frac{P}{V_S} = \frac{1100}{22000} = 0.05A$

(e) Power in secondary is power in primary in an ideal transformer = 1,100 W

93. According to question, angle of prism, $A = 60°$, and $i = \frac{3}{4}A$

In the minimum deviation position

$$i = e = \frac{3}{4}A$$

As, $\delta = i + e - A = \frac{3}{4}A + \frac{3}{4}A - A = \frac{1}{2}A = 30°$

As $\delta_m = (\mu - 1)A$ or, $\frac{\delta_m}{A} = (\mu - 1)$

or $\frac{30°}{60°} = (\mu - 1)$ or $\frac{1}{2} = \mu - 1$

or $\mu = \frac{3}{2}$

As, $\mu = \frac{c\text{ (speed of light in vaccum)}}{v\text{ (speed of light in prism)}}$

$\therefore$ speed of light in prism, $v = \frac{c}{\mu} = \frac{3 \times 10^8}{3/2} = 2 \times 10^8$ m/s.

94. Given: $\mu_{lens} = \mu_{liquid} = 1.5$.

By Lens-maker's formula,

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= \left(\frac{\mu_{lens}}{\mu_{liquid}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$\frac{1}{f} = 0$ ie, Focal length, $f = \infty$ (infinity)

95. Given, $f = -10$ cm, $m = 2$, $u = ?$

For a real image, $m = \frac{v}{u}$ or $v = +2u$.

Also, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\Rightarrow \frac{1}{+2u} + \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \frac{3}{+2u} = \frac{1}{f}$$

$$\therefore \quad u = \frac{3}{2}f = \frac{3}{2} \times -10 = \frac{-30}{2} = -15\text{cm}.$$

96. As, $f_e = \frac{1}{10} = 0.1\text{ m} = 10\text{ cm}$

$$f_o = \frac{1}{1} = 1\text{ m} = 100\text{ cm}$$

Magnifying power in normal adjustment

$$M = -\frac{f_o}{f_e} = -\frac{100}{10}$$

$\therefore \quad M = -10$

97. Length of object $(O) = +3$ cm

u = – 60 cm f = + 30 cm

$\because \frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ [Mirror formula]

or $\frac{1}{30} = \frac{1}{v} + \frac{1}{(-60)}$

or $\frac{1}{v} = \frac{1}{30} + \frac{1}{60} = \frac{2+1}{60}$

$\Rightarrow \quad v = 20$ cm

$$\frac{I}{O} = -\frac{v}{u} \quad \text{or,} \quad \frac{I}{(+3)} = -\frac{(+20)}{(-60)}$$

$I = 1$ cm

So, the virtual, erect and diminished image will be formed on the other side of the mirror.

98. Real and inverted image of an object can be taken on the screen.

Given, v = + 10 cm :

Magnification, m = – 19; f = ?

Magnification, $m = \frac{I}{O} = \frac{v}{u} \quad \Rightarrow \quad -19 = \frac{v}{u}$

$$v = -19u \quad \Rightarrow \quad u = -\frac{v}{19}$$

Using lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{-\left(\frac{v}{19}\right)} = \frac{1}{v} + \frac{19}{v}$$

$$\frac{1}{f} = \frac{20}{v}$$

$\because$ v = 10 cm $\quad \therefore \quad f = \frac{1}{2}$ cm

99. Resultant power of the combination

$$P = P_1 + P_2 = 6 - 2 = 4D$$

$$\therefore \quad \frac{1}{f} = 4 \Rightarrow f = \frac{1}{4} m = 25\text{cm}$$

100. When a lens immersed in a liquid, disappears then,

$$\mu_{liquid} = \mu_{lens} = 1.45$$

101. For a plano-convex lens, $R_1 = \infty$

$R_2 = -R$

f = 0.3 m = 30 cm

μ = 1.5

Using lens maker's formula,

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{30} = (\mu - 1)\left(\frac{1}{\infty} - \frac{1}{-R}\right) \quad \Rightarrow \quad \frac{1}{30} = \frac{(1.5 - 1)}{R}$$

$\therefore \quad R$ = 15 cm

102. Given, $f = \frac{2}{3}R$, $R_1 = +R, R_2 = -R$

$\because$ Using lens maker's formula,

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{\frac{2R}{3}} = (\mu - 1)\left(\frac{1}{R} + \frac{1}{R}\right) \quad \Rightarrow \quad \frac{3}{2R} = (\mu - 1)\left(\frac{2}{R}\right)$$

$$\Rightarrow \quad \mu - 1 = \frac{3}{4} \quad \Rightarrow \quad \mu = 1 + \frac{3}{4}$$

$$\therefore \quad \mu = \frac{7}{4}$$

103. Refractive index, $\mu = \frac{c}{v} = \frac{1}{\sin i_c}$

$\Rightarrow \quad v = c\sin i_c = 3\times10^8 \times \sin 30°$

$= 3\times10^8 \times \frac{1}{2} = 1.5 \times 10^8$ m/s

104. Given, $R_1 = +10$ cm, $R_2 = -15$ cm, $f = +12$ cm, $\mu = ?$

From lens maker's formula,

$$\frac{1}{f} = (\mu-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{12} = (\mu-1)\left(\frac{1}{10} + \frac{1}{15}\right) = (\mu-1)\left(\frac{5}{30}\right)$$

or, $\mu - 1 = \frac{1}{2} \quad \therefore \quad \mu = \frac{3}{2}$

105. Given : $f_a = 20$ cm; ${}^a\mu_g = 1.5$, ${}^a\mu_w = 1.33$

Using lens maker's formula,

$$\frac{1}{f} = (\mu-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \therefore \quad \frac{f_w}{f_a} = \frac{({}_a\mu_g - 1)}{({}_w\mu_g - 1)}$$

or, $\frac{f_w}{20} = \frac{1.5-1}{\left(\frac{1.5}{1.33} - 1\right)}$

$\therefore \quad f_w = \frac{0.5\times1.33}{0.17} = 78.2$ cm

106. Given, $f_1 = +20$ cm

${}_a\mu_g = 1.6, \quad {}_a\mu_w = 1.3$

$\Rightarrow \quad {}_w\mu_g = \frac{{}_a\mu_g}{{}_a\mu_w} = \frac{1.6}{1.3}$

Using lens maker's formula (in water) for converging lens.

$$\frac{1}{f_2} = ({}_w\mu_g - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \qquad ...(i)$$

In air, $\frac{1}{f_1} = ({}_a\mu_g - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \qquad ...(ii)$

Dividing eq. (ii) by eq. (i), we get

$$\frac{f_2}{f_1} = \frac{\left({}_a\mu_g - 1\right)}{\left({}_w\mu_g - 1\right)} = \frac{(1.6-1)}{\left(\frac{1.6}{1.3}-1\right)} = \frac{0.6\times1.3}{0.3}$$

$$\Rightarrow \quad \frac{f_2}{f_1} = 2.6$$

Therefore, new focal length,

$$f_2 = 2.6\times f_1 = 2.6\times 20 = 52 \text{ cm}$$

107. Here,

$f_o = 4$ cm , $f_e = 10$ cm

$u_o = -6$ cm , $v_e = -D = -25$ cm

For objective lens,

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$$

$$\frac{1}{4} = \frac{1}{v_o} + \left(\frac{1}{6}\right) \Rightarrow \frac{1}{v_o} = \frac{1}{4} - \frac{1}{6} = \frac{1}{12}$$

$$v_0 = 12 \text{ cm}$$

$\therefore$ Magnifying power of compound microscope,

$$M = -\left(\frac{v_o}{u_o}\right)\left(1+\frac{D}{f_e}\right)$$

$$= -\left(\frac{12}{6}\right)\left(1+\frac{25}{10}\right) = -2\left(\frac{7}{2}\right) = -7$$

Length of microscope $L = |v_o| + |u_e|$

where, $v_o = 12$ cm

For eye lens,

$v_e = -25$ cm, $f_e = 10$ cm

$$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e}$$

$$\Rightarrow \quad \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{10}$$

or, $\frac{1}{u_e} = \frac{-2-5}{50} = \frac{7}{50}$

$\therefore \quad u_e = -\frac{50}{7} cm = -7.14 \text{ cm}$

$\therefore$ Length of microscope

$L = |v_0| + |u_e| = 12 + 7.14$

$= 19.14 \text{ cm}$

108. For astronomical telescope,

$f_o = 15\text{m} = 1500 \text{ cm}$

$f_e = 1 \text{ cm}$

Angular magnification $(m) = -\frac{f_o}{f_e} = -\frac{15 \times 100 \text{ cm}}{1 \text{ cm}} = -1500$

The angle subtended by moon at objective

$$\alpha = \frac{D}{\text{Radius of lunar orbit}}$$

$$\alpha = \frac{3.42 \times 10^6 \text{ m}}{3.8 \times 10^8 \text{ m}} \quad \text{...(i)}$$

Also, then angle subtended by image formed by objective on itself

$$\alpha = \frac{d}{f_o} \quad \text{...(ii)}$$

where, d = diameter of image

From Eqs. (i) and (ii), we get

$$\frac{3.42 \times 10^6}{3.8 \times 10^8} = \frac{d}{1500} \quad [\because f_o = 15 \text{ m} = 1500 \text{ cm}]$$

$$d = \frac{1500 \times 3.42 \times 10^6}{3.8 \times 10^8} = 13.5 \text{ cm}$$

The diameter of the image formed is 13.5 cm

109. Given, $f_o = 20$ cm, $f_e = 1$ cm, $v_e = -25$ cm

For objective

$u_o = -100$ cm, $f_o = 20$ cm

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$$

$$\frac{1}{20} = \frac{1}{v_o} - \frac{1}{(-100)}$$

$$\Rightarrow \frac{1}{v_0} = \frac{1}{20} - \frac{1}{100} = \frac{5-1}{100} = \frac{4}{100} \qquad v_0 = 25 \text{ cm}$$

For eye lens

$f_e = 1$ cm, $v_e = -25$, $u_e = ?$

$$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e} \Rightarrow \frac{1}{1} = \frac{1}{-25} - \frac{1}{u_e}$$

or, $$1 + \frac{1}{25} = -\frac{1}{u_e} \Rightarrow \frac{26}{25} = -\frac{1}{u_e}$$

$$u_e = -\frac{25}{26} = 0.96 \text{ cm}$$

Magnification (m)

$$m = -\frac{v_o}{u_0}\left(1 + \frac{D}{f_e}\right) = -\left(\frac{25}{100}\right)\left(1 + \frac{25}{1}\right)$$

$$m = -\frac{1}{4} \times 26 = -6.5$$

Length of telescope $L = (v_0) + (u_e)$

$$L = 25 + 0.96 = 25.96 \text{ cm}$$

110. The diameter of objective of the telescope

$= 150 \times 10^{-3}$ m

$f_o = 4$ m

$f_e = 25 \times 10^{-3}$ m and $D = 0.25$ m

Magnifying power,

$$M = -\frac{f_0}{f_e}\left(1 + \frac{D}{f_e}\right) = -\frac{4}{25 \times 10^{-3}}\left(1 + \frac{0.25}{25 \times 10^{-3}}\right)$$

$$M = -\frac{4000}{25}(1 + 10) = -\frac{4000 \times 11}{25}$$

$$M = -176$$

Resolving power $= \dfrac{1}{d\theta}$

$$d\theta = \frac{1.22\lambda}{D} = \frac{1.22 \times 6 \times 10^{-7}}{0.25} = 2.9 \times 10^{-6} \text{ rad}$$

$\therefore$ Resolving power $= \dfrac{1}{2.9 \times 10^{-6}} = 0.34 \times 10^{6}$

111. For lens of focal length 10 cm.

$$f = +10 \text{ cm},$$
$$u = -30 \text{ cm}$$

Using lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{10} = \frac{1}{v} - \frac{1}{(-30)}$$

$\Rightarrow$ $v = 15$ cm

The image formed by first lens acts as a virtual object for plano-concave lens.

For plano-concave lens,

$u = +10$ cm, $f = -10$ cm, $v = ?$

Using lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad -\frac{1}{10} = \frac{1}{v} - \frac{1}{10}$$

$$\Rightarrow \quad \frac{1}{v} = 0 \quad \therefore \quad v = \infty$$

The refractive ray becomes parallel to principal axis for convex lens of focal length 30 cm.

$u = -\infty$, $v = ?$, $f = 30$ cm

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\Rightarrow \quad \frac{1}{30} = \frac{1}{v} - \frac{1}{(-\infty)}$$

$\Rightarrow$ $v = 30$ cm

So, final image is formed at a distance of 30 cm from second convex lens on the other side of it.

112. For lens L_1,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$u = -15$ cm, $v = ?$, $f = +10$ cm

$$\frac{1}{10} = \frac{1}{v} + \frac{1}{15}$$

Distance of image from lens L_1,

v = 30 cm

For lens L_3, $\frac{1}{f''} = \frac{1}{v''} - \frac{1}{u''}$

Distance of image from lens L_3,

$$v'' = 10 \text{ cm}$$

$$\frac{1}{10} = \frac{1}{10} + \frac{1}{u''} \quad \Rightarrow \quad u'' = \infty$$

The refracted rays from lens L_1 becomes parallel to principal axis. It is possible only when image formed by L_1 lies at first focus of L_2 i.e., at a distance of 10 cm from L_2.

$\therefore$ Separation between L_1 and L_2

$$= 30 + 10 = 40 \text{ cm}$$

The distance between L_2 and L_3 may take any value.

113. From Snell's law

$$n = \frac{\sin i}{\sin r} = \frac{c}{v}$$

$\Rightarrow$ V $\propto$ sin r for given value of i

$\Rightarrow$ Smaller angle of refraction, smaller the velocity of light in medium.

Velocity of light is minimum in medium, A as angle of refraction is minimum i.e., 15°.

114. Here,

$f_o = 1.25$ cm, $f_e = 5$ cm

When final image forms at infinity then magnification produced by eye lens is given by

$$m = -\frac{L}{f_0} \cdot \frac{D}{f_e} \quad \text{or,} \quad -30 = -\frac{L}{1.25} \times \frac{25}{5}$$

$$\therefore \quad L = \frac{30 \times 1.25}{5} = 7.50 \text{ cm}$$

For objective lens

$$v_o = L = 7.5 \text{ cm}$$

$$f_o = 1.25 \text{ cm}$$

$$u_0 = ?$$

Applying lens formula

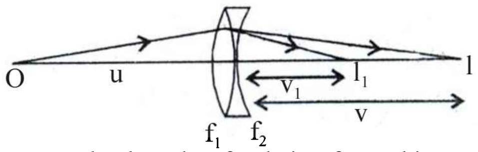
$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o} \quad \Rightarrow \quad \frac{1}{1.25} = \frac{1}{7.5} - \frac{1}{u_0}$$

$$\Rightarrow \quad \frac{1}{u_0} = \frac{1}{7.5} - \frac{1}{1.25} = \frac{1.25 - 7.5}{7.5 \times 1.25}$$

$$\therefore \quad u_o = -\frac{7.5 \times 1.25}{6.25} = -1.5 \text{ cm}$$

The object must be at a distance of 1.5 cm from objective lens.

115. Let us consider an object O lying at a distance u from a combination of two lenses of focal length f_1 and f_2. The image of O is formed at I due to two lenses at a distance v from the combination.



The image may be thought of as being formed in two stages. The convex lens forms the image of O at I_1 at a distance v_1 from the lens. The image I_1, then serves as a virtual object for the concave lens and its image is formed at I.

For refraction at the first lens, which is a convex lens,

$$\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u} \qquad \text{...(i)}$$

For refraction at the second lens which is a concave lens

$$-\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v_1} \qquad \text{...(ii)}$$

$(u = v_1, v = v)$

Adding eqs. (i) and (ii)

$$\frac{1}{f_1} - \frac{1}{f_2} = \frac{1}{v} - \frac{1}{u} \qquad \text{...(iii)}$$

If F is the focal length of the combination, then

$$\frac{1}{F} = \frac{1}{v} - \frac{1}{u} \qquad \text{... (iv)}$$

From eqs. (iii) and (iv)

$$\frac{1}{F} = \frac{1}{f_1} - \frac{1}{f_2}$$

or $\quad F = \dfrac{f_1 f_2}{f_2 - f_1}$

116. (a) Given : $f_0 = 140$ cm, $f_e = 5.0$ cm

(i) Magnifying power $M = f_0 / f_e$ in normal adjustment

$= 140 / 5 = 28$

(ii) $M = \frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$ when image is formed at least distance of distinct vision.

$$= \frac{140}{5}\left(1+\frac{5}{25}\right) = 28 \times 1.2 = 33.6$$

(b) Separation between the objective and the eye piece
$L = f_0 + f_e = 140 + 5 = 145$ cm

117. As $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ f= 15 cm

$$\frac{1}{15} = (\mu - 1)\left(\frac{1}{R} + \frac{1}{R}\right) \quad R_1 = R$$

$$R_2 = -R$$

$$\frac{1}{15} = (\mu - 1)\frac{2}{R} \Rightarrow \frac{\mu - 1}{R} = \frac{1}{30}$$

When the lens is cut into two equal halves
$R_1 = R, R_2 = \infty$

$$\therefore \quad \frac{1}{f'} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right) \Rightarrow = (\mu - 1)\times\frac{1}{R} \Rightarrow \frac{1}{f'} = \frac{1}{30}$$

$\therefore$ f' = 30 cm.

118. (i) Given : $i = e = 3A/4$, $A = 60°$

From formula,

$$i + e = A + \delta$$

or, $3A/4 + 3A/4 = A + \delta$

$$\Rightarrow \frac{A}{2} = \delta \text{ or } \frac{60°}{2} = \delta$$

$\Rightarrow \delta = 30°$

(ii) Since i = e, the prism is in the minimum deviation position, therefore, the refractive index of the prism

$$\mu = \frac{\sin(A + \delta_m)/2}{\text{Sin}A/2} = \frac{\sin(60° + 30°)/2}{\sin(60°/2)}$$

$= 0.707/0.5 = 1.414$

119. Given : Focal length of convex lens

$f_1 = 25$ cm

Focal length of concave lens

$f_2 = -20$ cm

Let P_1 and P_2 be the powers of the two lenses, then

$$P_1 = \frac{100}{25} = 4D \text{ and } P_2 = \frac{-100}{20} = -5D \quad \left(\because P = \frac{1}{f(\text{in metre})}\right)$$

$\therefore$ Power of the combination

$$P = P_1 + P_2 = 4D - 5D = -1D$$

–ve sign shows that the combination is diverging in nature.

120. **Given :** Focal length of convex lens, $f_1 = 30$ cm
focal length of concave lens, $f_2 = -40$ cm
As we know power of the lens

$$P = \frac{1}{f(\text{in metre})}$$

Power of the convex lens

$$P_1 = \frac{100}{f_1} = \frac{100}{30} = \frac{10}{3} = 3.33\,D$$

Power of the concave lens

$$P_2 = \frac{-100}{40} = -2.5D$$

$\therefore$ Power of the combination

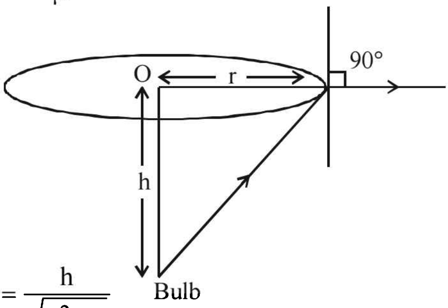
$$P = P_1 + P_2 = 3.33\,D - 2.5\,D = 0.83\,D$$

Since the power of combination is +ve, hence system, is converging in nature.

121. Given : $h = 60$ cm, $\mu = 4/3 = 1.33$, $A = \pi r^2 = ?$,

$$\frac{\sin\theta_c}{\sin 90°} = \frac{1}{\mu} \quad \therefore \sin\theta_c = \frac{1}{\mu}$$

or $$\frac{h}{\sqrt{r^2 + h^2}} = \frac{1}{\mu}$$



$$\Rightarrow \frac{r^2 + h^2}{r^2} = \frac{n^2}{1}$$

$$\Rightarrow 1 + \frac{h^2}{r^2} = \mu^2 - 1$$

$$\Rightarrow r^2 = \frac{h^2}{\mu^2 - 1} \quad \text{or, } r = \frac{h}{\sqrt{\mu^2 - 1}}$$

$$\therefore \quad r = \frac{60}{\sqrt{(1.33)^2 - 1}} = 70.3\text{cm}$$

Therefore, area of the surface of water through which light comes out

$$A = \pi r^2 = 3.14 \times (70.3)^2 = 1.55\,m^2$$

122. The biconvex lens will behave as a converging lens, in water because refractive index of water (1.33) is more than the refractive index of the material of the lens (1.25).

On the other hand it acts as a diverging lens in air because the refractive index of air is less than that of the material of the lens.

123. Critical angle of ray 1:

$\sin(c_1) = 1/\mu_1 = 1/1.35$

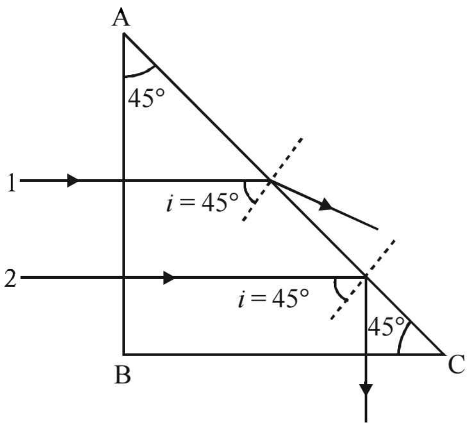
$\Rightarrow c_1 = \sin{-1}(1/1.35) = 47.73°$

Similarly, critical angle of ray 2:

$\sin(c_2) = 1/\mu_2 = 1/1.45$

$\Rightarrow c_2 = \sin{-1}(1/1.45) = 43.6°$

Both the rays will fall on the side AC with angle of incidence (i) equal to 45°.



Critical angle of ray 1 is greater than that of i. Hence, it will emerge from the prism, as shown in the figure. Critical angle of ray 2 is less than that of i. Hence, it will be internally reflected.

124. $\mu = \dfrac{1}{\sin c}$

$\therefore \quad \sin c = \dfrac{1}{\mu} = \dfrac{1}{\sqrt{3}} = \sin 60°$

$\therefore c = 60°$.

125. For the position of image of a point object S formed by the convex lens,

$u = -60$ cm

and $f = 20$ cm

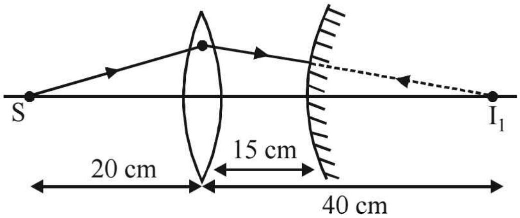
From the lens formula, we have

$1/v - 1/u = 1/f \Rightarrow 1/v = 1/f + 1/u$

$\Rightarrow 1/v = 1/20 + 1/(-60)$

$\Rightarrow 1/v = (3 - 1)/60 = 2/60 \Rightarrow v = 30$ cm

The positive sign shows that the image is formed to the right of the lens.



The image I_1 is formed behind the mirror and acts as a virtual source for the mirror. The convex mirror forms the image I_2, whose distance from the mirror can be calculated as,

$1/v + 1/u = 1/f$

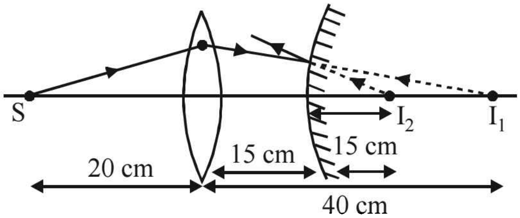
Here: $u = 15$ cm

and, $f = R/2 = 10$ cm $\Rightarrow 1/v = 1/f - 1/u$

$\Rightarrow 1/v = 1/10 - 1/15 \Rightarrow 1/v = (3 - 2)/30 = 1/30$

$\Rightarrow v = 30$ cm

Hence, the final virtual image is formed at a distance of 30 cm from the convex mirror, as shown in the figure.



126. The convex lens is in contact with a plane mirror. The image distance is equal to the object distance. Thus, it is clear that the point object is placed at the centre of the curvature of the lens.

From relation $f = \dfrac{R}{2}$

We use the relation, where, R is the distance between the centre of the curvature

and the pole and f = focal length.

Here, R = 20 cm

$\therefore$ Focal length of the lens = 20/2 = 10 cm

127. For the least distance of clear vision, the total magnification is given by:

$$m = \frac{-D}{f_0}\left(1+\frac{d}{f_e}\right) = m_o m_e \qquad ...(i)$$

where, D is the separation between the eyepiece and the objective
f_o is the focal length of the objective
f_e is the focal length of the eyepiece
D is the least distance for clear vision
Also, the given magnification for the eyepiece:

$$m_e = 5 = 1+\frac{d}{f_e} \Rightarrow 5 = 1+\frac{20}{f_e}$$

$$\Rightarrow f_e = 5 \text{ cm}$$

Substituting the value of m and me in equation (1), we get;

$$m_o = \frac{20}{5} = 4$$

Now, we have; $m = \frac{D}{|f_0|} \Rightarrow f_0 = \frac{14}{4} = 3.5$ cm

128. As, $\theta = 45° \therefore \cos\theta = \cos 45° = \frac{1}{\sqrt{2}}$

$$\because \quad I = I_0 \cos^2\theta$$

$$\therefore \quad I = I_0\left(\frac{1}{\sqrt{2}}\right)^2$$

$$\frac{I}{I_0} = \frac{1}{2} \quad \Rightarrow I : I_0 = 1 : 2$$

129. Distance between the two sources

$d = 0.15$ mm $= 1.5 \times 10^{-4}$ m

Wavelength, $\lambda = 450$ nm $= 4.5 \times 10^{-7}$ m

Distance of screen from source, $D = 1$m

(a) The distance of *nth* order bright fringe from central fringe is given by

$$y_n = \frac{Dn\lambda}{d}$$

For second bright fringe,

$$y_2 = \frac{2D\lambda}{d} = \frac{2\times 1\times 4.5\times 10^{-7}}{1.5\times 10^{-4}}$$

$$= 6 \times 10^{-7+4}$$

$$y_2 = 6 \times 10^{-3} \text{ m}$$

The distance of the second bright fringe

$$y_2 = 6 \text{ mm}$$

(b) The distance of *n*th order dark fringe from central fringe is given by

$$y'_n = (2n-1)\frac{D\lambda}{2d}$$

For second dark fringe $n=2$

$$y'_n = (2\times2-1)\frac{D\lambda}{2d} = \frac{3D\lambda}{2d}$$

$$y'_n = \frac{3}{2}\times\frac{1\times4.5\times10^{-7}}{1.5\times10^{-4}}$$

The distance of the second dark fringe,

$$y'_n = 4.5 \text{ mm}$$

130. Given, $D = 1\text{m}$, $d = 4\times10^{-3}$ m, $\lambda_1 = 560$ nm, and $\lambda_2 = 420$ nm

Let *n*th order bright fringe of λ_1 coincides with $(n+1)$th order bright fringe of λ_2

$$\Rightarrow \quad \frac{Dn\lambda_1}{d} = \frac{D(n+1)\lambda_2}{d} \quad (\lambda_1 > \lambda_2)$$

$$\Rightarrow \quad n\lambda_1 = (n+1)\lambda_2$$

$$\Rightarrow \quad \frac{n+1}{n} = \frac{\lambda_1}{\lambda_2}$$

$$1+\frac{1}{n} = \frac{560\times10^{-9}}{420\times10^{-9}} \quad \Rightarrow \quad 1+\frac{1}{n} = \frac{4}{3}$$

$$\Rightarrow \quad \frac{1}{n} = \frac{1}{3} \Rightarrow n = 3$$

$\therefore$ Least distance from the central fringe where bright fringes of two wavelength coincides

= distance of 3rd order bright fringe of λ_1

$$\Rightarrow \quad y_n = \frac{3D\lambda_1}{d}$$

$$= \frac{3\times1\times560\times10^{-9}}{4\times10^{-3}}$$

$$y_n = 420\times10^{-6}\, m$$
$$= 0.42\times10^{-3}\, m$$

$$\therefore \quad y_n = 0.42 \ mm$$

Thus, 3rd bright fringe of λ_1 and 4th bright fringe of λ_2 coincide at 0.42 mm from central fringe.

131. Given, $\lambda = 6000\,\text{Å} = 6 \times 10^{-7}$ m
and $d = 1 \times 10^{-4}$ m
Separation between slit and screen, $D = 1.5$ m, the separation between two dark lines on either side of the central maxima

$$= \text{fringe width of central maxima} = \frac{2D\lambda}{d}$$

$$= \frac{2 \times 1.5 \times 6 \times 10^{-7}}{1 \times 10^{-4}}$$

$$= 18 \times 10^{-3}\,\text{m} = 18\,\text{mm}$$

132. The intensity of transmitted light from P

$$I = \frac{I_0}{2} \quad \left(\because \text{Average of } \cos^2\theta = \frac{1}{2}\right)$$

The intensity of transmitted light from P_2,

$$= \frac{I_0}{2}\left(\cos^2 30°\right) = \frac{I_0}{2} \times \left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3I_0}{8}$$

$\therefore$ The intensity of transmitted light from P_3, (third polaroid)

$$= \frac{3I_0}{8}\left[\cos(90° - 30°)\right]^2$$

$$= \frac{3I_0}{8}(\cos 60°)^2 = \frac{3I_0}{8} \times \left(\frac{1}{2}\right)^2$$

$$= \frac{3I_0}{8} \times \frac{1}{4} = \frac{3I_0}{32}$$

133. Using formula, intensity of emergent light from P_2, $I = I_0 \cos 2\theta$, where θ is the angle between P_1 and P_2.
when $\theta = 90° \Rightarrow I = I_0 \times 0 \; (\therefore \cos\theta = 0)$
Intensity of emergent light,

$$I = 0$$

134. Given, $OP = y_n$
The distance OP equals one-third of fringe width of the pattern,

$$\text{i.e., } y_n = \frac{\beta}{3} = \frac{1}{3}\left(\frac{D\lambda}{d}\right) = \frac{D\lambda}{3d}$$

$$\Rightarrow \frac{dy_n}{D} = \frac{\lambda}{3}$$

Path difference, $S_2P - S_1P = \dfrac{dy_n}{D} = \dfrac{\lambda}{3}$

Now for phase difference corresponding to path difference.

Phase difference $= \frac{2\pi}{\lambda} \times$ Path difference $= \frac{2\pi}{\lambda} \times \frac{\lambda}{3}$

$\therefore$ Phase difference $= \frac{2\pi}{3}$

If intensity at central fringe is I_0, then intensity at a point, P where phase difference is ϕ, is given by

$$I = I_0 \cos^2 \phi$$

$$\Rightarrow \quad I = I_0 \left(\cos \frac{2\pi}{3}\right)^2 = I_0 \left(-\cos \frac{\pi}{3}\right)^2$$

$$= I_0 \left(-\frac{1}{2}\right)^2 = \frac{I_0}{4}$$

Hence, the intensity at point P would be $\frac{I_0}{4}$

135. Let, θ be the angle between the pass axis A and C.

Intensity of light passing through $A = \frac{I_0}{2}$

Intensity of light passing through C $= \frac{I_0}{2} \cos^2 \theta$

Intensity of light passing through B

$$= \left(\frac{I_0}{2} \cos^2 \theta\right) . \cos^2 (90° - \theta) = \frac{I_0}{2} (\sin \theta \cos \theta)^2$$

But, $\frac{I_0}{2} (\sin \theta \cos \theta)^2 = \frac{I_0}{8}$

As, $(\sin \theta \cos \theta)^2 = \frac{1}{4}$

$$\therefore \quad \left(\frac{\sin 2\theta}{2}\right)^2 = \frac{1}{4} \text{ or } \frac{\sin 2\theta}{4} = \frac{1}{4}$$

or $\sin 2\theta = 1 \Rightarrow 2\theta = 90°$

$\therefore \quad \theta = 45°$

136. $\mu = 1.5$,

$\nu = 6 \times 10^{14}$ Hz

speed of light in glass,

$$v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.5} = 2.0 \times 10^8 \text{ ms}^{-1}$$

∴ Wavelength in glass

$$\lambda = \frac{v}{\nu} = \frac{2\times10^8}{6\times10^{14}} = 3.3\times10^{-7}\,m$$

137. Given : $\lambda = 450\,nm = 450\times10^{-9}\,m$
$D = 1.5\,m$
$y = 3\,mm = 3\times10^{-3}\,m, d = ?$

We know that the first minima lies at a distance y given by the relation

$$d\frac{y}{D} = \lambda \quad \text{or,} \quad d = \frac{D\lambda}{y}$$

$$= \frac{1.5\times450\times10^{-9}}{3\times10^{-3}} = 2.25\times10^{-4}\,m$$

138. Given : $a = 1\times10^{-4}\,m, D = 1.8\,m, \lambda_1 = 590\,nm = 590\times10^{-9}\,m,$
$\lambda_2 = 596\,nm = 596\times10^{-9}\,m$

To obtain first maxima, phase difference,

$$a\sin\theta = (2n+1)\frac{\lambda}{2}$$

for $n = 1$

$$a\sin\theta = 3\frac{\lambda}{2} \quad \text{or} \quad a\,.\frac{y}{D} = 3\frac{\lambda}{2}$$

$$\Rightarrow \quad y = \frac{3}{2}\lambda\frac{D}{a}$$

Separation between the positions of the first maxima

$$= y_2 - y_1 = \frac{3}{2}\frac{D}{a}\lambda_2 - \frac{3}{2}\frac{D}{a}\lambda_1 = \frac{3}{2}\frac{D}{a}(\lambda_2 - \lambda_1)$$

$$= \frac{3}{2}\times\frac{1.8}{1\times10^{-4}}\times(596-590)\times10^{-9}$$

$$= 16.2\times10^{-5}\,m$$

139. The linear distance between two dots is $l = \frac{2.54}{300}$ cm

$\simeq 0.84\times10^{-2}$ cm. At a distance of Z cm this subtends an angle.

$$\phi \sim l/z \therefore z = \frac{l}{\phi} = \frac{0.84\times10^{-2}\,cm}{5.8\times10^{-4}} \sim 14.5\,cm$$

140. $\because$ de-Broglie wavelength,

$$\lambda = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2mqV}} \quad (\because K = qV)$$

Here potential is kept constant.

$$\Rightarrow \quad \frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p q_p}{m_\alpha q_\alpha}}$$

$$= \sqrt{\left(\frac{m_p}{m_\alpha}\right)\left(\frac{q_p}{q_\alpha}\right)} = \sqrt{\left(\frac{1}{4}\right)\left(\frac{1}{2}\right)}$$

$$\frac{\lambda_\alpha}{\lambda_p} = \frac{1}{2\sqrt{2}} \quad \Rightarrow \quad \lambda_\alpha : \lambda_p = 1 : 2\sqrt{2}$$

141. de-Broglie wavelength of accelerated charge particle,

$$\lambda = \frac{h}{\sqrt{2mqV}} \Rightarrow \lambda \propto \frac{1}{\sqrt{mqV}}$$

Ratio of wavelengths of proton and α-particle

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\left(\frac{m_\alpha}{m_p}\right)\left(\frac{q_\alpha}{q_p}\right)\left(\frac{V_\alpha}{V_p}\right)}$$

Here, $\frac{m_\alpha}{m_p} = 4$, $\frac{q_\alpha}{q_p} = 2$,

$$\frac{V_\alpha}{V_p} = \frac{X}{512}, \frac{\lambda_p}{\lambda_\alpha} = 1$$

$$1 = \sqrt{4 \times 2 \times \left(\frac{X}{512}\right)} \quad \Rightarrow \quad 1 = \frac{X}{64}$$

$\therefore$ x = 64 V

142. de-Broglie wavelength is given by

$$\lambda = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2mqV}} \quad (\because K = qV)$$

$$\Rightarrow \quad \lambda \propto \frac{1}{\sqrt{mqV}}$$

∴ Ratio of de-Broglie wavelengths of proton and α-particle

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha V_a}{m_p q_p V_p}} = \sqrt{\left(\frac{m_\alpha}{m_p}\right)\left(\frac{q_\alpha}{q_p}\right)\left(\frac{V_\alpha}{V_p}\right)}$$

Here, $\frac{m_\alpha}{m_p} = 4, \frac{q_\alpha}{q_p} = 2, \frac{V_\alpha}{V_p} = \frac{64}{128} = \frac{1}{2}$

$$\therefore \quad \frac{\lambda_p}{\lambda_\alpha} = \sqrt{4 \times 2 \times \frac{1}{2}} = 2$$

or, $\lambda_p : \lambda_\alpha = 2:1$

143. Energy of incident radiation

$$= E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{400 \times 10^{-9}}$$

$$= \frac{6.6 \times 10^{-26} \times 3}{4 \times 10^{-7} \times 1.6 \times 10^{-19}} eV = 3.1 \text{ eV}$$

For A, $h\nu > \phi_0$ hence it shows photoelectric effect.

For B, $h\nu < \phi_0$ hence it does not show photoelectric effect.

144. $p = \frac{h}{\lambda} = \frac{h}{0.01 \times 10^{-10}} = 10^{12} \times 6.6 \times 10^{-34}$

$= 6.6 \times 10^{-22}$ kg/s

145. Given

$v_{\text{particle}} = 3v_{\text{electron}}$

and $\lambda_{\text{particle}} = 1.813 \times 10^{-4} \lambda_{\text{electron}}$

(i) As $\lambda = \frac{h}{mv}$ (de-Broglie equation)

$$\Rightarrow \quad \frac{m_{\text{particle}}}{m_{\text{electron}}} = \frac{\lambda_{\text{electron}} \times v_{\text{electron}}}{\lambda_{\text{particle}} \times v_{\text{particle}}}$$

$\therefore \quad m_{\text{particle}} = 1839\ m_{\text{electron}}$

$m_{\text{particle}} = 1839 \times 9.1 \times 10^{-31}$

$= 1.673 \times 10^{-2}$ kg

Particle is either a proton or a neutron.

146. (i) For electron or photon, momentum

$$p=\frac{h}{\lambda}=\frac{6.63\times10^{-34}}{10^{-9}}=6.63\times10^{-25}\,\text{m}$$

(ii) Energy of photon, $E=\frac{hc}{\lambda}=\frac{\left(6.63\times10^{-34}\right)\times\left(3\times10^{8}\right)}{10^{-9}\times\left(1.6\times10^{-19}\right)}$

$$=1243\text{ eV}$$

(iii) Kinetic energy of electron, $E=\frac{p^2}{2m}$

$$=2.9\times10^{-31}\times\left(1.6\times10^{-19}\right)$$

$$=1.52\text{ eV}$$

147. The de-Broglie wavelength of the electrons is given by:

$$\lambda=\frac{h}{\sqrt{2meV}}$$

Here:

$m=$ mass of the electron $=9.1\times10^{-31}$ kg
$e=$ charge on the electron $=1.6\times10^{-19}$ C
$V=$ accelerating potential $=50$ kV
$h=$ Planck's constant $=6.626\times10^{-34}$ Js

$$\Rightarrow\lambda=\frac{6.626\times10^{-34}}{\sqrt{2\,(9.1\times10^{-31})\,(1.6\times10^{-19})\,(50\times10^{3})}}$$

$$\Rightarrow\lambda=0.0549\text{ Å}$$

Resolving power of a microscope, R=$2\mu\sin\theta/\lambda$

For an electron microscope, the electrons are accelerated through a 60,000 V potential difference. Thus the wavelength of electrons is found to be,

$$\lambda=\frac{12.27}{\sqrt{V}}=\frac{12.27}{\sqrt{60000}}=0.05\text{ Å}$$

As, λ is very small (approximately 10^{-5} times smaller) for electron microscope than an optical microscope which uses yellow light of wavelength (5700 Å to 5900 Å). Hence, the resolving power of an electron microscope is much greater than that of optical microscope.

148. Energy of a photon is given by
$E = h\nu$

Number of photons emitted per second, $n = \frac{P}{E}$

where, P = Power emitted
On putting the values, we get,
$n = 3 \times 10^{-3} / 6.63 \times 10^{-34} \times 5 \times 10^{14}$
$= 9.05 \times 10^{15}$

149. Energy of a photon is given by, ν
$E = h\nu$
Number of photons emitted per second,

$n = \frac{P}{E}$ where, P = power emitted

On putting the values, we get,

$$n = \frac{2.0 \times 10^{-3}}{6.63 \times 10^{-34} \times 6.0 \times 10^{14}} = 5.03 \times 10^{15}$$

150. According to the de Broglie hypothesis, the momentum (p) of an electron is given by

$$p = \frac{h}{\lambda} \qquad \text{... (i)}$$

Energy of photon, $E = \frac{hc}{\lambda} = 6 \times 10^{-17} J$ (Given)

$$\Rightarrow \quad \lambda = \frac{(6.625 \times 10^{-34})(3 \times 10^{8})}{(6 \times 10^{-17})}$$

$\Rightarrow \lambda = 3.31 \times 10^{-9}$ m
From eq^n (i), we have

$$p = \frac{6.626 \times 10^{-34}}{3.31 \times 10^{-9}} = 2 \times 10^{-25} \text{ kg m s}^{-1}$$

151. The angle of deviation δ for a ray of light in a prism is given by
$\delta = i + e - A$
where i = Angle of incidence of ray
e = Angle of emergence and
A = Angle of prism
$\Rightarrow \delta = 2i - A \quad (\because e = i)$

Given : $i = e = \frac{3}{4}A$

$$\therefore \delta = 2 \times \frac{3}{4}A - A = \frac{1}{2}\text{ A}$$

As the prism is equilateral, $\angle A = 60°$

$$\therefore \delta = \frac{1}{2} \times 60° = 30°$$

152. When a concave lens made up of certain material is placed in a medium of refractive index less than the refractive index of the material of lens it behaves as a diverging lens and when it is placed in a medium of refractive index greater than the refractive index of the material of lens it behaves as a converging lens. So, if a concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65 it will behave as a converging lens.

153. (a) Angular width, $\Delta\theta = \frac{\beta}{D} = \frac{(\lambda D/d)}{D} = \frac{\lambda}{d}$

$$\therefore\ d = \frac{\lambda}{\Delta\theta} = \frac{6000 \times 10^{-10}(m)}{1° \times \pi/180(rad)}$$

$$= 3.44 \times 10^{-5}\text{m} = 0.0344 \text{ mm}$$

(b) The frequency and wavelength of reflected wave will not change.

The refracted wave will have same frequency.

The velocity of light in water is given by,

$$v = \lambda f$$

where, v = velocity of light

λ = wavelength of light

f = frequency of light

If velocity will decrease, wavelength (λ) will also decrease.

154. Given, focal length of objective lens, f_0 = 15 m

Focal length of eyepiece, f_e = 1 cm = 0.01 m

(i) Angular magnification by the telescope

$$m = -\frac{f_0}{f_e} = -\frac{15}{0.01} = -1500$$

Let d_i be the diameter of the image of the moon formed by the objective lens.

$\therefore$ Angle subtended by the image $= \frac{d_i}{f_0} = \frac{d}{15}$

(ii) Diameter of object, $d_0 = 3.48 \times 10^6$ m
Radius of orbit, $r = 3.8 \times 10^8$ m
The angle subtended by the diameter of the moon

$$= \frac{\text{Diameter of moon}}{\text{Radius of lunar orbit}}$$

The angle subtended by the image is equal to the angle subtended by the object.

$$\therefore \quad \frac{d_i}{15} = \frac{3.48 \times 10^6}{3.8 \times 10^8}$$

$$\text{or} \quad d_i = \frac{3.48 \times 15 \times 10^{-2}}{3.8} = 13.73 \times 10^{-2}\,\text{m}$$

or $d_i = 13.73$ cm
Thus, the diameter of the image of moon is 13.73 cm.

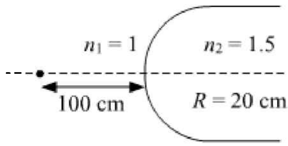
155. According to the Brewster law

Refractive index $\mu = \tan i_p$ where i_p is the polarising angle

$\mu = \tan 60° = \sqrt{3}$

The refractive index of the material is 1.73.

156. Using the relation, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$



$$\Rightarrow \frac{1.5}{V} - \frac{1}{(-100)} = \frac{1.5-1}{20} = \frac{1}{40}$$

$$\Rightarrow \frac{1.5}{V} - \frac{1}{40} - \frac{1}{100} = \frac{5-2}{200} = \frac{3}{200}$$

$$\Rightarrow v = \frac{1.5 \times 200}{3} = 100\,\text{cm}$$

Hence, the image is formed at 100 cm in the denser medium.

157. (a) Given: Radius of curvature of mirror R = 20 cm

$\therefore$ Focal length of mirror, f = –10 cm

We know that magnification of mirror (Read images) are formed by concave mirrors),

Magnification of image, m = –2

We know that magnification

$$m = -\frac{v}{u} = -\frac{I}{0} \Rightarrow -2 = -\frac{v}{u} \Rightarrow v = 2u$$

Using mirror formula

$$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}=\frac{1}{2u}+\frac{1}{u}=\frac{3}{2u}$$

$$\Rightarrow u=\frac{3}{2}f=\frac{3}{2}\times(-10)=-15cm$$

$$\therefore v=2u=-30cm$$

Therefore, the distance of the object is 15cm in front of the mirror and the position of the image is 30cm in front of the mirror,

158. (a) Given: wavelength of incident light

$\lambda_{air}=589nm=589\times10^{-9}m$

Refractive index of water, ${}^{a}\mu_{w}=1.33$

Frequency of the refractive light

$$f=\frac{C}{\lambda_{air}}=\frac{3\times10^{8}}{589\times10^{-9}}$$

Speed of light in air, $C=3\times10^{8}$ m/s

or, $f=5.09\times10^{14}$ Hz

Wavelength of refracted light $\lambda_{water}=\frac{\lambda_{air}}{{}^{a}\mu_{w}}$

$$=\frac{589\times10^{-9}}{1.33}=4.42\times10^{-7}m$$

Speed of refracted light, $V_{water}=\frac{C}{{}^{a}\mu_{w}}$

$$=\frac{3\times10^{8}}{1.33}=2.2\times10^{8}ms^{-1}$$

(b) Given : focal length of lens, f = 20 cm and refractive index of lens, $\mu=1.55$

Let the radius of the curvature of each of the two surfaces of the lens be R.

If $R_1=R$ then $R_2=-R$

Using lens maker's formula,

$$\frac{1}{f}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

or, $$\frac{1}{20}=(1.55-1)\left[\frac{1}{R}+\frac{1}{R}\right]=\frac{1.1}{R}$$

$\therefore$ $R=20\times1.1=22$ cm

159. According to the question, angle of prism A = 60°
(∴ prism is an equilateral)

Here, $i = \frac{3}{4}A = 45°$

As the ray undergoes minimum deviation

∴ i = e

and $r_1 = r_2 = \frac{A}{2} = 30°$

Using Snell's law

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin 45°}{\sin 30°} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} - \frac{2}{\sqrt{2}} = \sqrt{2} = 1.414$$

∴ Speed of light in the prism

$$v = \frac{C}{\mu} = \frac{3\times10^8}{1.414} = 2.12 \times 10^8 \text{ m/s}$$

160. The radius of atom whose principal quantum number is n, is given by

$r = n^2 r_0$

$r_0 = 5.3\times10^{-11}$ m

For second excited state, $n = 3$

∴ $r = 3^2 \times r_0 = 9\times5.3\times10^{-11}$

or, $r = 4.77 \times 10^{-10}$ m

161. (i) The kinetic energy (E_k) of the electron in an orbit is equal to negative of its total energy (E)

$E_k = -E$

$= -(-1.5) = 1.5$ eV

(ii) The potential energy (E_p) of the electron in an orbit is equal to twice its total energy (E).

i.e., $E_p = 2E$

$= 1.5 \times 2 = 3$ eV

(iii) As a result of transition of electron from excited state to ground state.

Energy of radiation = 1.5 – (– 13.6)

[∵ Ground state energy of H-atom = – 13.6 eV]

⇒ $\frac{hc}{\lambda} = 12.1$ eV = energy of radiation

$$\therefore \lambda = \frac{12.1\times1.6\times10^{-19}}{6.62\times10^{-34}\times3\times10^{-8}}$$

⇒ $\lambda = 1.025 \times 10^{-27}$ m = 1025 Å

162. Given, the electron in hydrogen atom is initially in third excited state.

$\therefore \; n = 3$

And the total number of spectral lines of an atom can exists is given by the relation $\frac{n(n-1)}{2}$

Here, $n = 3$

So, number of spectral lines $= \frac{3(3-1)}{2} = \frac{3 \times 2}{2} = 3$

Hence, when a hydrogen atom moves from third excited state to ground state, it emits three spectral lines.

163. According to Bohr's theory of hydrogen atom, energy of photon released, $E_2 - E_1 = h\nu$

Given, $E_1 = -1.151 \text{ eV}$

$$E_2 = -0.85$$

$$E_2 - E_1 = -0.85 - (-1.51)$$

$$= 1.51 - 0.85$$

$$E_2 - E_1 = 0.66 \text{ eV}$$

$$\therefore \quad E = E_2 - E_1 = 0.66 \text{ eV}$$

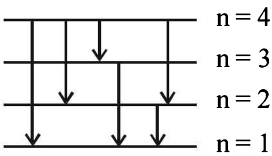
So, the wavelength of emitted spectral line,

$$\lambda = \frac{1242 \text{eV} - \text{nm}}{E(\text{in eV})} = \frac{1242 \text{ eV} - \text{nm}}{0.66 \text{ eV}}$$

$$\lambda = 1.88 \times 10^{-6} \text{ m} \approx 18751 \times 10^{-10} \text{ m}$$

The wavelength belongs to Paschen series of hydrogen spectrum.

164. The possible transitions from n = 4 to n = 1 level are



(1) n = 4 to n = 3, n = 3 to n = 2, n = 2 to n = 1

(2) n = 4 to n = 2,

(3) n = 4 to n = 1,

(4) n = 3 to n = 1

At each level of transition, a photon would be emitted. Hence the maximum number of photons would be 6. The minimum number of photon would be for n = 4 to n = 1, i.e., 1 photon.

165. Here, $a_0 = 5.3 \times 10^{-11}$ m

For first excited state, n = 2

Radius in the first excited state,

$$r = n^2 a_0 = (2)^2 \times 5.3 \times 10^{-11}$$
$$= 21.2 \times 10^{-11}\ \text{m}$$

Total energy in this state

$$E = -\frac{13.6}{n^2} = -\frac{13.6}{2^2} = -3.4\text{eV}$$

166. Energy of the electron in the n^{th} state of an atom is given as,

$$E_n = \frac{-13.6Z^2}{n^2}\text{eV}$$

Here, z is the atomic number of the atom.

For hydrogen atom, z = 1

Energy required to excite an atom from the initial state (n_i) to the final state (n_f) $= \frac{-13.6}{n_f^2} + \frac{13.6}{n_i^2}\text{eV}$

This energy must be equal to or less than the energy of the incident electron beam.

$$\therefore \quad \frac{-13.6}{n_f^2} + \frac{13.6}{n_i^2} = 12.5$$

Energy of the electron in the ground state $\frac{-13.6}{1^2}\text{eV} = -13.6\ \text{eV}$

$$\therefore \quad \frac{-13.6}{n_f^2} + 13.6 = 12.5$$

$$\Rightarrow \quad -13.6 - 12.5 = \frac{13.6}{n_f^2}$$

$$n_f = 3.5$$

State cannot be a fraction number.

$\therefore\ n_f = 3$

Hence, hydrogen atom would be excited up to 3^{rd} energy level.

Rydberg formula for the spectrum of the hydrogen atom is given below:

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Here, λ is the wavelength and R is the Rydberg constant.

$R = 1.097 \times 10^7 \text{ m}^{-1}$

For the first member of the Lyman series: $n_1 = 1$ and $n_2 = 2$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$

$\lambda = 1215$ Å

For the first member of Balmer series: $n_1 = 2$ and $n_2 = 3$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$\Rightarrow \lambda = 6563$ Å

167. Energy of the electron in the n^{th} state of an atom is given as,

$$E_n = \frac{-13.6Z^2}{n^2} \text{eV}$$

Here, z is the atomic number of the atom.

For hydrogen atom, $z = 1$

Energy required to excite an atom from initial state (n_i) to final state (n_f)

$$= -\frac{13.6}{n_f^2} + \frac{13.6}{n_i^2} \text{eV}$$

This energy must be equal to or less than the energy of the incident electron beam.

$$\therefore -\frac{13.6}{n_f^2} + \frac{13.6}{n_i^2} = 12.9$$

Energy of the electron in the ground state $= \frac{13.6}{1^2} = -13.6$ eV

$$\therefore -\frac{13.6}{n_f^2} + 13.6 = 12.9 \quad \Rightarrow 13.6 - 12.9 = \frac{13.6}{n_f^2}$$

$$n_f^2 = \frac{13.6}{0.7} = 19.43 \qquad \Rightarrow n_f = 4.4$$

State cannot be a fraction number.

$\therefore n_f = 4$

Hence, the hydrogen atom would be excited up to 4th energy level. Rydberg's formula for the spectrum of the hydrogen atom is given by,

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Here, λ is the wavelength.

Rydberg's constant, $R = 1.097 \times 10^7 m^{-1}$

For the first member of the Paschen series:

$n_1 = 3$

$n_2 = 4$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left[\frac{1}{3^2} - \frac{1}{4^2}\right]$$

$\lambda = 18761$ Å

For the first member of Balmer series:

$n_1 = 2$

$n_2 = 3$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$\lambda = 6563$ Å

168. The wavelength of emitted photon is 275 nm which would have an energy,

$$E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{275 \times 10^{-9}} = 7.22 \times 10^{-19} J = \frac{7.22 \times 10^{-19}}{1.6 \times 10^{-19}} eV$$

$\Rightarrow E = 4.5$ eV.

This energy would be possessed by an electron going from 0 eV to –4.5 eV as

$E = E_2 - E_1 = 0 - (-4.5)$ eV $= 4.5$ eV is energy of photon corresponding to transition B.

169. Mass defect,

Δm = mass of ${}^{23}_{10}Na$ – mass of ${}^{23}_{11}Na$ = (22.994466 – 22.989770) u = 0.004696 u

$\therefore$ Energy released

$E = (0.004696 \times 931.5)$ MeV $= 4.372$ MeV

As the daughter nucleus and anti-neutrino carry negligible K.E, hence the maximum kinetic energy of electrons is 4.372 MeV.

170. mass defect of He $= [2m(n) + 2\,m_p] - m_{He}$

Since He, has $2p^+$ and $2n^0$,

$2m_p + 2m_n = 2 \times 1.00728 + 2 \times 1.00867 = 4.0319\,u$

$\therefore \quad \Delta m\,(He) = 4.0319 - 4.00150 = 0.0304\,u$

1 a m u gives energy 931.5 MeV

$\therefore \quad Q\,(He) = \Delta mc^2 = 0.0304 \times 931.5$

MeV $= 28.32$ MeV.

171. The nuclear density is same for all nuclei.

$$\frac{\rho_1}{\rho_2} = 1.$$

172. During α decay, the mass number of a nucleus decreases by 4 and charge number decreases by 2. During β decay mass no. remains unchanged and charge no. increases by 1.

$$\alpha = {}_4^2He\,;\ \beta = {}_0^{-1}e$$

$$A_{190}^{75} \xrightarrow{\alpha} A_{1(186)}^{73} \xrightarrow{\beta} A_{2(186)}^{74} \xrightarrow{\alpha} A_{3(182)}^{72} \xrightarrow{\gamma} A_{4(182)}^{72}$$

During γ decay, the mass number and charge number of a nucleus remains unchanged. Thus mass number and atomic no. of A_4 are 182 and 72 respectively.

173. Energy released per fission

$= (110 + 130) \times 8.5\,MeV - 240 \times 7.6\,MeV$

$= 240 \times (8.5 - 7.6)\,MeV$

$= 240 \times 0.9 = 216.0\,MeV$

174. $A = 225, R = 1.1 \times 10^{-15} A^{1/3}$

Let A_1 and A_2 be the mass no. s of the two new nuclei for med. Then

$$A_1 = \frac{3}{3+2}A = \frac{3}{5} \times 225 = 135$$

$$A_2 = \frac{2}{3+2}A = \frac{2}{5} \times 225 = 90$$

$R_1 = 1.1 \times 10^{-15} A_1{}^{1/3} = 1.1 \times 10^{-15} \times (135)^{1/3}$

$= 5.643 \times 10^{-15}\,m \quad (\because (135)^{1/3} = 5.13)$

$R_2 = 1.1 \times 10^{-15} A_2{}^{1/3} = 1.1 \times 10^{-15} (90)^{1/3}$

$= 4.93 \times 10^{-15}\,m \qquad (\because (90)^{1/3} = 4.48).$

175. Let N_A be the concentration of A after time t_A and N_B be the concentration of B after time, t_B.

From radioactive disintegration equation

$$N_A = N_0 e^{-\lambda_A t_A}$$

$$N_B = 4N_0 e^{-\lambda_B t_B} \qquad [\text{As } N_{0B} = 4N_{0A}]$$

Now, half-life of A is 100 yr and B is 50 yr.

So, $\lambda_A = \frac{\text{In } 2}{100}$ and $\lambda_B = \frac{\text{In } 2}{50}$

Dividing, we get

$$\frac{\lambda_A}{\lambda_B} = \frac{1}{2} \text{ or } \lambda_B = 2\lambda_A$$

Let after t years, $N_A = N_B$ So, $\frac{N_A}{N_B} = \frac{e^{-\lambda_A t}}{4e^{-\lambda_B t}}$

$$4e^{-\lambda_B t} = e^{-\lambda_A t} \Rightarrow 4 = e^{-(\lambda_A - \lambda_B)t}$$

$$\ln 4 = -(+\lambda_A - 2\lambda_A)t \qquad [\because \lambda_B = 2\lambda_A]$$

$$\ln 4 = \lambda_A t$$

$$t = \frac{\text{In } 4}{\text{In } 2} \times 100 \qquad \left[\because \lambda_A = \frac{\ln 2}{100}\right]$$

$$= 200 \text{ yr}$$

Therefore, after 200 years amounts of A and B become equal.

176. Given : at $t = 0, N = N_0$ and at $t = T$,

$$N = N_0/n$$

As we know,

$$N = N_0 e^{-\lambda t} \quad \therefore \quad \frac{N_0}{n} = N_0 e^{-\lambda t}$$

or $\quad n = e^{\lambda T}$

Taking *log* of both sides, we have

$$\ln n = \lambda T$$

or $\quad \lambda = \ln n/T$

As we know that

$$T½ = \frac{0.693}{\lambda} = \frac{0.693T}{\ell n n}$$

177. Given fusion reaction

$${}_1^2\text{H} + {}_1^3\text{H} \longrightarrow {}_2^4\text{He} + n$$

Total mass of the reactants

$$= 2.014102 + 3.016049 = 5.030151 \text{ u}$$

Total mass of the product

$$= 4.002603 + 1.00867 = 5.011273 \text{ u}$$

$\Rightarrow$ Mass defect = 0.018878 u

$\therefore$ Energy released = $(0.018878 \times 931.5 \text{ MeV}/c^2) \times c^2$

[Using $E = \Delta mc^2$]

$$= 17.584857 \text{ MeV}$$

178. As we know, according to Bohr's theory angular momentum

$$mvr = \frac{nh}{2\pi} \qquad \therefore \qquad mvr_2 = \frac{nh}{2\pi}$$

The de-Broglie wavelength is given as,

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{nh} \times (2\pi r_2) = \pi r_2$$

As $r_2 = 0.529 \times n^2 \times 10^{-10}$ m

Therefore, wavelength

$$\lambda = \pi \times 0.529 \times 10^{-10} \times n^2 = 3.14 \times 0.529 \times 10^{-10} \times 2^2 \simeq 6.64 \times 10^{-10} m$$

179. For shortest wavelength, of the spectral lines emitted in balmer series, $n = \infty$

As we know, $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$

$$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{2^2} - 0\right) = \frac{R}{4}$$

$$\therefore \quad \lambda = \frac{4}{R} = \frac{4}{10^7} = 4 \times 10^{-7} m$$

180. The binding energy of the nucleus of mass number 240,

$$B_1 = 7.6 \times 240 = 1824 \text{ MeV}$$

The binding energy of each product nucleus,

$$B_2 = 8.5 \times 120 = 1020 \text{ MeV}$$

Then, the energy released as the nuclues breaks is given by

$$E = 2B_2 - B_1 = 2 \times 1020 - 1824 = 216 \text{ Mev}$$

181. Given: Binding energy of ${}_1^2\text{H}$, $E_1 = 2.23$ MeV

Binding energy of ${}_2^3\text{He}$, $E_2 = 7.73$ MeV

Energy in the fusion reaction is given by

$$\Delta E = E_2 - 2E_1 = 7.73 - (2 \times 2.23) = 3.27 \text{ Mev}$$

182. When gaseous hydrogen is bombarded with an electron beam, the energy of the gaseous hydrogen

$= -13.6 + 12.5\ eV = -1.1\ eV.$

Orbital energy $E = \frac{-13.6}{(n)^2} eV$

For $n = 3$, $E = \frac{-13.6}{(3)^2} eV = \frac{-13.6}{9} eV = -1.5\ eV$

This energy is approximately equal to the energy of gaseous hydrogen. This implies that the electron has jumped from n = 1 to n = 3 level.

During its de-excitation, electrons can jump from n = 3 to n = 1 directly, which forms a line of the Lyman series of the hydrogen spectrum. For Lyman series, $\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n^2}\right]$

For first member n = 3

$$\therefore \frac{1}{\lambda_1} = R\left[\frac{1}{1^2} - \frac{1}{(3)^2}\right] = R\left[\frac{1}{1} - \frac{1}{9}\right]$$

$$\therefore \frac{1}{\lambda_1} = 1.097 \times 10^7\left[\frac{9-1}{9}\right]$$

($\because$ Rydberg constant $R = 1.097 \times 10^7 m^{-1}$)

$$\therefore \frac{1}{\lambda_1} = 1.097 \times 10^7 \times \frac{8}{9} \quad \text{or,} \quad \lambda_1 = 1.025 \times 10^{-7}\ m$$

For n = 3

$$\therefore \frac{1}{\lambda_2} = R\left[\frac{1}{1^2} - \frac{1}{(2)^2}\right] = R\left[\frac{1}{1} - \frac{1}{4}\right]$$

$$\therefore \frac{1}{\lambda_2} = 1.097 \times 10^7\left[\frac{4-1}{4}\right]$$

$$\therefore \frac{1}{\lambda_2} = 1.097 \times 10^7 \times \frac{3}{4} \quad \text{or,} \quad \lambda_2 = 1.215 \times 10^{-7}\ m$$

For Balmer series $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$

For first member n = 3

$$\therefore \quad \frac{1}{\lambda_3} = R\left[\frac{1}{2^2} - \frac{1}{(3)^2}\right] = 1.097 m \times 10^7 \times \left[\frac{1}{4} - \frac{1}{9}\right]$$

or, $\lambda_3 = 6.56 \times 10^{-7} m$

183. (a) The output resistance (r_o)

$$= \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B = \text{constant}}$$

From the given graph, at $I_B = 60\mu A$

$V_{CE} = 2V$, $V_{CE} = 16V$

Collector current changes from 8 mA to 8.5 mA

i.e., $\Delta V_{CE} = 16 - 2 = 14V$

$\Delta I_C = 8.5 - 8 = 0.5$ mA$=5\times10^{-4}$A

$$\therefore \quad r_o = \left(\frac{\Delta V_C}{\Delta I_C}\right)_{I_B=60\mu A} = \frac{14}{5\times10^{-4}}$$

$$\therefore \quad r_o = 2.8\times10^4\Omega = 28\,K\Omega$$

(b) The current amplification factor,

$$\beta_{AC} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}=\text{constant}}$$

At, $V_{CE} = 2V$

$I_B = 10\mu A$ to $60\mu A$

$\therefore \quad \Delta I_B = (60 - 10) = 50\mu A$

I_C Changes from 1.8 mA to 8mA $\Delta I_C = 8 - 1.5 = 6.5$ mA

$$\Rightarrow \quad \beta_{AC} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}} = \frac{6.5\times10^{-3}A}{50\times10^{-6}A} = 130$$

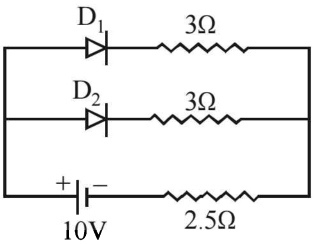
184. Diodes D_1 and D_2 are ideal, therefore, they do not offer any resistance. Hence the two 3 ohm resistors are in parallel, hence,

$R_P = 3 \times 3/3 + 3 = 9/6 = 1.5\,\Omega$

Now, R_P and 2.5 ohm resistors are in series, hence, net resistance $R = R_P + 2.5 = 1.5 + 2.5 = 4.0\Omega$

Hence, current through the circuit and through 2.5 Ω resistors

$I = V/R = 10/4 = 2.5$ A



185. From the output characteristics at point Q,

$V_{CE} = 8\text{V}$ and $I_C = 4\text{ mA}$

$V_{CC} = I_C RC + V_{CE}$

$$R_c = \frac{V_{CC} - V_{CE}}{I_C} \; ; \; R_c = \frac{16-8}{4\times10^{-3}} = 2\text{K}\Omega$$

Since, $V_{BB} = I_B R_B + V_{BE}$

$$R_B = \frac{16-0.7}{30\times10^{-6}} = 510\text{ K}\Omega$$

$$\text{Now, } \beta = \frac{I_C}{I_B} = \frac{4\times10^{-3}}{30\times10^{-6}} = 133$$

$$\text{Voltage gain} = A_V = -\beta\frac{R_C}{R_B} = -133\times\frac{2\times10^3}{510\times10^3} = 0.52$$

$$\text{Power gain} = A_p = \beta\times A_V$$

$$= -\beta^2\frac{R_C}{R_B} = (133)^2\times\frac{2\times10^3}{510\times10^3} = 69$$

186. In 'n' region; number of e^- is due to As:

$n_e = N_D = 1\times10^{-6}\times5\times10^{28}$ atoms/m^3

$n_e = 5\times10^{22}$/m^3

The minority carriers (hole) is

$$n_h = \frac{n_i^2}{n_e} = \frac{(1.5\times10^{16})^2}{5\times10^{22}} = \frac{2.25\times10^{32}}{5\times10^{22}}$$

$n_h = 0.45\times10$/m^3

Similarly, when Boron is implanted a 'p' type is created with holes

$n_h = N_A = 200\times10^{-6}\times5\times10^{28} = 1\times10^{25}$/m^3

This is far greater than e^- that existed in 'n' type wafer on which Boron was diffused.

Therefore, minority carriers in created 'p' region

$$n_e = \frac{n_i^2}{n_h} = \frac{2.25 \times 10^{32}}{1 \times 10^{25}} = 2.25 \times 10^7/\text{m}^3$$

187. The maximum line of sight distance

$$d = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

$$= \sqrt{2 \times 6400 \times 10^3 \times 36} + \sqrt{2 \times 6400 \times 10^3 \times 49}$$

$$= 8 \times 6 \times 10^2 \sqrt{20} + 8 \times 7 \times 10^2 \sqrt{20}$$

$$= 8 \times 10^2 (6 + 7)\sqrt{20}$$

$$= 10400 \times 4.472 = 46.51 \times 10^3$$

$$= 4.651 \times 10^4 \text{ m}$$

188. Let the height of a TV tower is h. Then, the transmission range is $d = \sqrt{2hR}$. Where R is the radius of the earth.

Let h' be the increased height

$$\therefore \quad h' = h + \frac{21h}{100} = \frac{121}{100}h$$

Therefore, new transmission range is, $d = \sqrt{2\left(\frac{121}{100}h\right)R}$

$$= \frac{11}{10}\sqrt{2hR} = \frac{11}{10}d$$

Hence, the percentage change in the transmission range will be

$$\frac{\Delta d}{d} \times 100\% = \left(\frac{d' - d}{d}\right) \times 100\%$$

$$= \left(\frac{\frac{11}{10}d - d}{d}\right) \times 100\% = \left(\frac{11}{10} - 1\right) \times 100\%$$

$$= \frac{1}{10} \times 100\% = 10\%$$

Thus, the transmission range will be increased by 10%.

189. Here, maximum amplitude, $A_{max} = 16V$.

Minimum amplitude, $A_{min} = 4V$

$\because$ Modulation index, $(\mu) = \frac{A_m}{A_c} = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$

$$\therefore \quad \mu = \frac{16-4}{16+4} = \frac{12}{20} = \frac{3}{5}$$

$$\mu = \frac{3}{5} = 0.6$$

190. Maximum distance upto which the signals can be transmitted $d = ?$

$$\because \quad d = \sqrt{2hR}$$

where, R = radius of earth = 6400 km

$= 6.4 \times 10^6$ m

$$\therefore \quad d = \sqrt{2 \times 80 \times 6.4 \times 10^6} \qquad [\because h = 80 \text{ m given}]$$

or, $d = 32 \times 10^3$ m = 32 km.

191. Here, $A_C = 18$ V,

$A_m = ?$

Modulation index

$\mu_c = 50\% = 0.50$

As we know, $\mu_0 = \frac{A_m}{A_c}$ $0.5 = \frac{A_m}{18}$

$$\Rightarrow \quad A_m = 0.5 \times 18$$

or $\quad A_n = 9V$

192. Maximum distance between the two antennas is

$$d_m = d_T + d_R$$

$$= \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

where, d_T = maximum horizon for transmitting antenna
and d_R = maximum horizon for receiving antenna

$$= \sqrt{2 \times 6.4 \times 10^6 \times 45} + \sqrt{2 \times 6.4 \times 10^6 \times 80}$$

$$= (3 \times 8 \times 10^3 + 4 \times 8 \times 10^3)\,\text{m}$$

$$= 56 \times 10^3\,\text{m} = 56\,\text{km}$$

193. Maximum distance between the two antenna

$$d_{max} = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

$$= \sqrt{2 \times 6.4 \times 10^6 \times 45} + 0 \quad [\because\ h_R = 0]$$

$$= 24 \times 10^3\,\text{m} = 24\,\text{km}$$

194. $\dfrac{2x}{\text{time}}$ = velocity

$$2x = 3 \times 10^8\,\text{m/s} \times 4.04 \times 10^{-3}\,\text{s}$$

$$x = \frac{12.12 \times 10^5}{2}\,\text{m} = 6.06 \times 10^5\,\text{m} = 606\,\text{km}$$

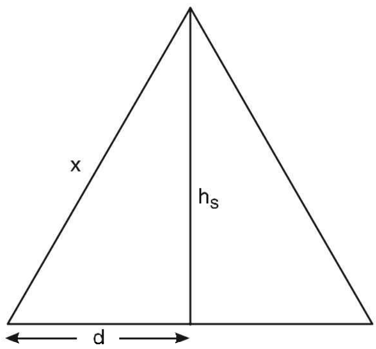
$$d^2 = x^2 - h_s^2 = (606)^2 - (600)^2 = 7236;\ d = 85.06\,\text{km}$$

Distance between source and receiver

$$= 2d \cong 170\,\text{km}$$

$$d_m = 2\sqrt{2Rh_T},\ 2d = d_m,\ 4d^2 = 8\,Rh_T$$

$$\frac{d^2}{2R} = h_T = \frac{7236}{2 \times 6400} \approx 0.565\,\text{km} = 565\,\text{m}.$$



195. (i) $\frac{I}{I_o} = \frac{1}{4}$, so $\ln\left(\frac{1}{4}\right) = -\alpha x$

or $\ln 4 = \alpha x$ or $x = \left(\frac{\ln 4}{\alpha}\right)$

(ii) $10 \log_{10} \frac{I}{I_o} = -\alpha x$ where α is the attunation in dB/km.

Here $\frac{I}{I_o} = \frac{1}{2}$

or $10 \log\left(\frac{1}{2}\right) = -50\alpha$ or $\log 2 = 5\alpha$

or $\alpha = \frac{\log 2}{5} = \frac{0.3010}{5} = 0.0602$ dB/km

196. Given : $A_C = 50$ V, $\mu = 0.5$, $A_m = ?$,

As we know $\mu = \frac{A_m}{A_C}$

Hence, $A_m = A_C \times \mu = 50 \times 0.5 = 25$ V (Amplitude of A.M. wave)

Frequencies of sidebands

(1500 ± 10) kHz = 1510 kHz and 1490 kHz.

197. Given: Output voltage, $V_O = 2V$, output resistance, $R_O = 2k\Omega$, base resistance, $R_i = 1\ k\Omega$

Current amplification factor, $\beta = 100$

Then input signal voltage is calculated as :

$$\frac{V_o}{V_i} = \frac{R_o}{R_i} \times \beta \Rightarrow \frac{2}{V_i} = \frac{2}{1} \times 100 \quad \Rightarrow V_i = 10\,\text{mV}$$

Now, collector current $I_C = \frac{V_o}{R_o} = \frac{2}{2} = 1\ mA$

Therefore, base current $I_B = \frac{I_C}{\beta} = \frac{1\,mA}{100} = 10\mu A$

198. According to question,

Upper side band frequency, $f_c + f_m = 660\,\text{kHz}$ ....(i)

Lower side band frequency, $f_c - f_m = 640\,\text{kHz}$ ...(ii)

Adding equation (i) and (ii), we get

$2f_c = 660\ \text{kHz} + 640\ \text{kHz}$

$\therefore \quad f_c = 650\ \text{kHz}$

Now $f_c + f_m = 660\ \text{kHz}$

$\therefore \quad f_m = 660\ \text{kHz} - 650\ \text{kHz}$

$\therefore \quad f_m = 10\,\text{kHz}$

Band width for amplitude modulation

= Upper side – lower side = $(f_c + f_m) - (f_c - f_m) = 2f_m$

$\therefore$ Bandwidth for amplitude modulation

$= 2 \times 10\ \text{kHz} = 20\ \text{kHz}$

□□□

CHAPTER 9

How will you solve numericals based on laws/theorems ....?

(A) *Electrostatics*

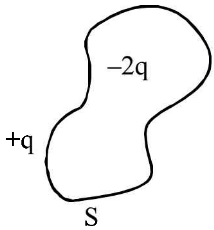
1. Two protons in a molecule is separated by a distance 3×10^{-10} m. Find the electrostatic force exerted by one proton on the other.

[Delhi 2008C]

2. Three charges 10 μC, 5μC and –5μC are placed in air at three corners A, B and C of an equilateral triangle of side 0.1m. Find the resultant force experienced by charge placed at corner A. **[Foreign 2011]**

3. A charge q is enclosed in a cube. What is the electric flux associated with one of the faces of cube?

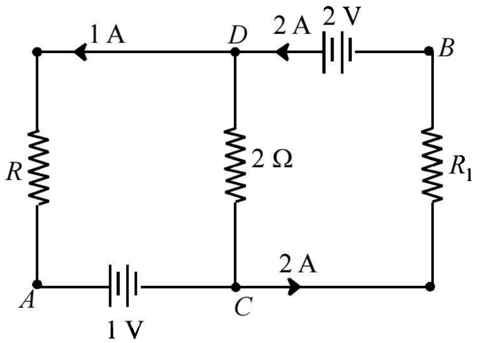
4. The following figure shows a surface S which is enclosing –2q charge. The charge +q is kept outside the surface S. Calculate the net outward/inward flux from the surface S.



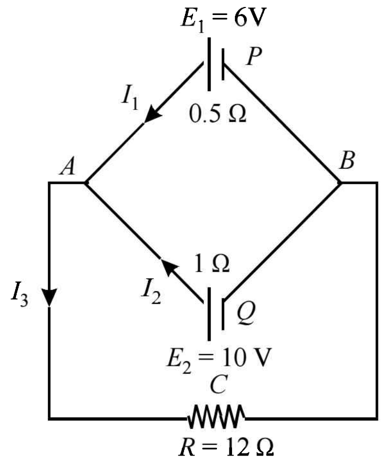
(B) *Current Electricity*

5. In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B.

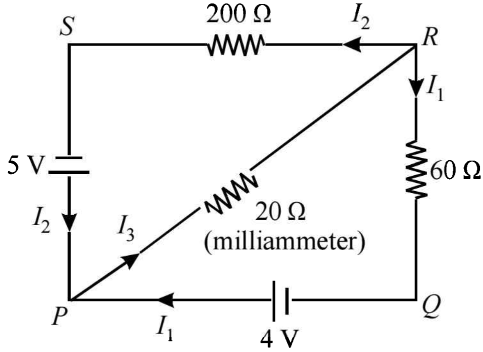
[Delhi 2009, All India 2011]



6. Apply Kirchoff's rules to the loops *ACBPA* and *ACBQA* to find the value for the currents I_1, I_2 and I_3 in the network. **[All India 2010]**



7. Apply Kirchhoff's rules to the loops *PRSP* and *PRQP* to find the value for the current I_1, I_2 and I_3in given circuit. **[All India 2010]**

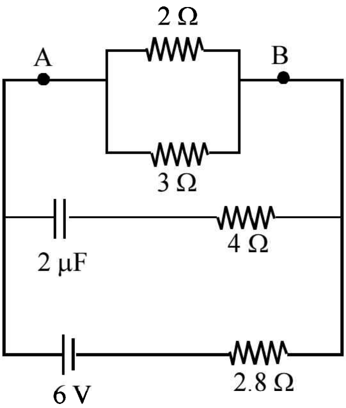


8. A battery of 10V and negligible internal resistance is connected across the diagonally opposite corners of a cubical network consisting of 12 resistors each of 1 Ω resistance. Use Kirchhoff's rules to determine.

(a) the equivalent resistance of the network and

(b) the total current in the network. **All India 2010]**

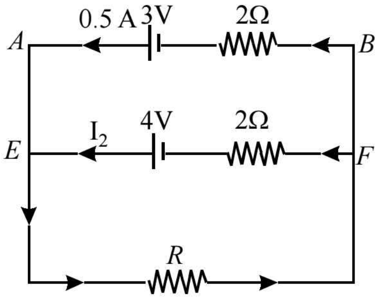
9. Calculate the steady current through the 2Ω resistor in the **[Foreign 2010]**



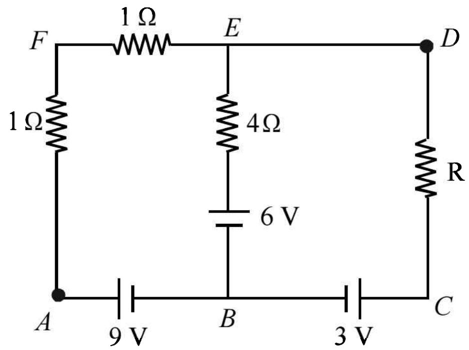
10. Using Kirchhoff's rules in the given circuit, determine

(i) the voltage drop across the unknown resistor *R* and

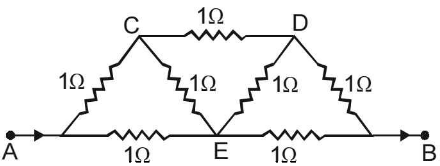
(ii) the current *I* in the arm *EF*. **[All India 2011]**



11. Using Kirchoff's rule, determine the value of unknown resistance *R* in the circuit so that no current flows through 4Ω resistance. Also, find the potential difference between points *A* and *D*. **[Delhi 2012]**



12. In the diagram below each resistance is of 1Ω. Find the equivalent resistance between A and B using kirchoff's law.



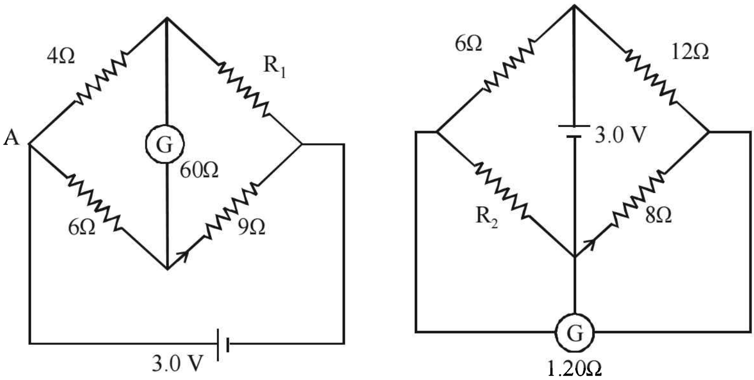
13. The length of a potentiometer wire is 600 cm and it carries a current of 40 mA. For a cell of emf 2V and internal resistance 10 W, the null point is found to be at 500 cm. If a voltmeter is connected across the cell, the balancing length is decreased by 10 cm. Find :

(i) The resistance of whole wire

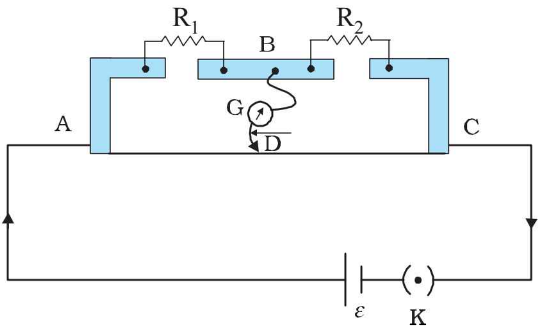
(ii) Reading of voltmeter

(iii) Resistance of voltmeter

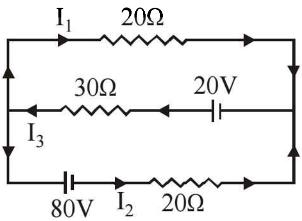
14. Figure shows two circuits each having a galvanometer and a battery of 3V. When the galvanometer in each arrangement do not show any deflection, obtain the ratio R_1/R_2. **[All India 2013]**



15. In the meterbridge experimental set up, shown in the figure, the null point 'D' is obtained at a distance of 40 cm from end A of the meterbridge wire. If a resistance of 10 Ω is connected in series with R_1, null point is obtained at AD = 60 cm. Calculate the values of R_1 and R_2. **[Delhi 2013]**



16. Use Kirchhoff's rules to determine the value of the current I_1 flowing in the circuit shown in the figure. **[Delhi 2013C]**



17. A potentiometer wire of length 1 m has a resistance of 10 Ω. It is connected to a 6 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 40 cm. **[Delhi 2014]**

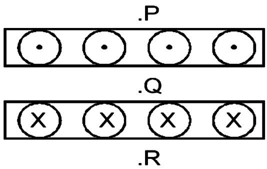
18. A potentiometer wire of length 1.0 m has a resistance of 15 Ω. It is connected to a 5 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 60 cm. **[Delhi 2014]**

19. In a meter bridge shown in the figure, the balance point is found to be 40 cm from end A. If a resistance of 10 Ω is connected in series with *R*, balance point is obtained 60 cm from A. Calculate the values of *R* and *S*. **[All India 2015]**

(C) *Magnetism*

20. A current of 5A is flowing from South to North in a straight wire. Find the magnetic field due to a 1 cm piece of wire at a point 1 m North-East from the piece of wire. **[All India 2011]**

21. Two large metal sheets carry surface current as shown in fig. The current through a strip of width dl is kdl where k is a constant. Find the magnetic field at the point P, Q and R.



22. A galvanometer of coil resistance 20 ohm, gives a full scale deflection with a current of 5 mA. What arrangements should be made in order to measure currents upto 1.0 A ? **[Delhi 2011C]**

23. Two galvanometers, which are otherwise identical are fitted with different coils. One has a coil of 50 turns and resistance 10Ω while the other has 500 turns and a resistance of 600Ω . What is the ratio of the deflection when each is connected in turns to a cell of e.m.f 2.5V and internal resistance 50Ω ?

24. A sample of paramagnetic salt contains 2×10^{24} atomic dipoles, each of moment 1.5×10^{-23} JT^{-1}. The sample is placed under a homogeneous magnetic field of 0.84 T and cooled to a temperature of 4.2 K. The degree of magnetic saturation achieved is equal to 15%. What is the total dipole moment of the sample for a magnetic field of 0.98 T and a temperature of 2.8 K. Assume Curie's law.

(D) *EMI, Alternating Current and EM Waves*

25. A metal rod of length 1 m is rotated about one of its ends in a plane right angles to a field of inductance 2.5×10^{-3} Wh/m^2. If it makes 1800 revolutions/min. Calculate induced e.m.f. between its ends.
[Foreign 2012]

26. Using Lenz's law, predict the direction of induced current in the situations described by the following fig. (1) to (5).

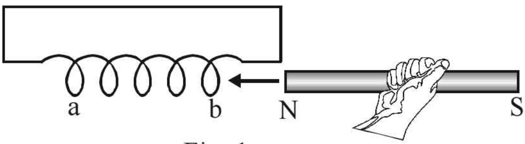


Fig -1

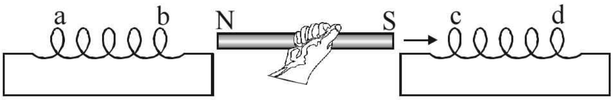


Fig.2

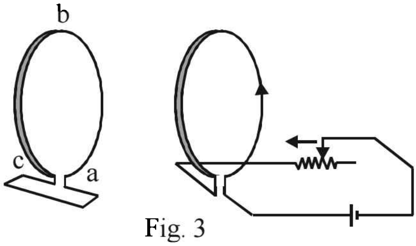


Fig. 3

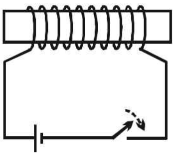
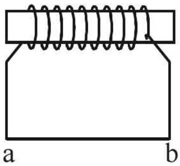


Fig. 4



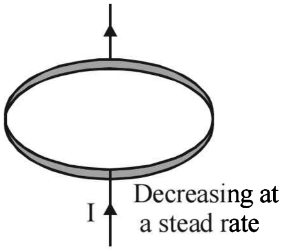


Fig.5

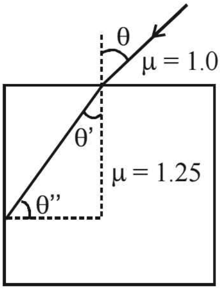
27. A low loss transformer has 230 V applied to primary and gives 4.6 V in secondary. The secondary is connected to a load which draws 5 A current. Find the current in primary.

28. In a given coil of self-inductance of 5 mH, current changes from 4 A to 1 A in 30 ms. Calculate the emf induced in the coil. **[All India 2015]**

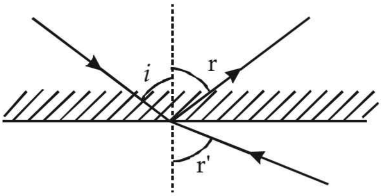
(E) Optics

29. The intensity of the polarised light becomes 1/20th of its initial intensity after passing through the analyser. What is the angle between the axis of the analyser and the initial amplitude of the light beam ? **[Delhi 2008C]**

30. Consider the situation shown in figure. Find maximum angle for which the light suffers total internal reflection at the vertical surface.



31. A ray of light from a denser medium strike a rarer medium at an angle of incidence i (see Fig). The reflected and refracted rays make an angle of 90° with each other. The angles of reflection and refraction are r and r'. Calculte the value of critical angle.



32. A beam of polarised light makes an angle of 60° with the axis of the polaroid sheet. How much is the intensity of light transmitted through the sheet ?

33. A ray of light strikes a glass plate at an angle of 60° with the glass surface. If the reflected and refracted rays are at right angles to each other, find the refractive index of the glass.

34. Two polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. An unpolarised light of intensity I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 60° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3. **[All India 2014]**

35. When one centimeter thick surface is illuminated with light of wavelength λ, stopping potential is V and when the same surface is illuminated by light of wavelength 2 λ, stopping potential is V/3. Determine threshold wavelength for metallic surface.

36. Find the Brewster angle for air-glass interface, when the refractive index of glass = 1.5. **[All India 2017]**

(F) *Atoms and Nuclei*

37. The ground state energy of hydrogen atom is –13.6eV. The photon emitted during the transition of electron from n = 2 to n = 1 state, is incident on the photosensitive material of unknown work function. The photoelectrons are emitted from materials with a maximum kinetic energy of 8 ev. Calculate the threshold wavelength of the material used. **[Foreign 2008]**

38. The ionisation energy of hydrogen atom is 13.6 eV. Following Bohr's theory, find the energy corresponding to a transition between the 3rd and the 4th orbit is

39. Two radioactive substances X and Y initially contain equal number of nuclei. X has a half life of 1 hour and Y has half life of 2 hours. After two hours what will be the ratio of the activity of X to the activity of Y?

40. The half life of radium is 1620 years and its atomic weight is 226. Find the number of atoms that will decay from its 1 gm sample per second.

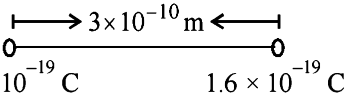
41. The ground state energy of hydrogen atom is –13.6 eV. If an electron makes a transition from an energy level –0.85 eV to – 1.51 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does this wavelength belong? **[All India 2012]**

42. The half life of a certain radioactive material against α-decay is 100 days. After how much time, will the undecayed fraction of the material be 6.25%? **[All India 2015]**

SOLUTIONS

1. According to coulomb's law, the electrostatic force F between two charges q_1 and q_2, which are seperated by distance r is

$$F = \frac{1}{4\pi\varepsilon_o} \times \frac{q_1 q_2}{r^2}$$



Here, $q_1 = q_2 = 1.6 \times 10^{-19}C$, $r = 3 \times 10^{-10}$ m

$$\text{so, } F = 9 \times 10^9 \frac{(1.6 \times 10^{-19})^2}{9 \times 10^{-20}} = 2.56 \times 10^{-9} C \text{ (Repulsive)}$$

2. Here, $q_A = 10\mu C = 10^{-5}C$

$q_B = 5 \times 10^{-6}C$

$q_C = -5 \times 10^{-6}C$

$AB = BC = AC = 0.1m$

Now, $F_{AB} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_A q_B}{AB^2} = \frac{9 \times 10^9 \times 10^{-5} \times 5 \times 10^{-6}}{(0.1)^2}$

$F_{AB} = 45$ N (repulsive)

Also, $F_{AC} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_A q_C}{AC^2} = \frac{9 \times 10^9 \times 10^{-5} \times 5 \times 10^{-6}}{(0.1)^2}$

$F_{AC} = 45$ N (attractive)

The forces F_{AB} and F_{AC} are inclined at angle of 120°. If F is the resultant force on the charge q_A, then

$$F = \sqrt{F_{AB}^2 + F_{AC}^2 + 2F_{AB} \cdot F_{AC} \cos 120°}$$

$$= \sqrt{45^2 + 45^2 + [2 \times 45 \times 45(-0.5)]}$$

$$= 45\sqrt{1+1-1} = 45N$$

The resultant force acts on the charge $10\mu C$ charge along AP, where point P lies on a line, parallel to side BC of the ΔABC.

3. According to Gauss's theorem,

$$\text{Total electric flux } \phi = \frac{1}{\varepsilon_o} \times \text{total enclosed charge}$$

$$= \frac{1}{\varepsilon_o} \times q.$$

Since cube has six faces, hence electric flux linked with each face = $(1/6\phi) = q/6\varepsilon_o$.

4. According to Gauss's law, the net flux is

$$\phi = \frac{1}{\varepsilon_0} \times \text{net charge enclosed by closed surface} = \frac{-2q}{\varepsilon_0}$$

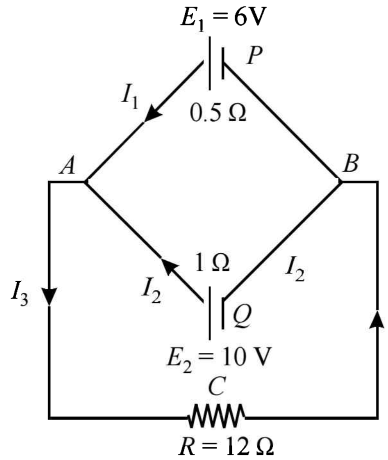
(Because +q is outside the surface S, so net flux due to +q is zero)

5. Applying Kirchhoff's current law at junction *D* we get,
Current through the path DC
$= 1A$
Now, applying Kirchhoff's voltage law to the path *ACDB*.

$$V_A + 1 + 1 \times 2 - 2 = V_B$$

when $V_A = 0$, then $V_B = 1V$
Hence, the potential at point B, $V_B = 1$ V

6.



Applying Kirchhoff's voltage law in loop *ACBPA*,

$$-12I_3 + 6 - 0.5I_1 = 0$$

$$\Rightarrow \quad 5I_1 + 120I_3 = 60 \qquad \text{...(i)}$$

In loop *ACBQA*,

$$-12I_3 + 10 - I_2 \times 1 = 0$$

$$\Rightarrow \quad 12I_3 + I_2 = 10 \qquad \text{...(ii)}$$

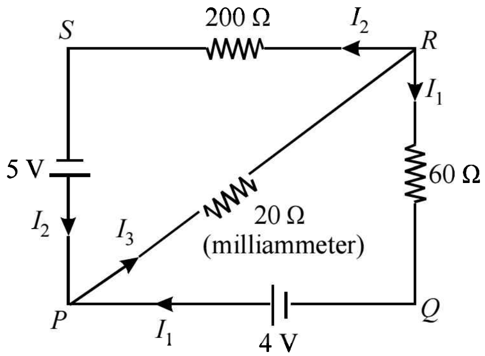
Also from Kirchhoff's junction rule

$$I_1 + I_2 = I_3 \qquad \text{...(iii)}$$

Solving Eqs. (i), (ii) and (iii), we get

$$I_1 = -\frac{84}{37}A;\ I_2 = \frac{106}{37}A;\ I_3 = \frac{22}{37}A$$

7.



Applying Kirchhoff's second rule to the loop *PRSP*,

$$\Sigma E + \Sigma IR = 0$$

$$-I_3 \times 20 - I_2 \times 200 + 5 = 0$$

$$\Rightarrow \quad 4I_3 + 40I_2 = 1 \qquad \text{...(i)}$$

For loop *PRQP*,

$$-20I_3 - 60I_1 + 4 = 0$$

$$\Rightarrow \quad 5I_3 + 15I_1 = 1 \qquad \text{...(ii)}$$

Applying Kirchhoff's first rule at *P*

$$I_3 = I_1 + I_2 \qquad \text{...(iii)}$$

From Eqs. (i) and (iii), we have

$$4I_1 + 44I_2 = 1 \qquad \text{...(iv)}$$

From Eqs. (ii) and (iii), we have

$$20I_1 + 5I_2 = 1 \qquad \text{...(v)}$$

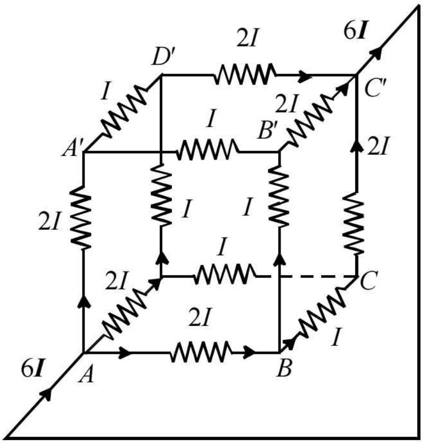
Solving the equations, we get

$$I_3 = \frac{11}{172}A = \frac{11000}{172}\text{mA}$$

$$I_2 = \frac{4}{215}A = \frac{4000}{215}\text{mA}$$

$$I_1 = \frac{39}{860}A = \frac{39000}{860}\text{mA}$$

8. Let $6I$ current be drawn from the cell. Since the paths AA', AD and AB are symmetrical, current through them is same.
As per Kirchhoff's junction rule, the current distribution is shown in the figure.



Let the equivalent resistance across the combination be R.

$$E = V_A - V_B = (6I)R$$

$\Rightarrow \quad 6IR = 10 \quad [\because E = 10V]$ ...(i)

Applying Kirchhoff's second rule in loop $AA'B'C'A$

$$-2I \times 1 - I \times 1 - 2I \times 1 + 10 = 0$$

$\Rightarrow \quad 5I = 10$

$I = 2\text{A}$

Total current in the network $= 6I = 6 \times 2 = 12$ A

From Eq. (i), $6IR = 10$

$\Rightarrow \quad 6 \times 2 \times R = 10$

$\therefore \quad R = \dfrac{10}{12} = \dfrac{5}{6}\Omega$

9. No current flows through 4Ω resistor as capacitor offers infinite resistance in DC circuits.
Also, 2Ω and 3Ω are in parallel combination

$\therefore \quad R_{AB} = \dfrac{2 \times 3}{2+3} = \dfrac{6}{5} = 1.2\text{A}$

Applying Kirchhoff's second rule in outer loop *AB* and cell.
Let *I* current flows through outer loop in clockwise direction.

$$-1.2I - 2.8I + 6 = 0$$

$\Rightarrow$ $4I = 6$

$\therefore$ $I = \frac{3}{2} A$

$\therefore$ Potential difference across AB

$$V_{AB} = IR_{AB} = \frac{3}{2} \times 1.2$$

$$V_{AB} = 1.8\text{V}$$

3Ω and 2Ω are in parallel combination.

$\therefore$ PD across 2Ω resistor is 1.8 V.

$\therefore$ Current I′ through 2Ω resistor is given by

$$I' = \frac{V}{R} = \frac{1.8}{2} = 0.9\text{A}$$

10. (i) Applying Kirchhoff's voltage law in the closed mesh *ABFEA*, we get,

$$V_B - 0.5 \times 2 + 3 = V_A \Rightarrow V_B - V_A = -2$$

$$V = V_A - V_B = +2\text{V}$$

Potential drop across R is 1 V as R, EF and upper row are in parallel.

(ii) Applying Kirchoff's first rule at E

$$0.5 + I_2 = I$$

where, *I* is current through *R*.

Now, Kirchhoff's second rule in closed mesh *AEFB,*

$$\Sigma E + \Sigma IR = 0$$

$$-4 + 2I_2 - 0.5 \times 2 + 3 = 0 \Rightarrow 2I_2 - 2 = 0$$

or, $I_2 = 1A$

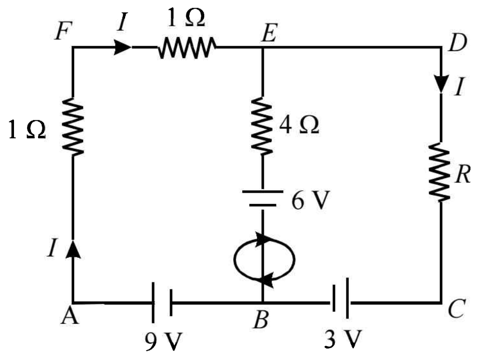
The current in arm *EF* = 1A

11. Applying Kirchhoff's voltage law in mesh *AFEBA*

$$-1 \times I - 1 \times I - 6 + 9 = 0$$

$\Rightarrow$ $-2I + 3 = 0$

$\Rightarrow$ $I = \frac{3}{2} A$ ...(i)



Applying Kirchhoff's voltage law in mesh AFDCA

$$-1\times I-1\times I-I\times R-3+9=0$$

$\Rightarrow\quad -2I-IR+6=0$

$\Rightarrow\quad 2I+IR=6$ ...(ii)

From eqs. (i) and (ii)

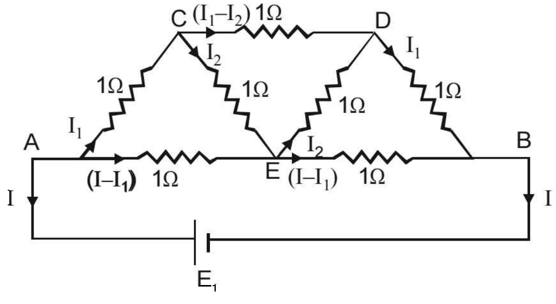
$$\left(2\times\frac{3}{2}\right)+\frac{3}{2}R=6 \quad\Rightarrow\quad R=2\Omega$$

For PD across A and D, along AFD

$$V_A-\frac{3}{2}\times1-\frac{3}{2}\times1=V_D$$

$$V_A-V_D=3V$$

12. Let a cell of e.m.f. E_1 be connected between A and B. The currents through the various arms will be as shown in the fig.



According to Kirchoff's second law, in closed circuit ACEA,

$0=I_1\times1+I_2\times1-(I-I_1)1$ or $I=2I_1+I_2$ ...(i)

In closed circuit CEDC;

$0=I_2\times1+I_2\times1-(I_1-I_2)1$ or $3I_2=I_1$ ...(ii)

Putting this value in eqn. (i), we get

$$I = 2I_1 + I_1/3 \quad \text{or} \quad I_1 = (3/7)I$$

In a closed circuit E_1 AE BE_1,

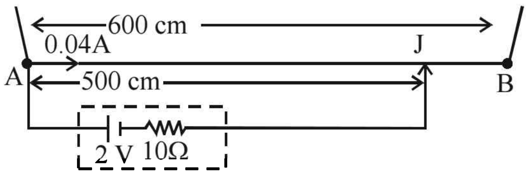
$$E_1 = (I - I_1)1 + (I - I_1)_1 = 2(I - I_1) = 2\left(I - \frac{3I}{7}\right) = \frac{8I}{7}$$

If R is the effective resistance between A and B, then $E_1 = IR$

So, $IR = 8I/7$ or $R = 8/7\,\Omega$

13. (i) Potential gradient of the potentiometer wire

$$= \frac{V_{AB}}{l_{AB}} = \frac{V}{6}$$



The balancing length of the cell is obtained at 500cm. Therefore

V_{AJ} = (Potential gradient of potentiometer wire) × l_{AJ}

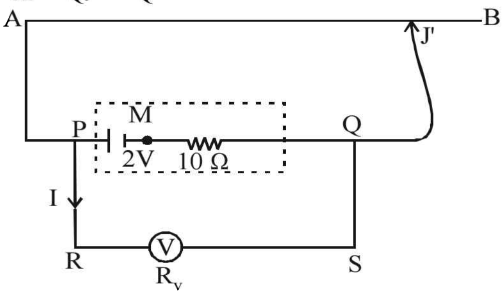
$$\frac{V}{6} \times 5 = 2 \Rightarrow V = \frac{12}{5} = 2.4 \text{ volt}$$

Applying Ohm's law

$$V_{AB} = I R_{AB} \Rightarrow R_{AB} = \frac{V_{AB}}{I} = \frac{2.4}{0.04} = 60\Omega$$

(ii) When a voltmeter is connected across the cell then the balancing point shifts 10 cm left. This is because a current now flows in the loop PRSQP and hence the potential drop across PQ decreases.

Here $I_{AP} = I_{QJ'} = 0\ I_Q$



The potential drop across PQ

V_{PQ} = (potential gradient for potential wire) $\times l_{AJ'}$

$$= \frac{2.4}{6} \times 4.9 = 1.96\text{V}$$

Thus the reading shown by voltmeter is 1.96 V.

(iii) Since the potential drop across PQ is 1.96, therefore the potential drop across MQ should be (2 – 1.96) = 0.04 volt.

Current I through the resistor of 10W

$$= \frac{V_{MQ}}{R_{MQ}} = \frac{0.04}{10} = 0.004\text{A}$$

Applying Ohm's law to PQSRP,

$2 = 0.004\,(10 + R_V) \Rightarrow R_V = 490\,\Omega.$

14. In both the arrangements, since the galvanometer shows no deflection, therefore, the bridge is balanced. The battery and the galvanometer can be interchanged in a balanced Wheatstone bridge without effecting the balance point.

Applying wheatstone bridge principle,

In the first arrangement,

$$\frac{P}{Q} = \frac{R}{S} \quad \Rightarrow \quad \frac{4}{R_1} = \frac{6}{9}$$

or, $$R_1 = \frac{9 \times 4}{6} = 6\Omega$$

And in the second arrangement

$$\frac{6}{12} = \frac{R_2}{8} \quad \Rightarrow \quad R_2 = \frac{8 \times 6}{12} = 4\Omega$$

$$\therefore \quad \frac{R_1}{R_2} = \frac{6}{4} = 1.5$$

15. Meter bridge is based on Wheatstone bridge principle

i.e., $$\frac{P}{Q} = \frac{R}{S}$$

When null point D is at 40 cm from end A

$l_1 = 40$ cm

and $l_2 = 100 - 40 = 60$ cm

$$\therefore \quad \frac{R_1}{R_2} = \frac{40}{60} = \frac{2}{3} \qquad \text{...(i)}$$

When a resistance of 10Ω, is connected in series with R_1,

$$l_1 = 60 \text{ cm}$$
$$l_2 = 100 - 60 = 40 \text{ cm}$$

$$\therefore \quad \frac{R_1 + 10}{R_2} = \frac{60}{40} = \frac{3}{2} \qquad \text{...(ii)}$$

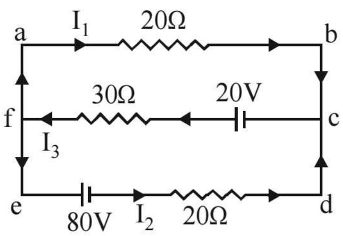
Dividing eqs, (ii) by (i)

$$\frac{R_1 + 10}{R_2} \times \frac{R_2}{R_1} = \frac{\frac{3}{2}}{\frac{2}{3}} = \frac{9}{4}$$

$$\therefore \quad 4(R_1 + 10) = 9R_1$$
$$4R_1 + 40 = 9R_1$$
or $$40 = 5R_1$$
$$\therefore \quad R_1 = 8\Omega$$

and $$R_2 = \frac{3}{2}R_1 = \frac{3}{2} \times 8 = 12\,\Omega$$

16.



From Kirchoff's Ist rule or junction rule

For junction f,

$$I_1 + I_2 = I_3$$
or, $$I_1 = I_3 - I_2 \qquad \text{...(i)}$$

From Kirchoff's 2nd rule or loop rule

In loop 'abcfa'

$$-20I_1 + 20 - 30I_3 = 0$$
or, $$2I_1 + 3I_3 = 2 \qquad \text{...(ii)}$$

In loop 'fcdef,'

$$30I_3 - 20 + 20I_2 - 80 = 0$$
or, $$3I_3 + 2I_2 = 10 \qquad \text{...(iii)}$$

Substituting equation eq.(i) in (ii)

$$2(I_3 - I_2) + 3I_3 = 2$$
or, $$5I_3 - 2I_2 = 2 \qquad \text{...(iv)}$$

Adding equations (iii) and (iv)

$$8I_3 = 12$$
or, $$I_3 = 3/2 \text{ A}$$

Substituting the value of I_3 in equation (iii) and solving we get,

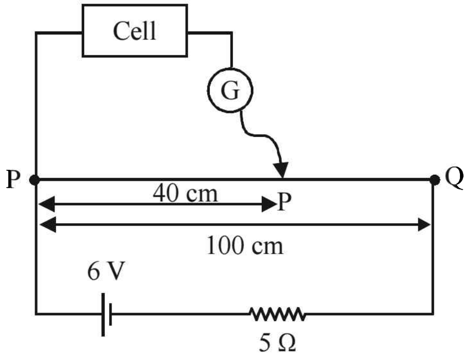
$I_2 = 11/4 A$

Substituting for I_3 and I_2 in equation (i)

$I_1 = 3/2 - 11/4 = -5/4$ A

17. Total resistance of the circuit,

$R = (R_{PQ} + 5)\,\Omega = 15\,\Omega$



Current in the circuit, $i = \frac{V}{R} = \frac{6}{15}$ A

$\therefore$ Voltage across PQ, $V_{PQ} = i.R_{OQ} = 4$ V

emf of the cell, $e = \frac{l}{L} V_0$

Here: balance point is at,

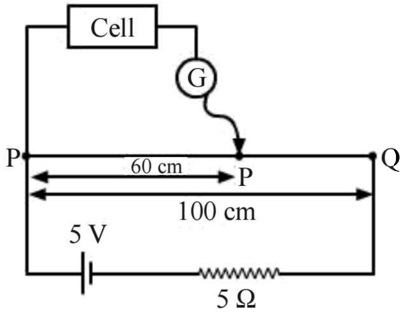
$l = 40$ cm

Total length of wire PQ = L = 1 m = 100 cm

$\therefore \quad e = \frac{40}{100}(4) = 1.6V$

18. Total resistance of the circuit,

$R = (R_{AB} + 5)\,\Omega = 20\,\Omega$



Current in the circuit, $i = \frac{V}{R} = \frac{5}{20}$ A

$\therefore$ Voltage across PQ, $V_{PQ} = i.R_{AB} = 3.75$ V

The emf of the cell connected as above is given by:

$$e = \frac{l}{L} V_o$$

Here balance point is at,

$l = 60$ cm

Total length of wire PQ = L = 1 m = 100 cm

$$\therefore e = \frac{60}{100}(3.75) = 2.25 \text{ V}$$

19. When balance point is at 40 cm, we have

$$\frac{R}{S} = \frac{40}{100-40} = \frac{40}{60} \quad \Rightarrow \quad \frac{R}{S} = \frac{2}{3}$$

$\Rightarrow$ 3 R = 2 S .... (i)

When a resistance of 10 Ω is added in series with *R*,

Then, equivalent reistance of $R' = R + 10$

Now, balance point is obtained at 60 cm.

$$\therefore \quad \frac{R+10}{S} = \frac{60}{100-60} = \frac{60}{40}$$

$$\Rightarrow \quad \frac{R+10}{S} = \frac{3}{2} \Rightarrow 2R + 20 = 3S \qquad \text{...(ii)}$$

Solving eqs (i) and (ii), we get

$S = 12\ \Omega$ and $R = 8\ \Omega$

20. $I = 5$ A, $dl = 1$cm = 0.01m, r = 1 m

$\theta = 45°$ [$\because$ Direction is North-East]

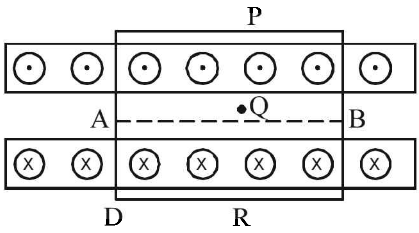
By using Biot Savart's Law,

$$\therefore \quad dB = \frac{\mu_0}{4\pi} \frac{Idl \sin\theta}{r^2}$$

$$= 10^{-7} \times \frac{5 \times 0.01 \times \sin 45°}{(1)^2} = 3.54 \times 10^{-9} \text{ T}$$

Its direction is vertically downwards.

21.



From symmetry, B at P and R should be same. Using Ampere's law,

$$\int_0^L \vec{B}\,.\,\vec{dl} = \mu_0 i = \mu_0(kL - kL)$$

$$\vec{B}.\vec{L} = 0 \Rightarrow B = 0 \text{ hence at P and R, } B = 0$$

Now, let us apply Ampere's law between Q and R.

Here, $$\int_0^L \vec{B}\,.\,\vec{d\ell} = \mu_0 kL$$

$$\Rightarrow BL + 0 \times L = \mu_0 kL \quad (\because \text{ B is zero at R})$$

$$\Rightarrow B = \mu_0 k \quad \text{towards right.}$$

22. The upper limiting value of current to be measured is to be increased by a factor

$$n = \frac{1.0\text{A}}{5\text{A}} = 200$$

$\therefore$ Resistance of the shunt required will be

$$S = \frac{G}{n-1} = \frac{20\Omega}{200-1} \approx 0.1\,\Omega$$

Hence, a shunt of resistance $0.1\,\Omega$ should be connected in parallel across the galvanometer coil.

23. $N_1 = 50, R_1 = 10\Omega, N_2 = 500, R_2 = 600\Omega$

$V = 2.5V, \theta_1 : \theta_2 = ?$

$$I_1 \frac{C}{N_1 BA}\theta_1 = \frac{E}{R_1 + r} \qquad \ldots\ldots \text{(i)}$$

$$I_2 \frac{C}{N_2BA}\theta_2 = \frac{E}{R_2 + r} \qquad \ldots\ldots \text{(ii)}$$

From eqs. (i) and (ii),

$$\frac{N_2}{N_1}\frac{\theta_1}{\theta_2} = \frac{R_2 + r}{R_1 + r} \quad \text{or} \quad \frac{\theta_1}{\theta_2} = \frac{R_2 + r}{R_1 + r}\frac{N_1}{N_2}$$

$$= \frac{600 + 50}{10 + 50}\frac{50}{500} = \frac{650}{60 \times 10} = 13 : 12.$$

24. Here, number of dipoles $n = 2 \times 10^{24}$

Dipole moment of each dipole, $M' = 1.5 \times 10^{-23}\ JT^{-1}$

Total dipole moment of sample

$= n \times M' = 2 \times 10^{24} \times 1.5 \times 10^{-23} = 30$

As saturation achieved is 15%, therefore, effective dipole moment

$$M_1 = \frac{15}{100} \times 30 = 4.5\ JT^{-1};\ B_1 = 0.84\ T, T_1 = 4.2\ K$$

$M_2 = ?\ B_2 = 0.98\ T, T_2 = 2.8\ K.$

According to Curie's law, $\chi_m = \frac{C}{T} = \frac{I_m}{H}$ or $I_m = \frac{CH}{T}$

As $I_m \propto M$ and $H \propto B$

$$\therefore\ M \propto \frac{CB}{T}, \qquad \frac{M_2}{M_1} = \frac{B_2}{B_1} \cdot \frac{T_1}{T_2}$$

$$\text{or} \quad M_2 = \frac{B_2 T_1 M_1}{T_2 B_1} = \frac{0.98 \times 4.2 \times 4.5}{2.8 \times 0.84}, M_2 = 7.875\ JT^{-1}.$$

25. Given : $\ell = 1m$, $B = 5 \times 10^{-3}\ Wb/m^2$

$$f = \frac{1800}{60} = 30 \text{ rotations/sec}$$

In one rotation, the moving rod of the metal traces a circle of radius $r = \ell$

$\therefore$ Area swept in one rotation = πr^2

$$\frac{d\phi}{dt} = \frac{d}{dt}(BA) = B.\frac{dA}{dt} = \frac{B\pi r^2}{T} = B f \pi r^2$$

$$= (5 \times 10^{-3}) \times 3.14 \times 30 \times 1 = 0.471 \text{ V}$$

$\therefore$ e.m.f. induced in a metal rod = 0.471 V

26. Applying Lenz's law

Fig. (1) along $a \rightarrow b$

Fig. (2) along $b \rightarrow a$

Fig. (3) along $c \rightarrow a$

Fig. (4) along $a \rightarrow b$

Fig. (5) no induced current since field lines lie in the plane of the loop.

27. Assuming no loss of power, $E_p I_p = E_s I_s$ (Law of transformer)

$$\therefore \mathbf{I}_p = \frac{E_s \mathbf{I}_s}{E_p} = 4.6 \times \frac{5}{230} = 0.1 \text{A}$$

28. Given:

Self inductance, L = 5 mH = 5×10^{-3} H

Change in current, dI = (1 – 4) = –3 A

Change in time, dt = 30 ms = 30×10^{-3} s

The emf induced in the coil is given by

$$e = -L\frac{dI}{dt} \Rightarrow e = \frac{(-5 \times 10^{-3}) \times (-3)}{30 \times 10^{-3}} \Rightarrow e = 0.5 \text{ V}$$

29. Here $I = \frac{1}{20} I_0 = 0.05\, I_0$

Using $I = I_0 \cos^2\theta$, we get $0.05\, I_0 = I_0 \cos^2\theta$

$$\Rightarrow \cos^2\theta = 0.05 \text{ or } \cos\theta = \sqrt{0.05} = 0.2236$$

$$\therefore \theta = \cos^{-1}(0.2236) = 76°9'$$

30. The critical angle for this case is

$$\theta'' = \sin^{-1}\frac{1}{1.25} = \sin^{-1}\frac{4}{5} \text{ or } \sin\theta'' = \frac{4}{5}$$

Since $\theta'' = \frac{\pi}{2} - \theta'$, we have $\sin\theta' = \cos\theta'' = \frac{3}{5}$

From Snell's law,

$$\frac{\sin\theta}{\sin\theta'} = 1.25 \text{ or } \sin\theta = 1.25 \times \sin\theta' = 1.25 \times \frac{3}{5} = \frac{3}{4}$$

$$\text{or } \theta = \sin^{-1}\frac{3}{4}$$

If θ'' is greater than the critical angle, θ will be smaller than this value. Thus, the maximum value of θ' for which total internal reflection takes place at the vertical surface is $\sin^{-1}(3/4)$.

31. $${}_1^{}\mu_2 = \frac{\sin 90^\circ}{\sin C} = \frac{1}{\sin C} \quad \text{[For critical angle]}$$

$$\therefore \quad C = \sin^{-1}\left(\frac{1}{{}_1\mu_2}\right) \qquad \ldots\text{(i)}$$

Applying Snell's law at P, we get

$${}_1\mu_2 = \frac{\sin r'}{\sin i} = \frac{\sin(90 - r)}{\sin r} \qquad [\because i = r; r' + r = 90^\circ]$$

$${}_1\mu_2 = \frac{\cos r}{\sin r} \qquad \ldots\text{(ii)}$$

From (i) and (ii)

$C = \sin^{-1}(\tan r)$

32. Here $\theta = 60^\circ$,

Using Malus law $I = I_0 \cos^2\theta$, we get

$$I = I_0(\cos 60^\circ)^2 = \frac{1}{4}I_0 \left(\because \cos 60^\circ = \frac{1}{2}\right)$$

$$\therefore \text{ Intensity of transmitted light} = \frac{1}{4} \times 100 = 25\%$$

Thus, the intensity of the transmitted light is 25% of the intensity of incident light.

33. When the reflected and refracted rays are at right angle to each other, the angle of incident is known as angle of polarisation (i_p).

Here, $\theta = 60°$, Using Brewester's law $\mu = \tan i_p$, we get

$\mu = \tan 60° = \sqrt{3} = 1.732$

34. According to law of Malus, $I^{11} = I^{1}\cos^2\theta$

$$I^{11} = \frac{I_0}{2}\cos^2(60°) = \frac{I_0}{2}\left(\frac{1}{2}\right)^2 = \frac{I_0}{8}$$

Therefore, a light of intensity $\frac{I_0}{8}$ will pass through P_3 and the angle between P_3 and P_2 will be 30° because of the condition given in the questions.

Intensity of light after falling on P_2,

$$I^{11} = I^{11}\cos^2(\theta)$$

$$= \frac{I_0}{8}\cos^2(30°) = \frac{I_0}{32}$$

35. According to Einstein's photoelectric equation, $e = (hv - hv_0)$

$$eV = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) \quad ...(1)$$

$$\frac{eV}{3} = hc\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right) \quad ...(2)$$

Dividing eq. (1) by eq. (2), we get $3 = \frac{\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)}{\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right)}$

$$\text{or } 3\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right) = \frac{1}{\lambda} - \frac{1}{\lambda_0}$$

$$\Rightarrow \frac{3}{2\lambda} - \frac{1}{\lambda} = \frac{3}{\lambda_0} - \frac{1}{\lambda_0} \text{ or } \frac{1}{2\lambda} = \frac{2}{\lambda_0}$$

$\therefore \quad \lambda_0 = 4\lambda$

36. **Brewster angle:** It is related to refractive index as $\mu = \tan i_p$

$\therefore \quad i_p = \tan^{-1}\mu = \tan^{-1} 1.5 = 56.3°$

37. Energy of electron in *n*th orbit of hydrogen atom

$$E_n = -\frac{13.6}{n^2} eV$$

For n = 1, $\Rightarrow$ $E_1 = -13.6\,eV$

For n = 2, $\Rightarrow$ $E_2 = -\frac{13.6}{4} = -3.4eV$

Energy of photon released $= E_2 - E_1$
$= (-3.4) - (-13.6)$
$= 10.2\text{ eV} = h\nu$

Also, $KE_{max} = 8\text{ eV}$

According to Einstein photoelectric equation

$KE_{max} = h\nu - \phi$

$8\text{ eV} = 10.2\text{ eV} - \phi$

Work function $(\phi) = 2.2\text{ eV}$

We know, work function

$$W = h\nu_0 = \frac{hc}{\lambda_0}$$

$$\lambda_0 = \frac{hc}{W} = \frac{6.634\times10^{-34}\times3\times10^{8}}{2.2\times1.6\times10^{-19}} = 564.5\text{ nm}$$

38. $E_n = 13.6/n^2$

$E_3 = -(13.9/9) = -1.51\text{ eV}$

and $E_4 = -(13.6/16) = -0.85\text{ eV}$

Now $E_4 - E_3 = -0.85 - (-1.51) = 0.66\text{ eV}$

39. According to radioactive decay law,

$$\frac{dN_X}{dt} = \lambda_1 N_X = \lambda_1 (N_0/4) \quad (\because N = N_0/2^n) \text{ and}$$

$$\frac{dN_Y}{dt} = \lambda_2 N_Y = \lambda_2 (N_0/2)$$

$$\therefore \left(\frac{dN_X}{dt}\right) \Big/ \left(\frac{dN_Y}{dt}\right) = \frac{\lambda_1}{2\lambda_2} = \frac{T_2}{2T_1} = \frac{2}{2\times1} = \frac{1}{1}$$

$$\left(\because \lambda = \frac{0.693}{T}\right)$$

40. According to Avogadro's hypothesis,

$$N_0 = \frac{6.02\times10^{23}}{226} = 2.66\times10^{21}$$

Halflife, $T = \frac{0.6931}{\lambda} = 1620\text{ years}$

$$\therefore \quad \lambda = \frac{0.6931}{1620\times3.16\times10^{7}} = 1.35\times10^{-11}\,s^{-1}$$

Because halflife is very much large as compared to its time interval, hence $N \approx N_0$

$$\frac{dN}{dt} = \lambda N = \lambda N_0 \quad \text{or} \quad dN = \lambda N_0 dt \quad \text{(Radioactive decay law)}$$

$$\therefore \quad dN = (1.35\times10^{-11})\,(2.66\times10^{21})(1) = 3.61\times10^{10}.$$

41. Photon is emitted when electron transits from higher energy state to lower energy state, the difference of energy of the state appear in form of energy of photon. According to Bohr's theory of hydrogen atom, energy of photon released, $E_2 - E_1 = hv$

Given, $E_1 = -1.51\text{ eV}$

$E_2 = -0.85\text{ eV}$

$\Delta E = E_2 - E_1$

$= -0.85 - (-1.51) = 1.51 - 0.85$

$\Delta E = E_2 - E_1 = 0.66\text{ eV}$

So, the wavelength of emitted spectral line,

$$\because \quad \Delta E = \frac{hc}{\lambda}$$

$$\therefore \quad \lambda = \frac{hc}{\Delta E} = \frac{6.634\times10^{-34}\times3\times10^{8}}{0.66\times1.6\times10^{-19}} = 1.88\times10^{-6}\,m$$

$\lambda = 1.88\times10^{-6}m$

As here, $\lambda = 1.88\times10^{-6}\,m \approx 18751\times10^{-10}\,m = 18751\text{ Å}$

The wavelength belongs to Paschen series of hydrogen spectrum.

42. Let t be the required time after which the undecayed fraction of the material will be 6.25%.

$\therefore \quad \frac{6.25}{100} = \frac{1}{16} \quad \therefore \quad N = \frac{N_0}{16}$

But $\quad N = N_0\left(\frac{1}{2}\right)^n \quad$ where $n = \frac{t}{T}$

$\Rightarrow \quad \frac{N_0}{16} = N_0\left(\frac{1}{2}\right)^n \Rightarrow n = 4$

$\therefore$ Time' $t = n \times T$

$\Rightarrow$ $t = 4 \times 100 = 400$ days

□ □ □

Sample Papers

GP_3166

SAMPLE PAPER-1

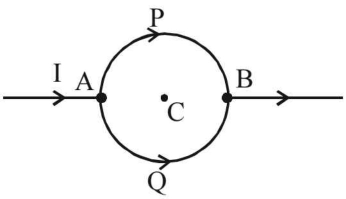
Time : 3 Hrs. **Max. Marks : 70**

GENERAL INSTRUCTIONS

1. All questions are compulsory.
2. There are **26** questions in total. Q. no. **1** to **5** carry **1** mark each, Q. **6** to **10** carry **2** marks each, Q. **11** to **22** carry **3** marks each, Q. **23** is a value based question carry **4** marks, Qs. **24** to **26** carry **5** marks each.
3. There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each. You have to attempt only one of the given choices in such questions.
4. Use of calculator is not allowed.
5. You may use the following physical constants wherever necessary:
   $c = 3 \times 10^8\ ms^{-1}$, $h = 6.6 \times 10^{-34}$ Js, $e = 1.6 \times 10^{-19}$ C,
   $\mu_0 = 4\pi \times 10^{-7}$ Tm A^{-1}.
   Boltzmann constant $k = 1.38 \times 10^{23}\ JK^{-1}$, Avogadro's number $N_A = 6.023 \times 10^{23}$ /mole,
   Mass of neutron $m_n = 1.6 \times 10^{-27}$ kg

SECTION - A

1. Consider the circuit shown here where APB and AQB are semi circles. What will be the magnetic field at the centre C of the circular loop?

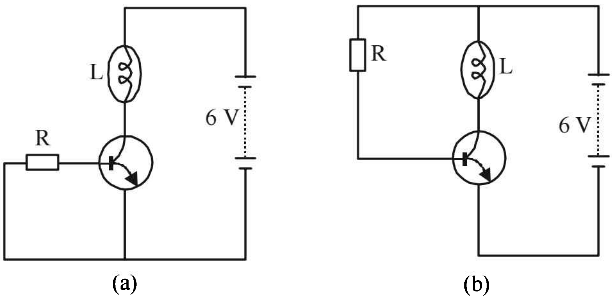


2. The magnetic flux threading a coil changes from 12×10^{-3} Wb to 6×10^{-3} Wb in 0.01 s. Calculate the induced e.m.f.
3. What is the cause of displacement current?

4. If the frequency of incident light is double, what will be the k.E. of the electrons emitted?
5. Which property of a p–n junction is used in rectification of a.c. voltages?

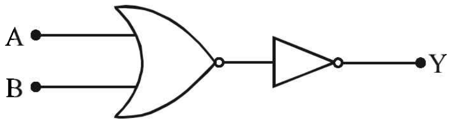
SECTION - B

6. The potentials of two charged conductors are V_1 and V_2 and their capacitances are C_1 and C_2 respectively. When these are connected by a wire, the changes in their potentials are ΔV_1 and ΔV_2 respectively. Prove that $\Delta V_1 / \Delta V_2 = C_2/C_1$.
7. If the temperature of a good conductor increases, how does the relaxation time of electrons in the conductor change ?
8. The velocity of light in air is 3×10^8 ms^{-1} and in a liquid is 2.5×10^8 ms^{-1}. If the ray of light passes from liquid to air, calculate the value of critical angle.
9. Define the terms magnetic declination and dip angle. Value of dip at a place in South India is 18°. Will it be more or less as that of the value in England ?
10. In only one of the circuits given below the lamp L lights. Which circuit is it ? Give reason for your answer.

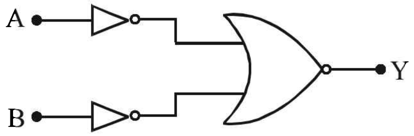


OR

You are given the two circuits as shown in Fig. Show that circuit (a) acts as OR gate while the circuit (b) acts as AND gate.



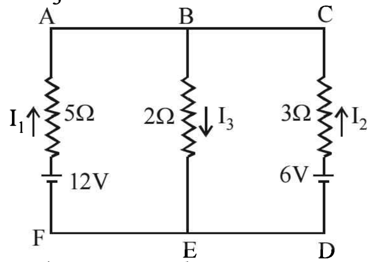
(a)



(b)

SECTION - C

11. Using kirchhoff's laws in the given electrical network, calculate the values of I_1, I_2 and I_3.



12. A pure inductor is connected across an a.c. source. Show mathematically that the current in it lags behind the applied emf by a phase angle of $\pi/2$. What is its inductive reactance? Draw a graph showing the variation of inductive reactance with the frequency of the a.c. source.

13. A converging lens A of focal length 10 cm is separated by 4 cm from a diverging lens B of focal length 15 cm. A parallel beam of light falls on A, emerges from B and is focussed at a point I. Find the position of I.

14. Obtain an expression for the kinetic energy of the electron in the Bohr model of hydrogen atom ($Z = 1$). Start from equating the electrostatic force with the centripetal force required and then use the quantisation condition for angular momentum.

15. Obtain a relation for law of radioactive decay.

OR

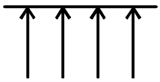
Obtain Bohr's quantisation condition of angular momentum on the basis of wave nature of electron.

16. Compare n-type and p-type semiconductors.

17. What is role of sky wave propagation in transmission of high frequency signals ? Explain.

18. Draw the ray diagram showing the formation of image of an object by the compound microscope.

19. A plate of mass 10 g is in equilibrium in air due to the force exerted by a light beam on the plate. Calculate power of the beam. Assume plate is perfectly absorbing.



20. Explain with a circuit diagram how the internal resistance of a cell can be measured by a potentiometer ?

21. A convex lens of focal length 20 cm and a concave lens of focal length 5 cm are kept along the same axis with a separation 'd' between them. what is the value of d, if a parallel beam of light incident on convex lens, leaves the concave lens as a parallel beam?

22. Show how OR gate is realised from NAND gate.

SECTION - D

23. Ramu was working with his son in his field. There was a big high tension tower. His son asked his father why not they remove high tension tower from their field so that they may get more space for crops. Ramu explained the necessity of high tension tower in their life and said that it is very high voltage ac transmission line.

(i) What values are displayed by Ramu?

(ii) Why long distance ac transmission is done at very high voltage?

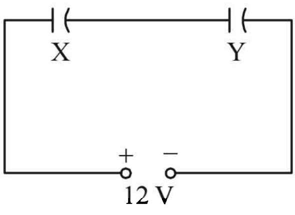
(iii) Name the device used for the transmission and distribution of electrical energy over long distances.

(iv) Write the principle on which transformer works.

SECTION - E

24. Using Gauss' theorem, derive an expression for the electric field intensity due to an infinitely long, straight wire of linear charge density λ C/m.

X and Y are two parallel plate capacitors having the same area of plates and same separation between the plates. X has air between the plates and Y contains a dielectric medium of $\varepsilon_r = 5$.



(i) Calculate the potential difference between the plates of X and Y.
(ii) What is the ratio of electrostatic energy stored in X and Y ?

OR

A hollow charged conductor has a tiny hole cut into its surface. Show that the electric field in the hole is $(\sigma/2\varepsilon_0)\,\hat{n}$, where $\hat{n}$ is the unit vector in the outward normal direction, and σ is the surface charge density near the hole.

An electric dipole of length 10 cm having charges $\pm 6 \times 10^{-3}$ C, placed at 30° with respect to a uniform electric field, experiences a torque of magnitude $6\sqrt{3}$ Nm. Calculate the magnitude of the electric field.

25. Explain with the help of a labelled diagram and underlying principle, construction and working of a cyclotron.

OR

What is the force acting on a moving charge in a magnetic field? Discuss the cases when the force is maximum and minimum and define the unit of magnetic field B?

A short conductor of length 5 cm is placed parallel to a long conductor of length 1.5 m near its centre. The conductors carry currents 4 A and 3A respectively in the same direction. What is the total force experienced by the long conductor when they are 3 cm apart?

26. Derive the relation,

(a) $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ where symbols have their usual meanings.

(b) A small object is placed at distance of 40 cm from a convex spherical refracting surface of radius of curvature 15 cm. If the surface separates air from glass of refractive index 1.5, find the position of the image.

OR

(a) Derive the lens maker's formula.

(b) The radii of curvature of the faces of a double convex lens are 10cm and 15m. It's focal length is 12cm. What is the refractive index of glass?

SAMPLE PAPER-2

Time : 3 Hrs. **Max. Marks : 70**

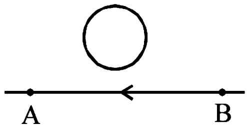
GENERAL INSTRUCTIONS

1. All questions are compulsory.
2. There are **26** questions in total. Q. no. **1** to **5** carry **1** mark each, Q. **6** to **10** carry **2** marks each, Q. **11** to **22** carry **3** marks each, Q. **23** is a value based question carry **4** marks, Qs. **24** to **26** carry **5** marks each.
3. There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each. You have to attempt only one of the given choices in such questions.
4. Use of calculator is not allowed.
5. You may use the following physical constants wherever necessary:
   $c = 3 \times 10^8\ ms^{-1}$, $h = 6.6 \times 10^{-34}$ Js, $e = 1.6 \times 10^{-19}$ C,
   $\mu_0 = 4\pi \times 10^{-7}$ Tm A^{-1}.
   Boltzmann constant $k = 1.38 \times 10^{23}\ JK^{-1}$, Avogadro's number $N_A = 6.023 \times 10^{23}$ /mole,
   Mass of neutron $m_n = 1.6 \times 10^{-27}$ kg

SECTION - A

1. Why is a voltmeter always connected in parallel with a circuit element across which voltage is to be measured?

2. The electric current in the direction from B to A is decreasing. What is the direction of induced current in the metallic loop kept above the wire as shown in the figure.



3. What factor determines the height of receiving antenna in space waves?

4. What is the value of power radiated by an antenna?

5. How does the refracted ray travel inside the prism at the minimum deviation position?

SECTION - B

6. Two point electric charges of unknown magnitude and sign are placed at a distance 'd' apart. The electric field intensity is zero at a point, not between the charges but on the line joining them. Write two essential conditions for this to happen.
7. Does the same phenomenon responsible for the colours of a soap bubble seen in sun light and the colours emerging from a prism?

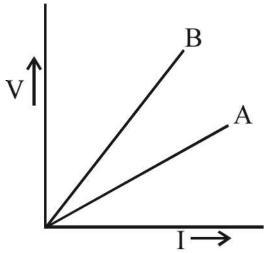
OR

Give two points of difference between interference and diffraction.

8. If the frequency of incident light on a metal surface is doubled, will the K.E. of electrons be doubled?
9. What is depletion region? Explain how barrier is created in this region?
10. Two metals A and B have work function 2eV and 6eV respectively which of these will emit radiation when irradiated by light of wavelength 400 nm?

SECTION - C

11. (i) V-I graph for parallel and series combination of two metallic resistors are as shown in the figure. Which graph shows parallel combination? Justify your answer.



(ii) A carbon resistor of 74 kΩ is to be marked with rings of different colours for its identification. Write the sequence of colours.

12. What is an equipotential surface? Show that the electric field is always directed perpendicular to an equipotential surface.
13. How will you convert a galvanometer into a voltmeter?
14. Describe briefly emission and absorption spectra.
15. Derive from Biot - Savart's law, the magnetic field at a point on the axis of a circular coil carrying current.

16. Give two characteristics of electromagnetic waves. Write the expression for velocity of electromagnetic waves in terms of permittivity and permeability of the medium.

17. A T.V. transmission tower at a particular station has a height of 160 m.

(a) What is coverage range

(b) How much population is covered by transmission, if the average population, density around the tower is $1200 km^{-2}$?

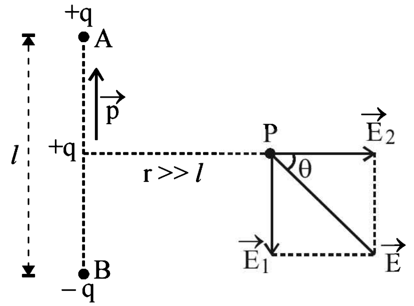
(c) By how much the height of the tower be increased to double its coverage range?

$R_{earth} = 6400$ km

OR

If the maximum values of signal and carrier waves are 4 volt and 5 volt respectively then find (i) the maximum and minimum value of the modulated amplitude in volts (ii) the percentage of modulation.

18. Define the electric field at the point P due to the system of three point charges, shown.



19. Derive an expression for the current obtained for n cells connected in series. Hence derive the condition for maximum current.

20. Derive the relation, $\delta = (n_{12} - 1)A$.

21. A plane wave front is incident on

(i) a prism (ii) a convex lens.

Draw the emergent wavefront in each case.

22. (i) What is meant by half-life of a radioactive element?

(ii) The half-life of a radioactive substance is 30 s. Calculate

(a) the decay constant and

(b) time taken for the sample to decay by 3/4th of the initial value.

SECTION - D

23. Bharat was performing an experiment to carry out a project, for that he required an ammeter of range 7.5 A. It was not available in the laboratory and in the market. So, he decided to convert a galvanometer of resistance 12 Ω and showing full scale deflection current of 2.5 mA into an ammeter of given range.
(i) What values do you think are there in Bharat?
(ii) How could he do that? Explain by showing calculations.

SECTION - E

24. Derive an expression for (i) induced e.m.f and (ii) induced current when a conductor of length l is moved with a uniform velocity v, normal to a uniform magnetic field B. Assume the resistance of conductor to be R.

OR

Describe briefly the principle, construction and working of a transformer. Why is its core laminated?

25. Discuss how transistor when given a feedback in the amplifier works as an oscillator.

OR

(i) Draw the circuit for studying the input and output characteristics of a transistor in CE configuration. Show, how from the output characteristics, the information the current amplification factor (β_{AC}) can be obtained?
(ii) Draw a plot of the transfer characteristics (V_0 versus V_i) for a base biased transistor in CE configuration. Show for which regions in the plot, the transistor can operate as a switch?

26. Drive the prism formula, $n_{12} = \dfrac{\sin\dfrac{(A+\delta_m)}{2}}{\text{Sin}\dfrac{A}{2}}$

Draw the graph showing the variation of the angle of deviation with angle of incidence, through a prism.

OR

(i) Why convex mirror is used to see the traffic at back while driving a car?
(ii) How will you explain twinkling of stars?
(iii) What is Rayleigh's law of scattering?
(iv) How are the rainbows formed?
(v) Does a beam of white light give a spectrum on passing through a hollow prism?

SAMPLE PAPER-3

Time : 3 Hrs. **Max. Marks : 70**

GENERAL INSTRUCTIONS

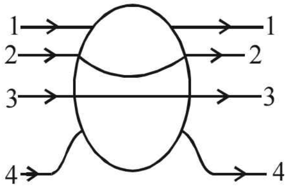
1. All questions are compulsory.
2. There are **26** questions in total. Q. no. **1** to **5** carry **1** mark each, Q. **6** to **10** carry **2** marks each, Q. **11** to **22** carry **3** marks each, Q. **23** is a value based question carry **4** marks, Qs. **24** to **26** carry **5** marks each.
3. There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each. You have to attempt only one of the given choices in such questions.
4. Use of calculator is not allowed.
5. You may use the following physical constants wherever necessary:
   $c = 3 \times 10^8\ ms^{-1}$, $h = 6.6 \times 10^{-34}$ Js, $e = 1.6 \times 10^{-19}$ C,
   $\mu_0 = 4\pi \times 10^{-7}$ Tm A^{-1}.
   Boltzmann constant $k = 1.38 \times 10^{23}\ JK^{-1}$, Avogadro's number $N_A = 6.023 \times 10^{23}$ /mole,
   Mass of neutron $m_n = 1.6 \times 10^{-27}$ kg

SECTION - A

1. What is expression for λ of an e^- moving under potential difference of 1V?
2. What is the work done in moving a charge of 50 nC between two points on an equipotential surface?
3. For long distance radio broadcast, we use short wave band only, why?
4. Why is slight shaking of a picture of a T.V. screen noticed when a low flying aircraft passes overhead?
5. State the condition in which terminal voltage across a secondary cell is equal to its e.m.f

SECTION - B

6. A metallic solid sphere is placed in a uniform electric field as shown in figure. Which path is followed by the lines of force?



7. What do you mean by chromatic aberration? How can it be removed?

OR

The size of the slit is increased three times in a single slit experiment; what changes are observed in (i) the intensity (ii) the width of the central maxima?

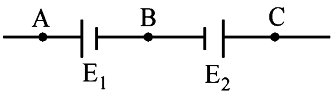
8. A choke coil and a bulb are connected in series to an a.c source. The bulb shines brightly. How does the brightness change when an iron core is inserted in the choke coil?

9. Calculate the potential at the centre of a square ABCD of side $\sqrt{2}$ m each due to charges 2, – 2, – 3 and 6 μC at 4 corner of it.

10. Describe the application of junction diode as a half wave rectifier.

SECTION - C

11. Two cells of e.m.f E_1 and E_2 ($E_1 > E_2$) are connected as shown in the figure.



When a potentiometer is connected between A and B, the balancing length of the potentionmeter wire is 300 cm. On connecting the same potentiometer between A and C, the balancing length is 100 cm. Calculate the ratio of E_1 and E_2.

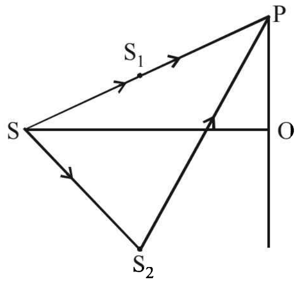
12. The work function of a sample is 1.8 eV. Light of $\lambda = 5000$ Å falls on it. Calculate
    (i) threshold frequency
    (ii) maximum kinetic energy of emitted electrons
    (iii) maximum velocity of emitted e^-

(iv) if intensity of the incident light be doubled then what will be the maximum kinetic energy of emitted electrons?

13. (a) A toroidal solenoid with an air core has an average radius of 15 cm, area of cross section 12 cm^2 and 1200 turns. Obtain the self inductance of toroid. Ignore field variation across the cross-section of the toroid.

(b) A second coil of 300 turns is wound closely on the above toroid. If the current in the primary coil is increased from 0 to 2 A in 0.05s, obtain the induced emf in the second coil.

14. In double slit experiment SS_2 is greater than SS_1 by 0.25 λ. Calculate the path difference between two interfering beam from S_1 and S_2 for maxima and minima on the point P as shown in figure.



15. On giving energy to H-atom, transition occurs from energy level n = 1 to n = 4. If the ionisation potential of hydrogen is 13.6 V. Find (i) energy absorbed in transition, (ii) the wavelength of emitted radiation if the atom comes back to its initial state.

16. Obtain approximately the ratio of nuclear radii of $^{197}_{79}Au$ and $^{107}_{47}Ag$. What is the approx ratio of their nuclear densities?

17. What are the probable causes of the earth's magnetism?

18. A parallel plate capacitor with air between its plates having plate area of 6×10^{-3} m^2 and separation between them 3 mm is connected to a 100 V supply. Explain what would happen when a 3 mm thick mica sheet of dielectric constant 6 is inserted between the plates (a) while voltage supply remains constant and (b) while voltage supply is disconnected.

19. Why modulation is necessary? What factors prevent efficient transmission of signals? How can we over come these'?

20. Explain the principle and working of a potentiometer. How will you find the value of e.m.f of a cell using a potentiometer?

OR

Define resistivity of material. State its S. I units and discuss its variation with temperature in case of (i) metals (ii) semiconductors and (iii) insulators.

21. A parallel plate capacitor made of circular plates each of radius R= 6 cm has a capacitor C = 100 pF. The capacitor is connected to a source of A.C. supply of r.m.s. voltage 230 V with an angular frequency of 300 rad/s.

(a) What is the r.m.s. value of the conduction current?

(b) Is the conduction current equal to the displacement current?

(c) Determine the magnitude of magnetic field intensity B at a point 3cm from the axis between the plates.

22. Describe the motion of a charged particle in a uniform magnetic field. Obtain an expression for the radius of the path of the charged particle moving perpendicular to uniform magnetic field.

SECTION - D

23. Ramu and somu were going to their friend's house by walk. It was a sunny day in the afternoon. It was very hot. Ramu was finding it very difficult to see around him. He had to strain his eyes to see. Suddenly, Somu took his cooling glasses from his pocket and asked him to wear them and later, Ramu slowly managed to see. Somu advised Ramu on the necessity of wearing sun glasses during summer season.

(i) What are the values shown by Somu?

(ii) Name the phenomenon based on which cooling glasses reduce the glare.

(iii) What is the resultant intensity of light if both polariser and analyser are rotated through same angle?

SECTION - E

24. What is induced e.m.f? Write Faraday's law of electromagnetic induction. Explain it mathematically. A conducting rod of length 'l', with one end pivoted, is rotated with a uniform angular speed 'ω' in a vertical plane, normal to a uniform magnetic field 'B'. Deduce an expression for the emf induced in this rod.

OR

Calculate an expression for the average power consumed in an LCR circuit over a complete time period. Hence define the power factor.

25. (i) How is p – n junction formed ? Explain.

(ii) Describe full wave rectification by diode.

(iii) Discuss how AND gate is realised from NAND gate.

OR

(i) Explain how reverse current suddenly increases at breakdown voltages?

(ii) A p-n junction when FB has a drop of 0.6 V which is assumed to be independent of current. The current in excess of 10 mA through the diode produces a large Joule's heating effect which burns the diode. If we want to use 1.5 V battery to F.B the diode, what should be the value of resistor used in series with the diode so that the maximum current doesn't exceed 6 mA?

26. (i) What is the effect on the interference fringes to a Young's doubles slit experiment when

(a) the separation between the two slits is decreased?

(b) the width of the source and slit is increased?

(c) the monochromatic source is replaced by a source of white light? Justify your answer in each case.

(ii) The intensity at the central maxima in Young's double slit experimental setup is I_0. Show that the intensity at a point, where the path difference is $\lambda/3$, is $I_0/4$.

OR

(i) What are polaroids? Write their uses.

(ii) A plane wave front is incident on

(a) a prism (b) a convex lens.

Draw the emergent wavefront in each case.

HINTS & SOLUTIONS

SAMPLE PAPER-1

SECTION - A

1. Total magnetic field at the centre of the loop will be zero because direction of magnetic field due to semicircle APB and semicircle AQB are opposite and magnitude is equal. (½ mark + ½ mark)

2. Here, $\phi_1 = 12 \times 10^{-3}$ Wb; $\phi_2 = 6 \times 10^{-3}$ Wb and dt = 0.01 s

Now, $e = -\dfrac{d\phi}{dt}$ (½ mark)

$$= -\frac{6\times10^{-3} - 12\times10^{-3}}{0.01} = \frac{6\times10^{-3}}{0.01} = 0.6\text{ V}$$ (½ mark)

3. The charging electric field between the plates of a capacitor causes displacement current. (1 mark)

4. K.E. will be more than doubled (1 mark)

5. The forward bias resistance is low as compared to reverse bias resistance. This property is used in rectification. (1 mark)

SECTION - B

6. Total charge before connecting is $(C_1V_1 + C_2V_2)$. On connecting, the conductor will be at equal potentials; so that the potential of one will increase and that of the other will decrease. The total charge is now $C_1(V_1 + \Delta V_1) + C_2(V_2 - \Delta V_2)$. This must be same as the total charge before connecting. (1 mark)

Hence

$$C_1[V_1 + \Delta V_1] + C_2[V_2 - \Delta V_2] = C_1V_1 + C_2V_2$$

$$\Rightarrow C_1V_1 + C_1\Delta V_1 + C_2V_2 - C_2\Delta V_2 = C_1V_1 + C_2V_2$$

$$\Rightarrow \frac{\Delta V_1}{\Delta V_2} = \frac{C_2}{C_1}$$ (1 mark)

7. $R = \dfrac{V}{I} = \dfrac{m\ell}{ne^2A\tau}$ ...(i) (1 mark)

Also R increases when temperature increases, because

$R_T = R_0 [1 + \alpha (T - T_0)]$ ...(ii)

So, T is proportional to R & R is inversely proportional to τ.

Thus, $T \alpha 1/\tau$

So, if temperature increases, relaxation time (τ) decreases. (1 mark)

8. Given : $c = 3 \times 10^8\ ms^{-1}$, $v = 2.5 \times 10^8 ms^{-1}$, c = ?

$$\mu = \frac{c}{v} = \frac{3 \times 10^8}{2.5 \times 10^8} = 1.2$$ (1 mark)

As, $\sin c = \frac{1}{\mu} = \frac{1}{1.2} = 0.8333$ (1 mark)

$\sin c \approx \sin 57° \quad \therefore \quad c = 57°$

9. **Declination (D) :** It is the angle between earth's geographic meridian and magnetic meridian at the given place. (½ mark)

Inclination (angle of dip) (θ) : It is the angle between earth's magnetic field and the horizontal at the given place. Hence, it is maximum i.e. 90° at magnetic north and south poles and minimum i.e. zero at magnetic equator. (½ mark)

As we go from equator to pole, angle of dip increases from zero to 90°. So, angle of dip in England will be more than in South India. (1 mark)

10. In case of (a) Emitter-base is forward biased and collector -base is reverse biased. (1 mark)

Hence current will flow and bulb will light up. (1 mark)

OR

(a) Output of NOR = $\overline{A + B}$

Output of NOT = $\overline{\overline{A + B}} = A + B$ (½ mark)

Truth table:

A	B	$\overline{A+B}$	$\overline{\overline{A+B}} = Y = A + B$
0	0	1	0
0	1	0	1
1	0	0	1
1	1	0	1

(½ mark)

$\therefore$ Circuit acts as OR gate.

(b) Output of 1st NOT gate = $\overline{A}$

Output of 2nd NOT gate = $\overline{B}$ (½ mark)

Output of NOR gate = $\overline{\overline{A}+\overline{B}} = A\,.\,B$

Truth table:

A	B	$\overline{A}$	$\overline{B}$	$\overline{A}+\overline{B}$	$\overline{\overline{A}+\overline{B}} = A.B = Y$
0	0	1	1	1	0
0	1	1	0	1	0
1	0	0	1	1	0
1	1	0	0	0	1

(½ mark)

∴ Circuit acts as AND gate.

SECTION - C

11. At point B, applying kirchhoff's 1st law,

$I_1 + I_2 = I_3$ .... (1)

For the loop ABEFA, applying 2nd law, (1 mark)

$5I_1 + 2I_3 = 12$

$\Rightarrow 5I_1 + 2(I_1 + I_2) = 12$

$\Rightarrow 7I_1 + 2I_2 = 12$ .... (2)

For the loop BCDEB, $-3I_2 - 2I_3 = -6$

$\Rightarrow 3I_2 + 2(I_1 + I_2) = 6$

$\Rightarrow 2I_1 + 5I_2 = 6$ .... (3) (1 mark)

Solving (2) and (3) we get

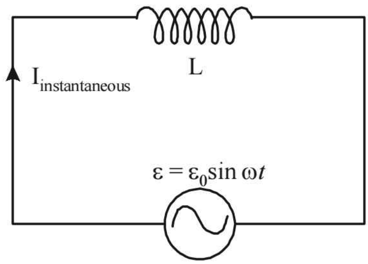
$$I_1 = \frac{48}{31}A,\ I_2 = \frac{18}{31}A,$$

$$I_3 = I_1 + I_2 = \frac{48}{31} + \frac{18}{31} = \frac{66}{31}A$$ (1 mark)

12. AC circuit containing only an inductor (L) : (Purely inductive circuit)
Let us consider a sinusoidally varying a.c. voltage given by

$\varepsilon = \varepsilon_0 \sin \omega t$ ...(i)

As per Faraday's laws of electromagnetic induction, induced emf across the inductor = (– L dI/dt)



(½ mark)

Applying Kirchhoff's rule, (½ mark)

$$\varepsilon_0 \sin\omega t - L\frac{dI}{dt} = 0$$

$$\therefore \quad \frac{dI}{dt} = \frac{\varepsilon_0}{L}\sin\omega t$$

$$\therefore \quad dI = \frac{\varepsilon_0}{L}\sin\omega t . dt$$

$$\int dI = \int \frac{\varepsilon_0}{L}\sin\omega t . dt$$ (½ mark)

$$I = -\frac{\varepsilon_0}{\omega L}\cos\omega t = \frac{\varepsilon_0}{\omega L}\sin(\omega t - \pi/2)$$

or $I = I_0 \sin(\omega t - \pi/2)$ ...(ii) (½ mark)

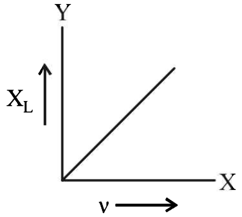
Equations (i) & (ii) shows that current lags behind the emf by $\pi/2$.

Inductive reactance : It is the opposition offered by an inductor towards the flow of A.C. through it.

It is given by (1 mark)

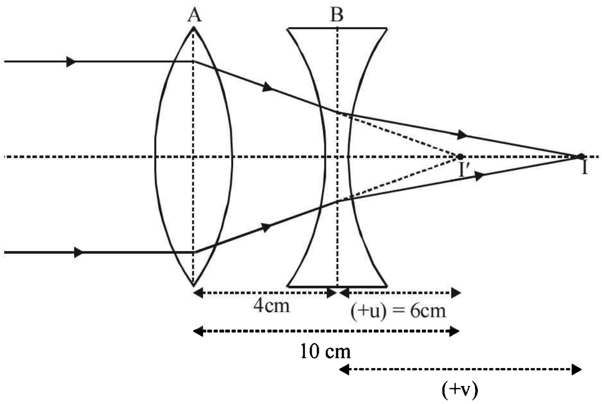
$X_L = \omega L$ (ohm)

or $X_L = 2\pi\nu L$ (ohm)



(½ mark)

13.



(1½ marks)

In the absence of diverging lens B, the beam of light will be focussed at a point I′ which is second principal focus of the converging lens A. Wben the diverging lens B is in place, I′ will act as a virtual point object for B and a final real point image I will be formed. Applying the lens formula for B, we have

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{v}-\frac{1}{+6}=\frac{1}{-15}$$ (1½ marks)

$$\Rightarrow \quad \frac{1}{v}=\frac{1}{6}-\frac{1}{15} \Rightarrow v=+10\,cm$$

i.e., the final point image I is at the distance 10 cm from B.

14. Given that F_C (electrostatic force) is equal to centripetal force.

$$\Rightarrow \quad \frac{mv^2}{r}=\frac{1}{4\pi \epsilon_0}\frac{e^2}{r^2} \quad ...(1)$$ (½ mark)

as $q_1 = q_2 = e$ and $Z = 1$

and $mvr = \frac{nh}{2\pi}$ (assumption of Bohr's model quantisation condition) ...(2) (½ mark)

From equation (1),

$$mv^2 r=\frac{1}{4\pi \epsilon_0}e^2 \quad ...(3)$$

Dividing (3) by (2),

$$v=\frac{1}{4\pi \epsilon_0}.e^2.\frac{2\pi}{nh}$$

$$v=\frac{e^2}{2\epsilon_0 nh}$$ (1 mark)

Kinetic energy,

$$K=\frac{1}{2}mv^2$$

$$=\frac{1}{2}.m\left(\frac{e^2}{2\epsilon_0 nh}\right)^2$$

$$=\frac{me^4}{8\epsilon_0^2 n^2h^2}$$ (1 mark)

15. If N = no. of nuclei in the sample
ΔN = no. of nuclei undergoing decay in time Δt then, the no. of nuclei undergoing decay per unit time is proportional to total no. of nuclei in the sample.

$$\therefore \quad \frac{\Delta N}{\Delta t} \propto N \Rightarrow \frac{\Delta N}{\Delta t} = \lambda N \text{ ; } \lambda = \text{decay or disintegration const.}$$

(1 mark)

Since, no. of nuclei decreases with time,

$\therefore$ $dN = -\Delta N$ in time Δt,

$\therefore$ Rate of change $\frac{dN}{dt} = -\lambda N$ (1 mark)

$$\left(\lim_{\Delta t \to 0} \frac{\Delta N}{\Delta t} = \frac{dN}{dt} \text{ is} - \text{ve} \right) \Rightarrow \frac{dN}{N} = -\lambda dt$$

Integrating from limit N_0 to N, $\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_{t_0}^{t} dt$

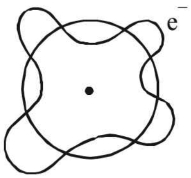
$\Rightarrow \ln N - \ln N_0 = -\lambda (t - t_0)$

Put, $t_0 = 0$ (initial time)

$\Rightarrow \ln \frac{N}{N_0} = -\lambda t \Rightarrow \frac{N}{N_0} = e^{-\lambda t} \Rightarrow N = N_0 e^{-\lambda t}$ (1 mark)

This is radioactive decay law.

OR



Wben an electron of mass m is confined to move on a line of length l with velocity v, the de-Broglie wavelength λ associated with electron is $\lambda = \frac{h}{mv} = \frac{h}{p}$ where p = linear momentum. (1 mark)

$\Rightarrow \quad p = \frac{h}{\lambda} = \frac{h}{2\ell / n} = \frac{nh}{2\ell}$ (½ mark)

(From vibration of a string, the λ of stationary wave produced in a string of length l confined at both ends is given by $\lambda = 2l/n$). Wben electron revolves in a circular orbit of radius 'r' then $2l = 2\pi r$. (½ mark)

$\therefore \quad p = \frac{nh}{2\pi r}$ or $p \times r = \frac{nh}{2\pi}$ or angular momentum $|\vec{L}| = p \times r$ is integral multiple of $h/2\pi$

which is Bohr's quantisation of angular momentum. (1 mark)

16. **n-type semicoductor** (½ × 6 marks)

1. Intrinsic semiconductor is doped by
2. It has an extra electron from the impurity.
3. Dopant atom is positively charged.
4. Holes are majority charge carriers.
5. n_e (no. of electron) >> n_h (no. of holes)
6. Donar energy level is close to

p-tpye semiconductor

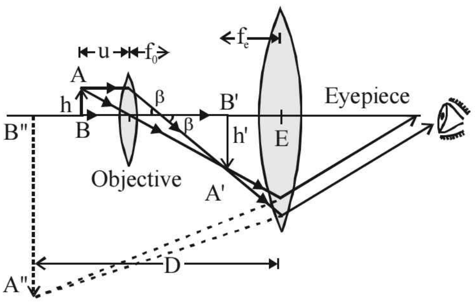
1. Intrinsic semiconductor is doped by trivalent petavalent atoms e.g. As, Sb etc. atoms e.g. Al, B etc.
2. It has an extra hole from the impurity.
3. Dopant atom is negatively charged.
4. Electrons are majority charge carriers.
5. n_h (no. of holes) >> n_e (no. of electron)
6. Acceptor level is close to valence band. conduction band.

17. The electromagnetic waves of frequency up to 30 MHz get reflected by the ionosphere. However, when the frequency of electromagnetic waves is above 40 MHz, they are no longer reflected by the ionosphere but undergo refraction. (1 mark)

Therefore, high frequency signals (in the frequency range from a few MHz to 30 MHz) are transmitted via reflection from the ionosphere. It is called sky wave propagation. (1 mark)

Wbereas the transmission of signal by surface wave propagation is limited to a distance of 100 km or so, sky wave propagation enables to transmit the signal practically all over the surface of the earth. (1 mark)

18. Ray diagram of compound microscope :



(3 marks)

19. For equilibrium, force exerted by the light beam should balance the weight of plate.

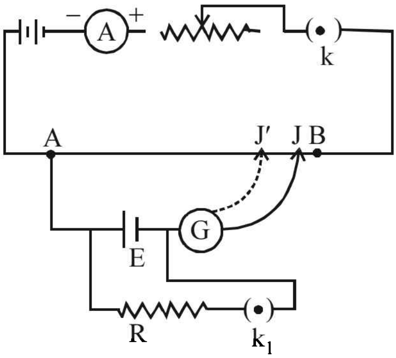
$F_{photon} = mg$ (1 mark)

$F_{photon} = \frac{IA}{c} = \frac{P}{c}$, where power $P = IA$ (1 mark)

$\Rightarrow \frac{P}{c} = 10 \times 10^{-3} \times 10$

$\Rightarrow \quad P = 3 \times 10^{7}$ W (1 mark)

20. When the key k_1 is off, the cell of e.m.f E is in open circuit.



(1 mark)

Let the null point in that case be J and AJ = ℓ_1

$\therefore \quad E = k\ell_1$

When the key is closed, the new null point is at J' and let AJ' = ℓ_2

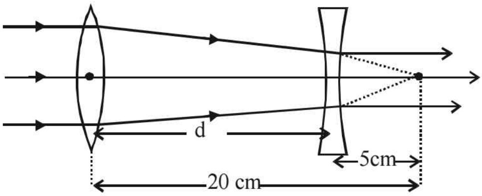
Then the potential difference between two poles of the cell = V = $k\ell_2$

$\therefore \quad \frac{E}{V} = \frac{\ell_1}{\ell_2}$ (1 mark)

$\therefore \quad$ Internal resistance of the cell

$= r = \left(\frac{E}{V} - 1\right)R \Rightarrow r = \left(\frac{\ell_1}{\ell_2} - 1\right)R$ (1 mark)

knowing R and measuring ℓ_1 and ℓ_2, r can be calculated.

21. 

(1 mark)

As the parallel beam of light is incident on convex lens, $u = -\infty$, f= 20 cm

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{v}-\frac{1}{-\infty}=\frac{1}{20}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{20} \quad \therefore v = 20\text{cm}$$ (1 mark)

In the absence of concave lens, the image would have been formed at a distance of 20 cm. This image acts as an object for concave lens which, formes its image at infinity.

$\therefore$ d = distance between the convex lens and concave lens

$\therefore$ virtual object distance for concave lens = (20 – d) cm.

$v = \infty$, f= – 5 m.

$$\text{As, } \frac{1}{v}-\frac{1}{u}=\frac{1}{f} \quad \therefore \frac{1}{\infty}-\frac{1}{(20-d)}=\frac{1}{-5}$$

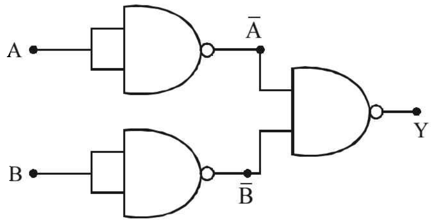
$$\Rightarrow (20-d) = 5 \Rightarrow 20-5=d$$ (1 mark)

$\therefore$ d = 15 cm

22. **Truth table**

A	B	$\bar{A}$	$\bar{B}$	Y
0	0	1	1	0
0	1	1	0	1
1	0	0	1	1
1	1	0	0	1

(1½ marks)



(1½ marks)

SECTION - D

23. **(i)** Social awareness, knowledgeable, understanding (1 mark)

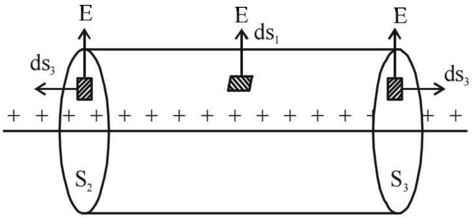
(ii) To minimize power loss due to generation of heat. (1 mark)

(iii) Transformer (1 mark)

(iv) Transformer works on the principle of mutual induction. (1 mark)

SECTION - E

24. **Electric field due to an infinity long straight wire :** Consider an infinitely long line charge having linear charge density λ. To determine its electric field at distance r, consider a cylindrical Gaussian surface of radius r and length l coaxial with the charge. By symmetry, the electric field E has same magnitude at each point of the curved surface S_1 and is directed radially outward.



(1 mark)

Total flux through the cylindrical surface,

$$\oint \vec{E}.\vec{ds} = \oint_{S_1} \vec{E}.\vec{ds_1} + \oint_{S_2} \vec{E}.\vec{ds_2} + \oint_{S_3} \vec{E}.\vec{ds_3}$$

$$= \oint_{S_1} Eds_1.\cos 0° + \oint_{S_2} Eds_2.\cos 90° + \oint_{S_3} Eds_3.\cos 90°$$

$$= E\int ds_1 = E \times 2\pi r l$$ (1 mark)

As λ is the charge per unit length and *l* is the length of the wire, so charge enclosed, $q = \lambda l$

By Gauss's Theorem,

$$\oint_S \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$$

$$E \times 2\ \pi\ rl = \frac{\lambda l}{\varepsilon_0}$$

or $$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$ (1 mark)

(i) Let V be the p.d. across X . Then p.d. across Y will be V/5.

$\therefore\ V+\frac{V}{5}=12 \text{ volt} \Rightarrow \frac{6V}{5}=12 \text{ volt}$

or V = 10 volt

P.D. across X = 10 volt

P.D. across Y = 10/5 = 2 volt. (1 mark)

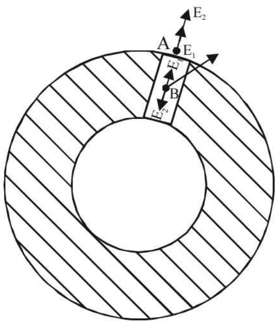
(ii) $\frac{\text{Energy stored in X}}{\text{Energy stored in Y}}=\frac{\frac{1}{2}C(10)^2}{\frac{1}{2}5C(2)^2}=\frac{100}{20}=5:1$

$\left[\because E=\frac{1}{2}CV^2\right]$ (1 mark)

OR

E_1 = field at A & B (which are 2 points just out-side & within the cavity as shown) due to the entire shell except that material which originally was there at the place of the cavity.

E_2 = field at A & B because of that material which were there originally in place of cavity.



(1 mark)

$\therefore$ If there were no cavity, the total field at point A would be

$= \frac{\sigma}{\varepsilon_0}$ i.e. $E_1+E_2=\frac{\sigma}{\varepsilon_0}$ ...(1)

And at point B would be zero (because inside a charged conductor electric field is always zero)

i.e. $E_1-E_2=0$ ...(2)

$\therefore$ $E_1=E_2$ (1 mark)

By putting it in (1), we get

$$E_1=\frac{\sigma}{2\varepsilon_0}$$

The direction will be radially outward because of symmetry.
(1 mark)

Given: Dipole length, 2a = 10 cm

Torque $\tau = 6\sqrt{3}$ Nm

$q = 6 \times 10^{-3}$ C. (1 mark)

We have $\tau = pE \sin\theta = 2aq\,E \sin\theta$.

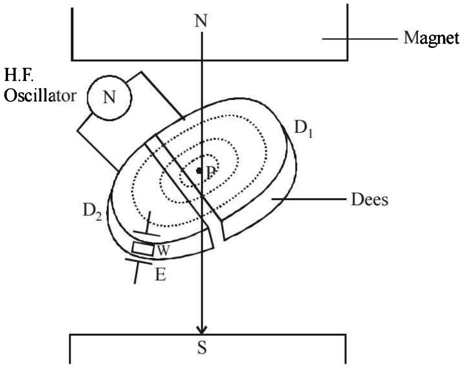
$$\Rightarrow \quad E = \frac{\tau}{2aq\sin\theta} = \frac{6\sqrt{3}}{10\times10^{-2}\times6\times10^{-3}\times\sin30°}$$

$$= 2\sqrt{3}\times10^{4}\,\text{N/C}.$$ (1 mark)

25. **Principle:** A positively charged particle is subjected to two perpendicular electric and magnetic fields. It is accelerated and hence gains energy due to the oscillating electric field by crossing the field again and again, whereas due to the magnetic field it travels in a circular path. (1 mark)

Construction:

(1 mark)



(i) D_1 and D_2 are two hollow, 'D' shaped, evacuated, metal chambers called Dees.

(ii) H.F. oscillator produces a high potential difference of the order of 10^4 volt between D_1 and D_2.

(iii) N, S are pole pieces of a strong electromagnet which produces a strong magnetic field perpendicular to the plane of the dees.

(iv) P is a source of positively charged particle.

(v) W is a window through which accelerated charged particle will come out.

(vi) E is a pair of deflecting plates which produces electric field to take out accelerated charged particle. (1 mark)

Theory and working: Let initially D_1 is at a negative potential and D_2 is at positive potential. Therefore, positive ions from P will be accelerated towards D_1 and in D_1, there will be a field free space so the particles will move with a constant speed v. But due to perpendicular magnetic field of strength B, it will describe a circular path of radius r in D_1.

$$\therefore \quad Bqv = \frac{mv^2}{r}$$

(centripetal force is provided by the magnetic Lorentz force)

$$\therefore \quad r = \frac{mv}{Bq}$$

Time to travel the semicircular path (1 mark)

$$= t = \frac{\pi r}{v} = \frac{\pi m}{Bq} = \text{constant.}$$

If this time is equal to half the time of cycle of electric oscillator, so as the particle will reach at the end of D_1, the polarities of D_1 and D_2 will change and the ion will be accelerated in D_2. In D_2 it will move with a constant speed and will travel another semicircular path of slightly greater radius. In this way, each time the particle will travel in a circular path of slightly greater radius and will acquire more energy. Finally it is taken out through the window (w) by applying an electric field across the deflecting plates E.

$$\text{Maximum K.E. of the particle} = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{Bqr}{m}\right)^2$$

$$\left[\because \frac{mv^2}{r} = Bqv \Rightarrow v = \frac{Bqr}{m}\right]$$ (½ mark)

$$(K.E.)_{Max} = \frac{B^2q^2r^2}{2m}$$

$$\text{Time period of the oscillating electric field} = T = 2t = \frac{2\pi m}{Bq}$$

$$\text{Cyclotron frequency} = \nu = \frac{1}{T} = \frac{Bq}{2\pi m}$$ (½ mark)

OR

The magnitude of the force $\vec{F}$ experienced by a moving charge is directly proportional to

(i) charge

(ii) component of velocity acting perpendicular to the direction of magnetic field. (1 mark)

(iii) the magnetic field applied.

i.e., $F \propto q(v\sin\theta)B$.

$F = K\,qvB\sin\theta = qvB\sin\theta\ (\because K = 1)$

Case (i) When a charged particle moving parallel to the direction of magnetic field (i.e., $\theta = 0°$ or $180°$),

then $F = qvB(\sin 0°) = 0$. (1 mark)

i.e., it does not experience any force.

Case (ii) When the moving charge is along a line perpendicular to the direction of magnetic field (i.e., $\theta = 90°$), it experience maximum force.

i.e., $F = qvB\ (\sin 90°) = qvB$.

Unit of magnetic field is tesla (T).

The magnetic field induction at a point is said to be 1 tesla if a charge of 1 coulomb, moving at right angle to the magnetic field with a velocity 1 m/s experiences a force of 1 newton.

(1 mark)

2nd Part

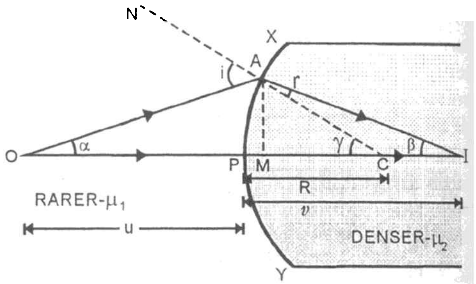
Force on the short conductor due to magnetic field of the long conductor $= F = \frac{\mu_0}{4\pi} \times \frac{2I_1I_2}{r} \times \ell$ (1 mark)

$$\therefore \quad F = \frac{10^{-7} \times 2 \times 4 \times 3}{0.03} \times 0.05 = 40 \times 10^{-7}\,N$$ (1 mark)

The force is attractive because the currents are in the same direction.

26. (a) Let a spherical refracting surface *XY* separate a rarer medium of refractive index μ_1 from a denser medium of refractive index μ_2. Suppose the surface is convex towards rarer medium side. Let *P* be the pole, *C* be the centre of curvature of this surface.

Consider a point object *O* lying on the principal axis of the surface, Fig.



(1 mark)

A ray of light starting from O and incident normally on the surface XY along OP passes straight. Another ray of light incident on XY along OA at $\angle i$ is refracted along AI at $\angle r$, bending towards the normal CAN. The two refracted rays actually meet at I, which is the real image of O.

From A, draw $AM \perp OI$.

Let $\angle AOM = \alpha$, $\angle AIM = \beta$

and $\angle ACM = \gamma$

As external angle of a triangle is equal to sum of internal opposite angles. Therefore, in ΔIAC

$$r + \beta = \gamma$$

$$r = \gamma - \beta$$

Similarly, in $\Delta OAC, i = \alpha + \gamma$ ....(1)

According to Snell's law, (½ mark)

$$\frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r} \simeq \frac{i}{r} \quad (\because \text{ angles are small}) \qquad ...(2)$$

$\therefore \quad \mu_1 = \mu_2 r$

Using (1) we get,

$$\mu_1(\alpha + \gamma) = \mu_2(\gamma - \beta)$$

As angles α, β and γ are small, using $\theta = l/r$, we get

$$\mu_1\left(\frac{AM}{MO} + \frac{AM}{MC}\right) = \mu_2\left(\frac{AM}{MC} - \frac{AM}{MI}\right) \qquad ...(3)$$

(1 mark)

As aperture of the spherical surface is small, M is close to P. Therefore,

$$MO \approx PO, MI \approx PI, MC \approx PC$$

From (3),

$$\mu_1\left(\frac{1}{PO} + \frac{1}{PC}\right) = \mu_2\left(\frac{1}{PC} - \frac{1}{PI}\right)$$

$$\therefore \quad \frac{\mu_1}{PO} + \frac{\mu_2}{PI} = \frac{\mu_2 - \mu_1}{PC}$$

Using new cartesian sign conventions, we put

$$PO = -u, PI = +v, PC = R$$

$$\frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R} \qquad \text{(1 mark)}$$

This is the required relation.

(b) $u = -40$ cm; $R = 15$ cm; $n_1 = 1$; $n_2 = 1.5$.

We have, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ (1½ marks)

$$\frac{1.5}{v} - \frac{1}{-40} = \frac{1.5-1}{15}$$

$$\frac{1.5}{v} + \frac{1}{40} = \frac{0.5}{15}$$

$$\frac{1.5}{v} = \frac{0.5}{15} - \frac{1}{40} = \frac{1}{120}$$

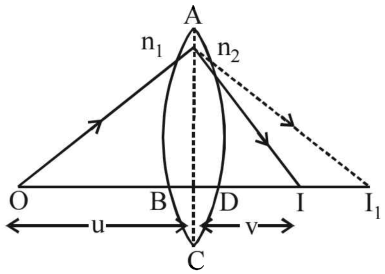
$$\frac{1.5}{v} = \frac{1}{120} \Rightarrow v = +180 \text{ cm.}$$

The image is formed at a distance of 180 cm in the direction of incident light.

OR

(a) Consider a double convex lens. The first refracting surface forms the image I_1 of the object O.

(½ mark)



The image I_1 acts as a virtual object for the second surface that forms the image at I. For the first interface ABC, (1 mark)

$$\frac{n_1}{OB} + \frac{n_2}{BI_1} = \frac{n_2 - n_1}{BC_1} \quad ...(i)$$

For the second interface ADC gives,

$$\frac{-n_1}{DI_1} + \frac{n_1}{DI} = \frac{n_2 - n_1}{DC_2} \quad ...(ii)$$

For a thin lens, $BI_1 = DI_1$.

Adding equation (i) and (ii) we get,

$$\frac{n_1}{OB} + \frac{n_1}{DI} = (n_2 - n_1)\left(\frac{1}{BC_1} + \frac{1}{DC_2}\right) \quad ...(iii)$$

(1 mark)

Applying sign convention,

$BC_1 = +R_1, DC_2 = -R_2.$

So equation (iii) becomes,

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad \text{(1 mark)}$$

This equation is known as lens maker's formula.

(b) f = + 12 cm.

$R_1 = +10$ cm.

$R_2 = -15$ cm.

$n_2 = ?, n_1 = 1$

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad \text{(1 mark)}$$

$$\frac{1}{12} = (n_2 - 1)\left(\frac{1}{10} - \frac{1}{-15}\right)$$

$$\Rightarrow (n_2 - 1) = \frac{1}{2} \Rightarrow n_2 = 1.5. \qquad \text{(½ mark)}$$

SAMPLE PAPER-2

SECTION - A

1. Voltage is measured across any two points of a conductor by a voltmeter connected in parallel because potential difference across parallel combination of elements remains same. (1 mark)

2. When the current in the wire BA decreases, according to Lenz's law, the induced current in the coil should oppose the decrease, so current in the coil will be in clockwise direction. (1 mark)

3. Since communication is by line of sight path, direct waves are blocked by the curvature of earth, so receiving antenna must be placed high enough to intercept the wave. (1 mark)

4. Power radiated is proportional to $(\ell/\lambda)^2$ by an antenna of length ℓ. (1 mark)

5. The refracted ray is parallel to the base of the prism in the position of minimum deviation. (1 mark)

SECTION - B

6. (a) The two charges are of opposite sign so that force will be attractive in nature. (1 mark)

(b) The two charges have different magnitudes – the charge of smaller magnitude will be nearer to the point where the total field intensity is zero. (1 mark)

7. No. The colours of a soap bubbles are seen due to interference of light. In the prism, colours appear due to dispersion of light. (2 marks)

OR

(i) Interference arises due to the superposition of waves from two coherent sorces. Diffraction pattern is obtained due to waves arising from different parts of the same wavefront. (1 mark)

(ii) In intereference pattern, all the bright fringes are of the same intensity. However, in the diffraction pattern, all bright fringes are not of the same intensity. (1 mark)

8. Let E_1, E_2 be energies for frequencies v_1, v_2 respectively. Let, $v_2 = 2v_1$.

If ϕ_0 = work function of metal, then $hv_1 = E_1 + \phi_0$ and

$hv_2 = 2hv_1 = E_2 + \phi_0$

Divide, $2 = \frac{E_2 + \phi_0}{E_1 + \phi_0}$

$\Rightarrow$ $2E_1 + 2\phi_0 = E_2 + \phi_0$

$\Rightarrow$ $2E_1 + \phi_0 = E_2$

$\Rightarrow$ K.E. will become more than double if frequency is doubled. (2 marks)

9. Electrons diffuse from n $\rightarrow$ p and holes diffuse from p $\rightarrow$ n side leaving a positively charged donor atom on n–side and negatively charged acceptor atom on p–side. This space charge region on either side is called depletion region. (1 mark)

Near the junction this region depletes the movement of free charges. Hence, electric field due to positive space charge on n–side and negative space charge on p–side is created. Due to this electrons and holes now drift in opposite direction in this field and further extend this region. Thus a different polarity potential is developed which prevents movement of electron from n–region to p–region, called **barrier potential** and there is no net current.

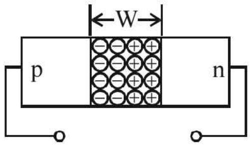
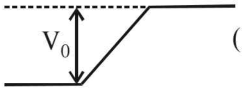


Fig (a) Diode under equilibrium V = 0



(b) Barrier potential under no bias (1 mark)

10. Energy of incident radiation $= E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{400 \times 10^{-9}}$

$$= \frac{6.6 \times 10^{-26} \times 3}{4 \times 10^{-7} \times 1.6 \times 10^{-19}} eV = 3.1 \text{ eV}$$

(1 mark)

For A, $h\nu > \phi_0$ hence it shows photoelectric effect.

For B, $h\nu < \phi_0$ hence it does not show photoelectric effect.

(1 mark)

SECTION - C

11. (i) $\because$ R series > R parallel and slope of V-I graph gives R.
Here $(\text{slope})_B > (\text{slope})_A$
$\therefore$ B denotes series combination and A denotes parallel combination. (2 marks)
(ii) $74 \text{ k}\Omega = 74 \times 10^3\ \Omega$. Violet, yellow and orange. (1 mark)

12. An equipotential surface is that at every point of which electric potential is same. (1 mark)
Consider two points A and B on the equipotential surface.
By definition, potential difference between two points A and B = work done in carrying a unit positive charge from A to B.

$\Rightarrow V_A - V_B = W_{AB} = \vec{E}.d\vec{\ell}$

But $V_A = V_B \quad \therefore \vec{E}.d\vec{\ell} = 0$

$\Rightarrow E dl \cos\theta = 0 \Rightarrow \cos\theta = 0 \Rightarrow \theta = 90° \ \therefore \vec{E} \perp d\vec{\ell}$

$\therefore$ Electric field $(\vec{E})$ is directed perpendicular to the equipotential surface. (2 marks)

13. A galvanometer can be converted into a voltmeter by adding a high resistance in series with it. If G be the galvanometer resitance and R is the high resistance added in series with it then total resistance of the voltmeter = G + R

$\therefore \ I_g$ = current through the combination $= \frac{V}{G+R}$

Where V is the potential difference across the combination

$$\therefore \quad G + R = \frac{V}{I_g} \qquad \therefore \quad R = \frac{V}{I_g} - G$$

Range of the voltmeter will be 0 to V volt. (3 marks)

14. There are two main types of spectra

(a) Emission spectra

(b) Absorption spectra

(a) **Emission spectra:** When continuous light from a source is observed in a spectrometer it is called emission spectra. It is of three types:

(i) Continuous emission spectra

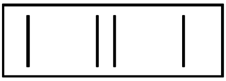
(ii) Line emission spectra

(iii) Band emission spectra

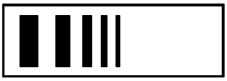
(i) **Continuous emission spectra** consists of a wide range of unseparated wavelengths e.g.: spectra of sunlight

(ii) **Line emission spectra** consists of a few bright lines separated from each other. Each line corresponds to a particular wavelength. It is emitted by atoms in gaseous state e.g.: mercury vapour lamp.

(iii) **Band emission spectra** consists of a number of bright patches where one end of band is sharper than the other. The bright edge is band head and faded edge is tail of the band e.g.: molecules of oxygen, nitrogen etc.



Line absorption spectra



Band absorption spectra

Line emission spectra

(1½ marks)

(b) **Absorption spectra:** When light from a source is passed through any transparent medium (solid, liquid or gas) and resultant light (transmitted, is observed in spectrometer, then certain dark regions are seen in the light corresponding to the wavelengths absorbed by the medium. This is absorption spectrum. It is of 3 types:

(i) continuous absorption spectra

(ii) line absorption spectra

(iii) band absorption spectra

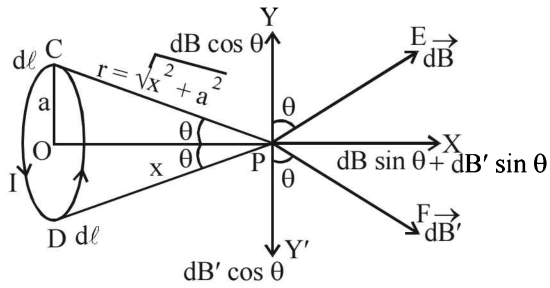
When white light passes through a pure green glass slab then the transmitted light has only green wavelength as all others are absorbed. This is **continuous absorption spectrum.**

When white light passes through gases like oxygen, iodine etc. it shows certain dark bands over a bright back ground. This is **band absorption spectra**.

When white light is passed over a gas a vapour, the absorption spectra shows dark lines over a bright background. This is **line absorption spectra.** (1½ marks)

15. Consider two small elements of coil of length dl each, at C and D diametrically opposite to each other.

(1 mark)



PC = PD = r

$$= \sqrt{a^2 + x^2} \text{ and } \angle CPO = \angle DPO = \theta$$

Magnetic field at P due to current element $d\ell$ at C = dB

$$= \frac{\mu_0}{4\pi} \cdot \frac{Id\ell \sin 90^\circ}{r^2} [\theta = 90^\circ]$$

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{r^2} = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{(a^2 + x^2)}$$

Direction of dB is along PE perpendicular to CP.

Magnetic field at P due to current element $d\ell$ at D = $dB' = \frac{\mu_0}{4\pi}$.

$$\frac{Id\ell \sin 90^\circ}{r^2} = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{(a^2 + x^2)}$$

acting along PF $\perp$ DP.

$$\therefore \quad dB = dB' = \frac{\mu_0}{4\pi} \cdot \frac{Id\ell}{(a^2 + x^2)}$$

Resolving dB and dB' in rectangular components,

(i) dB cosθ along PY and dB sinθ along PX

(ii) dB' cosθ along PY' and dB' sinθ along PX

Consine components being equal and opposite will cancel each other.

Total magnetic field at P due to current through the whole circular coil.

$$B = \int dB\sin\theta = \int \frac{\mu_0 I d\ell \sin\theta}{4\pi(a^2+x^2)} = \frac{\mu_0 I \sin\theta}{4\pi(a^2+x^2)} \int d\ell$$

$$\left[\because \sin\theta = \frac{a}{\sqrt{a^2+x^2}} \text{ and } \int d\ell = 2\pi a\right]$$

$$B = \frac{\mu_0 I}{4\pi(a^2+x^2)} \cdot \frac{a}{(a^2+x^2)^{1/2}} .2\pi a = \frac{\mu_0 I a^2}{2(a^2+x^2)^{3/2}} \text{ along PX}$$

If there are n number of turns of the coil,

$$B = \frac{\mu_0 n I a^2}{2(a^2+x^2)^{3/2}} = \frac{\mu_0}{4\pi} \cdot \frac{2nIA}{x^3} = \frac{\mu_0}{4\pi} \cdot \frac{2M}{x^3}$$

[Here $A = \pi a^2$ = area of the coil and $x >> a$ (2 marks)

$\therefore$ $a^2 + x^2 \approx x^2$, $M = nIA$ = magnetic dipole moment of the coil]

16. Characteristics of electromagnetic waves:

(i) They travel in free space with the same speed equal to $c = 3 \times 10^8$ m/s (1 mark)

(ii) Electromagnetic waves are transverse in nature.

Velocity of electromagnetic waves in any medium is given by (1 mark)

$$v = \frac{1}{\sqrt{\mu\varepsilon}},$$ (1 mark)

where μ is the permeability and ε is the permittivity of the medium

17. (a) Coverage range $d = \sqrt{2hR} = \sqrt{2 \times 160 \times 6.4 \times 10^6} = 45255$m

$= 45.255$ km (1 mark)

(b) Population covered = area covered × population density

$= \pi d^2 \times \rho = 3.14 \times (45.255)^2 \times 1200$

$= 77.24 \times 10^5 = 77.24$ lac

(c) Let new height of tower = h' (1 mark)

Total distance covered by it $d' = 2d$

$\Rightarrow \sqrt{2h'R} = 2\sqrt{2hR} \Rightarrow 2h'R = 4 \times 2hR$

$\Rightarrow h' = 4h$

$\Rightarrow h' = 4 \times 160 = 640m$

$\therefore$ Increase in height required $= h' - h = 640 - 160 = 320$ m(1 mark)

OR

$V_m = 4V$, $V_c = 5V$

Maximum modulated voltage $= V_m + V_c = 5 + 4 = 9$ Volts(1 mark)

Minimum modulated voltage $= V_c - V_m = 5 - 4 = 1$Volt (1 mark)

% of modulation, $\mu = \frac{V_m}{V_c} \times 100 = \frac{4}{5} \times 100 = 80\%$ (1 mark)

18. The electric field $\vec{E}_1$ at the point P due to point charges +q and – q at the point A and B, respectively, forming an electric dipole, is of magnitude

$$E_1 = \left(\frac{1}{4\pi\varepsilon_0}\right)\left(\frac{p}{r^3}\right) = \left(\frac{1}{4\pi\varepsilon_0}\right)\left(\frac{ql}{r^3}\right)$$ (1 mark)

and direction opposite to the electric dipole moment $\vec{p}$, as shown.

The electric field $\vec{E}_2$ at the point P due to the point +q at the point O is of magnitude

$$E_2 = \left(\frac{1}{4\pi\varepsilon_0}\right)\left(\frac{qr}{r^3}\right)$$

and direction along OP, as shown. since the two electric fields $\vec{E}_1$ and $\vec{E}_2$ are mutually perpendicular and hence, the resultant electric field at the point P has the magnitude.

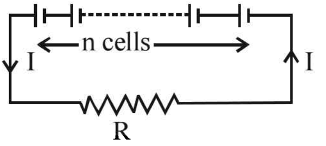
$$E = \sqrt{E_1^2 + E_2^2}$$ (1 mark)

$$= \left(\frac{1}{4\pi\varepsilon_0 r^3}\right)\sqrt{(q^2 l^2 + q^2 r^2)} = \left(\frac{q}{4\pi\varepsilon_0 r^3}\right)\sqrt{(l^2 + r^2)}$$

and direction making an θ with OP, i.e.,

$$\theta = \tan^{-1}\left(\frac{E_1}{E_2}\right) = \tan^{-1}\left(\frac{l}{r}\right)$$ (1 mark)

19.



n cells in series each of e.m.f. E and internal resistance r.

$\therefore$ Total internal resistance = nr

$\therefore$ Total resistance of the circuit = nr + R

Effective e.m.f of the cells = nE

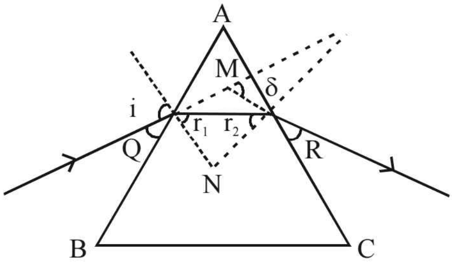
$\therefore$ current $= I = \dfrac{nE}{R + nr}$ (1½ marks)

If $R >> nr$, $I = \dfrac{nE}{R}$

If $R << nr$, $I = \dfrac{nE}{nr} = \dfrac{E}{r}$

$\therefore$ Maximum current can be drawn from a series combination if R is very high compared to r. (1½ marks)

20.



$\angle i$ = angle of incidence

$\angle e$ = angle of emergence

δ = angle of deviation

In the quadrilateral AQNR,

$\angle A + \angle QNR = 180°$ ...(i)

In the traingle QNR

$r_1 + r_2 + \angle QNR = 180°$ ...(ii)

$\therefore r_1 + r_2 = \angle A$ ...(iii)

(1½ marks)

The angle of deviation ,

$\delta = (i - r_1) + (e - r_2) = i + e - (r_1 + r_2)$

$\therefore \delta = i + e - A$ ...(iv)

According to snell's law, $\frac{\sin i}{\sin r_1} = n_{21}$

or, $\frac{i}{r_1} = n_{21}$ (since angles are small)

$\therefore\ i = r_1 . n_{21}$

Also, $\frac{\sin e}{\sin r_2} = n_{21} \Rightarrow \frac{e}{r_2} = n_{21}\ \ \therefore e = r_2.n_{21}$ using the equation (iv)

(1 mark)

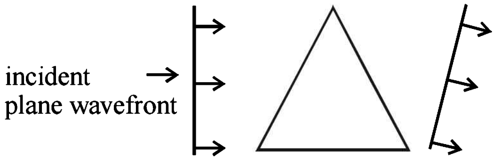
$\delta = r_1.n_{21} + r_2.n_{21} - A$

$= (r_1 + r_2)n_{21} - A = A.\ n_{21} - A$ (½ mark)

$\therefore\ \delta = (n_{21} - 1) - A$

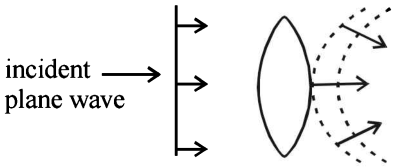
21. Refraction of a plane wave form by

(i) A thin prism.



(1½ marks)

(ii) A convex lens



(1½ marks)

22. (i) Half-life of a radioactive element is defined as the time during which half the number of atoms present initially in the sample of the element decay or it is the time during which number of atoms left undecayed in the sample is half the total number of atoms present initially in the sample. It is represented by $T_{1/2}$.

From the equation,

$N = N_0 e^{-\lambda t}$

At half-life, $t = T_{1/2}$, $N = \frac{N_0}{2}$

$\therefore \quad \frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}} \quad \Rightarrow \quad \frac{1}{2} = e^{-\lambda T_{1/2}}$

$\Rightarrow \quad e^{\lambda T_{1/2}} = 2$

Taking log on both sides

$\lambda\, T_{1/2} = \log_e 2$

$$T_{1/2} = \frac{\log_e 2}{\lambda} = \frac{\log_{10} 2 \times 2.303}{\lambda} = \frac{3010 \times 2.303}{\lambda}$$

After n half-life, the number of atoms left undecayed is given by

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$T_{1/2} = \frac{0.6931}{\lambda} \qquad \text{(1 mark)}$$

(ii) $T_{1/2} = 30$ s

(a) $\lambda = ?$

$$\because \; T_{1/2} = \frac{0.693}{\lambda}$$

$$\Rightarrow \lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{30} = 0.0231\, s^{-1} \qquad \text{(1 mark)}$$

(b) $\because \; N = N_0 \left(\frac{1}{2}\right)^n$

where, n = number of half-lives

N = number of undisintegrated nuclei present in the sample.

N_0 = original number of undisintegrated atom.

Here, $N = N_0 - \frac{3}{4} N_0 \Rightarrow N = \frac{1}{4} N_0$

$$N = N_0 \left(\frac{1}{2}\right)^n \Rightarrow \frac{N_0}{4} = N_0 \left(\frac{1}{4}\right)^n$$

$$\Rightarrow \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^2 \Rightarrow n = 2$$

$$\text{But number of half-lives} = \frac{\text{Total time taken}}{\text{Half - life}}$$

$$2 = \frac{\text{Total time taken}}{30\text{ s}}$$

Total time taken = 60 s = 1 min (1 mark)

SECTION - D

23. (i) Quality to solve the problem by using scientific knowledge. (1½ marks)

(ii) To convert a galvanometer into an ammeter of given range, he joined a resistance of appropriate value in parallel with the galvanometer.
Value of resistance is calculated as under

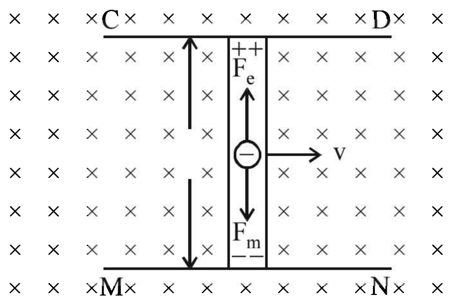
$$S = \frac{I_g G}{I - I_g} = \frac{(2.5 \times 10^{-3}) \times 12}{7.5 - 2.5 \times 10^{-3}}$$

$S = 4 \times 10^{-3} = 4\,\Omega$ (2½ marks)

SECTION - E

24. When a charge q moves with velocity $\vec{v}$ in a magnetic fields of strength $\vec{B}$, making an angle θ, then magnetic Lorentz force,

$F = qvB \sin\theta$



If $\vec{v}$ and $\vec{B}$ are mutually perpendicular, then θ = 90°

$\therefore F = qvB\sin 90° = qvB$

F is perpendicular to both $\vec{v}$ and $\vec{B}$. (1½ marks)

Let a time conducting rod PQ is placed on two parallel metallic wires CD and MN in a magnetic field of strength $\vec{B}$. The direction of $\vec{B}$ is perpendicular to the plane of paper, downward represented by (X). Let the rod is moving with velocity $\vec{v}$, perpendicular to is own length, towards the right. Since a metallic conductor contain free electrons, they will move within the metal rod. Charge on each electron = – e.

$\therefore$ Force experienced by each electron = f_m = evB and will be directed from P to Q. $\therefore$ The end P of the rod becomes positively charged and Q is negatively charged. So a potential difference is produced across the ends of the conductor. This is the induced e.m.f.

$\therefore$ Electric field produced in the rod $= E = \dfrac{V}{\ell}$

It is directed from P to Q.

The force on a free electron due to this electric field

$F_e = eE$ (1½ marks)

The direction of this force is from Q to P opposite to the electric field.

$\therefore$ The emf produced opposes the force within electrons caused due to Lorentz force by Lenz's law. As the number of electrons at Q becomes more and more, the magnitude of electric force F_e goes on increasing and at a stage F_e become equal and opposite to F_m. Under this condition the potential difference produced across the ends of rod becomes constant.

In this case, $F_e = F_m \Rightarrow eE = evB \Rightarrow E = Bv$

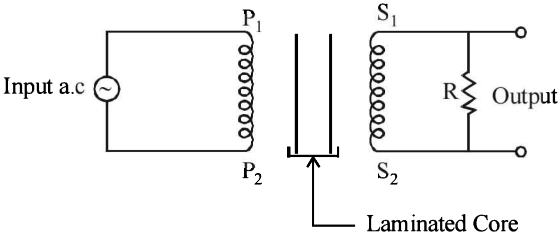
$\therefore$ Potential difference produced, $V = El = Blv$ volt.

$\therefore$ Induced current $= I = \dfrac{V}{R} = \dfrac{B\ell v}{R}$ Ampere. (2 marks)

OR

Transformer is a device used to change a.c. voltage. A transformer which increases the a.c. voltage is called step-up transformer and which decreases a.c. voltage is called step-down transformer.

Principle: It is based on the principle of mutual induction. When the amount of magnetic flux linked with a coil changes, an e.m.f is induced in the neighbouring coil. (1 mark)



Construction :

1. Core: It is of rectangular shape, made up of laminated soft iron sheets, insulated from each other.
2. P_1P_2 : Primary coil made up of copper wire. Turns are insulated from each other.
3. S_1S_2 : Secondary coil also made up of a copper wire of which turns are insulated from each other.
4. R is the load resistance across which the output voltage is taken.

For step up transformer, S_1S_2, has more number of turns than P_1P_2 and for step down transformer P_1P_2 has more number of turns than S_1S_2. (1½ marks)

Theory and Working : The primary coil P_1P_2 is connected to an alternating source so as current in P_1P_2 changes, magnetic flux linked with S_1S_2 also changes by mutual induction and that linked with P_1P_2 itself also changes by self induction.

Let n_p be the number of turns in P_1P_2

E_p be the alternating e.m.f. in P_1P_2 at time t.

$\frac{d\varphi}{dt}$ be the rate of change of magnetic flux linked with each turn of P_1P_2

For ideal transformer, self induced e.m.f. in P_1P_2 at time t = e.m.f. feed to P_1P_2 at time t

$$\Rightarrow -n_p \frac{d\varphi}{dt} = E_p \qquad ...(i)$$

If there is no leakage of magnetic flux between P_1P_2 and S_1S_2 then

$$E_S = -n_s \frac{d\varphi}{dt} \qquad ...(ii)$$

where n_s is the number of turns in S_1S_2 and E_S is the e.m.f associated with S_1S_2

By dividing equation (ii) with (i), $\frac{E_S}{E_P} = \frac{n_S}{n_P} = k$

where k is called transformation ratio.
For step-up transformer, since $E_S > E_P$
$\therefore$ $k > 1$ and $n_s > n_p$
For step-down transformer, since $E_S < E_P$
$\therefore$ $k < 1$
$\therefore$ $n_s < n_p$
If I_P be the current in the primary coil at time t and I_S be that in the secondary coil at time t, then
Input power = $E_P I_P$ and output power = $E_S I_S$
For ideal transformer, there is no loss of power,
$\therefore$ Output power = Input power
$\Rightarrow E_S I_S = E_P I_P$

$$\therefore \quad \frac{E_S}{I_S} = \frac{E_P}{I_P} = k$$

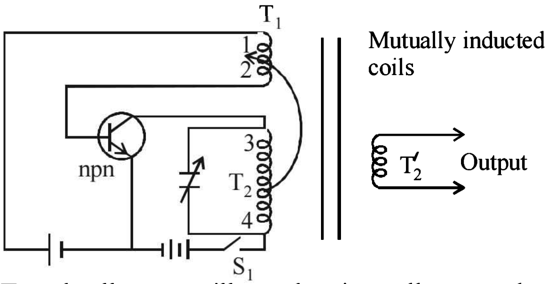
For step-up transformer, $k > 1$
$\therefore$ $I_P > I_S$
For step-down transformer, $k < 1$
$\therefore$ $I_S < I_P$

$$\text{Efficiency} = \eta = \frac{\text{Output power}}{\text{Input power}}$$

For ideal transformer, $\eta = 1$ i.e., efficiency is 100 % (1½ marks)

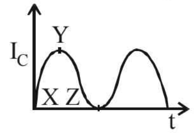
Laminated soft iron core is used to reduce the heat loss due to eddy current and hence to increase its efficiency. (1 mark)

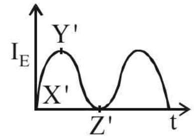
25. Output in an oscillator is self-sustained (However, external input is necessary once). A positive feedback (in phase) is given by means of inductive coupling (LC or RC). In inductive coupling, two coils are mutually inducted by winding them on the same core. BE junction – forward biased and BC junction – reverse biased. When switch S_1 is put ON, current from collector flows through coil T_2 but increases gradually from X to Y. Due to inductive coupling between coil T_2 and T_1, current flows in emitter circuit (feedback) and increases from X' to Y' till saturated. Since current is not increasing hence magnetic field around T_2 becomes static, hence feedback from T_2 to T_1 stops, emitter current falls. As a result collector current falls, magnetic field around T_2 decreases, T_1 sees the decay and emitter current further decreases to cut off value Z'. I_E and I_C stop flowing. Transistor comes to its original state and starts again. The time from saturation to cut off is determined by resonance frequency $v = \dfrac{1}{2\pi\sqrt{LC}}$ (3 marks)



(1 mark)

Tuned collector oscillator showing collector and emitter current due to coupling.

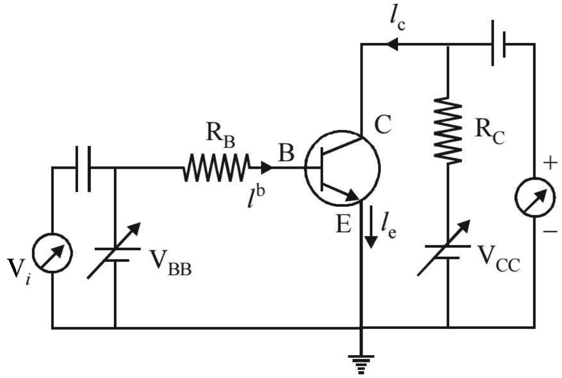




(1 mark)

OR

(i) Circuit is shown below

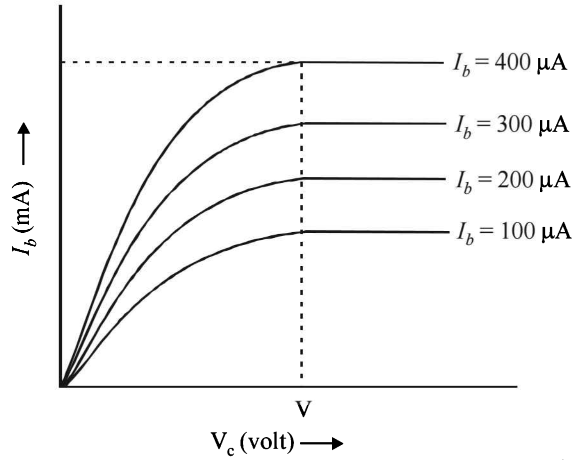


(1 mark)

Current amplification factor (β_{AC}) is the ratio of change in collector current (ΔI_c) to the change is base current (ΔI_b) at constant collector voltage i.e.,

$$\therefore \quad \beta_{AC} = \left.\frac{\Delta I_c}{\Delta I_b}\right| V_{CE = \text{constant}}$$

Output characteristics represent the variation of I_C with V_c, keeping I_b constant.



(2 marks)

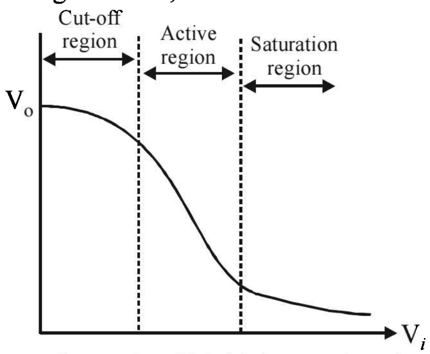
From above graph at $V_c = V$, the value of collector current increases with the increase in the base current, I_b.

Thus, $\beta_{AC} = \left.\frac{\Delta I_c}{\Delta I_b}\right| V_{CE = constant}$

(ii) Transfer characteristics curve, for a base-biased transistor in CE configuration are shown below.

In cut-off region and in saturation region, transistor acts as switch OFF an switch On respectively.

In cut–off region, as long as V_i is low, it enables to forward bias the transistor and V_o is high. Transistor is not conducting in this region. Hene, it is said to be switched OFF.

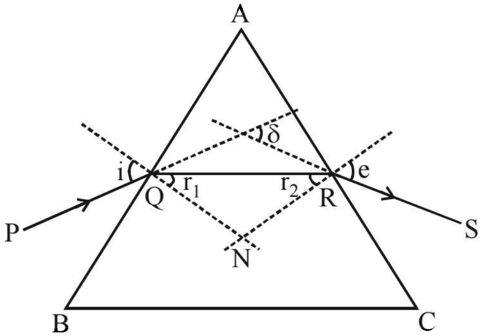


In saturation region, V_i is high enough and thus, the V_o is low. Transistor is conducting in this region and thus send to be switched ON.

Hence, low input give high output and high input gives low output.

(2 marks)

26. Consider a triangular prism ABC. The angles of incidence and refraction at the first face AB are i and r_1, while the angle of incidence at the second face AC is r_2 and the angle of emergence e. The angle between the emergent ray and the direction of the incident ray is called the angle of deviation, δ.



From the Quadrilateral

AQNR, $\angle A + \angle QNR = 180°$

From the triangle QNR,

$$r_1 + r_2 + \angle QNR = 180°$$

Comparing these two equations, (2 marks)

$$r_1 + r_2 = A \qquad ...(i)$$

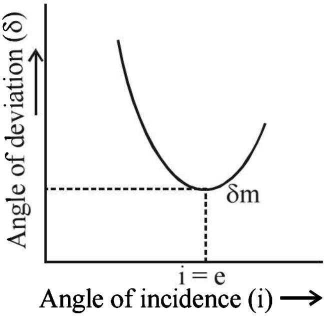
The total deviation, $\delta = (i - r_1) + (e - r_2)$

ie., $\delta = i + e - A$ ...(ii)

(since $r_1 + r_2 = A$)

Thus the angle of deviation depends on the angle of incidence.

A graph between angle of deviation and angle of incidence is shown below.



(1 mark)

From the graph we can see that at the minimum deviation δ_m, the refracted ray inside the prism becomes parallel to its base.

$\therefore \quad \delta = \delta_m, i = e \Rightarrow r_1 = r_2.$

equation (i) gives,

$$2r = A \text{ or } r = \frac{A}{2} \qquad \text{...(iii)}$$

Also equation (ii) gives,

$$\delta_m = 2i - A \quad \text{or} \quad i = \frac{(A + \delta_m)}{2} \qquad \text{...(iv)}$$

The refractive index of the prism is $n_{21} = \frac{n_2}{n_1} = \frac{\sin\left[\left(\frac{A+\delta_m}{2}\right)\right]}{\sin\left[\frac{A}{2}\right]}$ ...(v)

(2 marks)

For a small angled prism D_m is also very small.

$$\text{So,} \quad n_{21} = \frac{\sin\left[\left(\frac{A+\delta_m}{2}\right)\right]}{\sin\left[\frac{A}{2}\right]}$$

OR

(i) The convex mirror provides a wider field of view hence it is used to see the traffic at back. (1 mark)

(ii) The phenomenon of twinkling of stars is due to atmospheric refraction. (1 mark)

(iii) The amount of scattering of light is inversely proportional to the fourth power of wavelength $\left(\frac{1}{\lambda^4}\right)$. (1 mark)

(iv) Rainbows are formed due to the combined effect of dispersion, refraction and reflection of sunlight by water droplets. (1 mark)

(v) No, this is because dispersion of light connot occur through a hollow prism which contains air. (1 mark)

SAMPLE PAPER-3

SECTION - A

1. $\frac{12.27}{\sqrt{V}} = 12.27Å = \lambda$ (1 mark)

2. Work done to move the charge 50 nC on the equipotential surface is zero as the potential at every point is same. (1 mark)

3. Because ionosphere reflects in this band only. (1 mark)

4. The aircraft intercepts the waves reaching the antenna so it causes slight shaking of the picture. (1 mark)

5. Since, $V = E - Ir$, therefore, if $r = 0$ i.e the internal resistance of the cell is zero then the terminal voltage across a secondary cell is equal to its e.m.f. (1 mark)

SECTION - B

6. When a solid conducting sphere is placed in a uniform electric field $\vec{E}$, free electrons move in a direction opposite to $\vec{E}$. Electric lines of force starts from right part (i.e., negative region) and ends on left part (i.e., positive region). So path 4 is correct. (1 + 1 mark)

7. Because of dispersion, a lens has slightly different focal lengths for various wavelengths of light. When an image is formed by a lens, its edges are coloured. This defect is called chromatic aberration.

It can be removed by a combination of converging and diverging lenses or by using a spherical mirror. (1 + 1 mark)

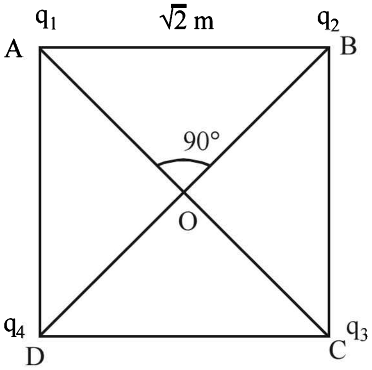
OR

(i) The intensity of central maximum increases by a factor 9. (1 mark)

(ii) The width of central maximum decreases by a factor of 3. (1 mark)

8. When an iron core is inserted in the choke coil, the brightness of the bulb decreases. When the iron core is inserted into the choke coil, the inductance of the coil increases. So the inductive reactance ($X_L = \omega L$) of the coil increases and impedance $\left(Z = \sqrt{R^2 + X_{L^2}}\right)$ also increases. Therefore, the current $I = \frac{V}{Z}$ decreases and consequently the bulb becomes dim. (2 marks)

9.



$AB = BC = CD = AD = \sqrt{2}$,

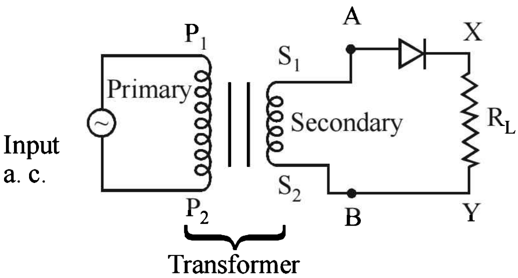
$BD = \sqrt{(\sqrt{2})^2 + (\sqrt{2})^2} = 2$ m (1 mark)

$\therefore \quad r = \frac{1}{2} BD = 1$ m

$$V = \frac{k}{r}[q_1 + q_2 + q_3 + q_4]$$

$$= \frac{9 \times 10^9}{1}[2 - 2 - 3 + 6] \times 10^{-6} = 2.7 \times 10^4 \text{ V.}$$ (1 mark)

10. (1 mark)



Diode rectification circuit

The diode in circuit is forward biased only when input cycle is positive. In an a.c. signal, voltage is positive only for half cycle, thus diode conducts current only for half cycle of the signal and remaining it doesn't conduct (reverse biased). The output voltage is varying in one direction only. (1 mark)

SECTION - C

11. For the points AB, $E_1 = k\ell_1 = k \times 300$ ....(1)

For the points AC, $E_1 - E_2 = k\ell_2 = k \times 100$ ... (2) (1 mark)

$$\frac{E_1 - E_2}{E_1} = \frac{1}{3} \Rightarrow 3E_1 - 3E_2 = E_1$$

$$\Rightarrow 3E_1 - E_1 = 3E_2$$

$$\Rightarrow 2E_1 - 3E_2$$

$$\Rightarrow \frac{E_1}{E_2} = \frac{3}{2}$$

$\Rightarrow E_1 : E_2 = 3 : 2$ (2 marks)

12. Taking $h = 6.6 \times 10^{-34}$ Js, $m = 9 \times 10^{-31}$ kg,
$c = 3 \times 10^8$ m/s, $\phi_0 = 1.8$ eV $= 1.8 \times 1.6 \times 10^{-19}$Js
$\lambda = 5000$ Å $= 5000 \times 10^{-10}$ m

(i) threshold frequency,

$$v_0 = \frac{\phi_0}{h} = \frac{1.8 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}}$$

$\Rightarrow v_0 = 6.87 \times 10^{-7}$ m (1 mark)

(ii) max k.E of emitted e^-,

$$K_{max} = \frac{hc}{\lambda} - \phi_0 = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{5000 \times 10^{-10}} - 1.8 \times 1.6 \times 10^{-19} J$$

$= 3.96 \times 10^{-19} - 2.88 \times 10^{-19} = 1.08 \times 10^{-19}$J (1 mark)

(iii) max velocity,

$$v = \sqrt{\frac{2K_{max}}{m}} = \sqrt{\frac{2 \times 1.08 \times 10^{-19}}{9 \times 10^{-31}}}$$

$= 4.9 \times 10^5$m/s $(\because K_{max} = \frac{1}{2}mv^2)$ (½ mark)

(iv) The k.E of photoelectrons is independent of intensity of incident light, hence if intensity is doubled K.E. remains same. (½ mark)

13. (a) The self inductance of a solenoid $= L = \dfrac{\mu_\circ N^2 A}{\ell}$

For Toroid, $\ell = 2\pi r$

$$\therefore \quad L = \frac{\mu_\circ N^2 A}{2\pi r}$$

Here, $N = 1200$, $A = 12\ cm^2 = 12 \times 10^{-4}\ m^2$, $r = 15\ cm = 15 \times 10^{-2} m$

$$\therefore \quad L = \frac{4\pi \times 10^{-7} \times (1200)^2 \times 12 \times 10^{-4}}{2\pi \times 0.15}$$

$$= 2.3 \times 10^{-3} H = 2.3\ mH$$ (1½ marks)

(b) Induced emf $= e = M\frac{dI}{dt}$ (numerically)

Mutual inductance of solenoid coil system

$$= M = \frac{\mu_\circ N_1 N_2 A}{\ell} = \frac{\mu_\circ N_1 N_2 A}{2\pi r}$$

Here, $N_2 = 300$, $N_1 = 1200$, $dI/dt = 2/0.05 = 40\ A/s$

$$\therefore \quad e = \left(\frac{\mu_0 N_1 N_2 A}{2\pi r}\right)\frac{dI}{dt}$$

$$= \frac{4\pi \times 10^{-7} \times 1200 \times 300 \times 12 \times 10^{-4} \times 40}{2\pi \times 0.15}$$

$$= 0.023 \text{ volt.}$$ (1½ marks)

14. Path difference $= (SS_2 + S_2P) - (SS_1 + S_1P)$

$= (SS_2 - SS_1) + (S_2P - S_1P)$

$= 0.25\lambda + (S_2P - S_1P)$

For maxima, path diff. $= n\lambda$

$\therefore \quad n\lambda = 0.25\lambda + S_2P - S_1P$

or, $S_2P - S_1P = n\lambda - 0.25\lambda = (n - 0.25)\lambda$.

For minima, path difference $= \left(n + \frac{1}{2}\right)\lambda$

$$\therefore \quad \left(n + \frac{1}{2}\right)\lambda = 0.25\lambda + S_2P - S_1P$$

$$\text{or,} \quad S_2P - S_1P = \left(n + \frac{1}{2}\right)\lambda - 0.25$$

$$\lambda = (2n + 0.5)\lambda.$$ (3 marks)

15. Ionisation energy = 13.6 × 1.6 × 10^{-19} J. The energy required to transit from initial to final level is given by

$$E = \frac{1}{(4\pi\varepsilon_0)^2}\frac{2\pi^2 me^4}{h^2}\left[\frac{1}{n_i^2}-\frac{1}{n_f^2}\right]$$

Put $n_i = 1$ and $n_f = \infty$ then E = 13.6 × 1.6 × 10^{-19}

$$= \underbrace{\frac{1}{(4\pi\varepsilon_0)^2}\frac{2\pi^2 me^4}{h^2}}_{\text{Constant K}}\left[\frac{1}{1^2}-\frac{1}{\infty}\right]$$

∴ K = 13.6 × 1.6 × 10^{-19} J

(i) Energy absorbed in transition from

$$n = 1 \text{ to } n = 4 \text{ is } E_3 = K\left[\frac{1}{1^2}-\frac{1}{4^2}\right] = \frac{15}{16}\times K$$

$$= \frac{13.6\times1.6\times10^{-19}\times15}{16}J$$

$$= 13.6\times\frac{15}{16}eV = 12.75\ eV$$ (2 marks)

(ii) The required wavelength of emitted radiation is

$$\lambda_3 = \frac{hc}{E_3} = \frac{6.6\times10^{-34}\times3\times10^8}{12.75\times1.6\times10^{-19}}$$

$= 9.74 \times 10^{-7}$m = 9740 Å. (1 mark)

16. $R = R_0 A^{1/3}$

$$\frac{R(^{197}Au)}{R(^{107}Ag)} = \left(\frac{197}{107}\right)^{1/3} = 1.23$$ (1½ marks)

Nuclear mass density ratio is constant = 1

$$= \frac{\rho(Au)}{\rho(Ag)}$$ as it is same for all nuclei (1½ marks)

17. (a) Earth's magnetic field can be due to molten charged metallic fluid in the core of the earth. As the fluid rotates with the rotation of the earth, a current is developed which causes magnetism. (1 mark)

(b) Since every substance is made up of charged particles like protons and electrons, due to earth's rotation about its axis a circulating current is produced which can cause magnetism. (1 mark)

(c) In earth's atmosphere, gases are in ionised state due to cosmic rays. As earth rotates, an electric current is set up due to movement of charged ions which can be the cause of magnetism. (1 mark)

18. $C_o = \frac{\varepsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 6 \times 10^{-3}}{3 \times 10^{-3}}$

$= 17.7 \times 10^{-12} = 17.7\,pF$

$Q = C_0 V = 17.7 \times 10^{-12} \times 100$

$= 17.7 \times 10^{-10}\,C.$

(a) $C = k C_0 = 6 \times 17.7 = 106.2\,pF.$ (1½ marks)

(b) After the supply is disconected

$Q = 17.7 \times 10^{-10}\,C.$

$C = 106.2 \times 10^{-12}\,F$

$V = \frac{Q}{C} = \frac{17.7 \times 10^{-10}}{106.2 \times 10^{-12}}$

$= 0.166 \times 10^{2} = 166.6$ volt. (1½ marks)

19. Message signals (base band) spread over a range of frequencies. Various factors prevent direct transmission of the signal such as;

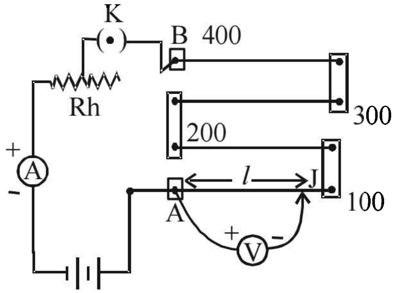
(i) **Size of antenna or aerial:** The size of the antenna should at least be equal to $\lambda/4$ in dimension so are to detect time variation properly . For electro magnetic waves of frequency 20 kHz, wavelength = 15 km, such large antennas are not practically possible. So we translate low frequency signal into high frequency before trans mission. (ii) Effective power radiated The power radiated by a linear antenna is $(\ell/\lambda)^2$. This means that long wavelength baseband signals would have less power during transmission but we need more power, hence high frequency (low λ) signals are better.

(ii) **mixing up of signals during transmission:** To prevent many signals transmitted atsame time from mixing, it is important that a bandwidth be allotted to each signal separately which is possible for high frequency only (low frequency signal has limited range) (2 marks)

The above limitations suggest that if low frequency message is translated into high frequency transmission then original signal can be sent in a more effective way. Hence modulation by means of message signal superimposed on a high frequency carrier wave is done, This reduces antenna size, increases power , gives a unique band width to each signal and prevents mixing of signals. (1 mark)

20. **Principle:** The fall of potential across any portion of the potentiometer wire is directly proportional to the length of that portion provided the wire is of uniform cross - sectional area and a constant current is flowing through it. (1 mark)

Working:



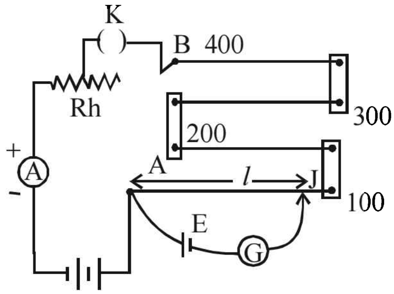
Let A be the area of cross-section of the wire. ρ be the specific resistance of the material of the wire V is the potential drop across the portion of the wire whose length is ℓ and resistance R and I be the current flowing through the wire.

$$V = IR = \frac{I\rho\ell}{A} = k\ell$$

∴ $V \propto \ell$ where I and A are constants

$\frac{V}{\ell} = k =$ potential gradient or falls of potential per unit length of the wire.

To find the e.m.f of a cell the following circuit is used.



The cell of e.m.f E to be measured is connected in parallel along with a galvanometer to the potentiometer wire. Let the null point is found at J and AJ = ℓ

∴ The potential drop across the potentiometer wire AJ is equal to the unknown e.m.f E.

∴ $E = k\ell$ where k is the potential gradient of the potentiometer wire. Knowing k and measuring ℓ from the attached scale E can be calculated. (2 marks)

OR

The resistivity of the material of a conductor is defined as the resistance of unit length and unit area of cross–section of the conductor. The S. I unit of resistivity is ohm metre (Ωm).

Resistivity of a material,

$\rho = \frac{m}{ne^2\tau}$ or $\rho \propto \frac{1}{n\tau}$ Where m is the mass of electron, n is the number density of electron and τ is the average relaxation time. This shows that the resistivity is related to two parameters of the material namely n and τ. (1 mark)

The variation of resistivity with temperature is different in different materials.

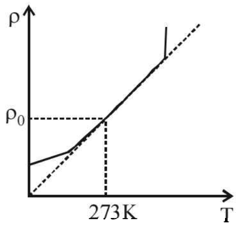
(a) **For metallic conductors :** The temperature dependence of resistivity of a metal is given by the relation,

$$\rho = \rho_0[1 + \alpha(T - T_0)] \quad ......(1)$$

Where ρ and ρ_0 are the resistivity at temperature T and T_0 respectively and α is called temperature coefficient of resistivity.

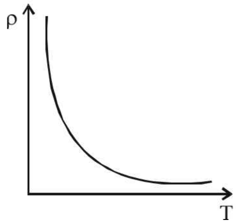
$$\therefore \quad \alpha = \frac{\rho - \rho_0}{\rho_0(T - T_0)} = \frac{d\rho}{\rho_0}.\frac{1}{dT} \quad .....(2)$$

The resistivity of a conductor increases with increase in temperature since α is positive. The variation of resistivity of copper with temperature is as shown.



(1 mark)

(b) **For Semiconductors :** For Semiconductors, the resistivity decreases as temperature increases since the value of α is negative.



(½ mark)

(c) **For insulators :** The resistivity increases exponentially with decrease in temperature. It becomes infinitely large at temperatures near absolute zero. (½ mark)

21. Here $R = 6$ cm $= 0.06$ m, $C = 100$ pF
$= 100 \times 10^{-12}$ F
$\omega = 300$ rad/s, $E_{rms} = 230$ volt.

(a) $I_{rms} = \frac{E_{rms}}{X_C} = \frac{E_{rms}}{1/\omega C} = E_{rms} \times \omega C$

$\therefore I_{rms} = 230 \times 300 \times 100 \times 10^{-12}$
$= 6.9 \times 10^{-6}$ A $= 6.9$ μ A. (1 mark)

(b) Displacement current

$$= I_D = \varepsilon_0 \frac{d\varphi_E}{dt} = \varepsilon_0 \frac{d}{dt}(EA) \quad [\because \varphi_E = EA]$$

$$\therefore \quad I_D = \varepsilon_0 A \frac{dE}{dt} = \varepsilon_0 A \frac{d}{dt}\left(\frac{Q}{\varepsilon_0 A}\right)$$

$$\left[\because \quad E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A} \text{ between the plates of the capacitor}\right]$$

$$\therefore \quad I_D = \varepsilon_0 A \times \frac{1}{\varepsilon_0 A} \frac{dQ}{dt} = I$$

$\therefore$ Displacement current between the plates of the capacitor = conduction current. (1 mark)

(c) $B = \frac{\mu_0}{2\pi} \frac{r}{R^2} . I_D$

[From Ampere's circuital law, $\oint \vec{B}.d\vec{l} = \mu_0 I_D$

$$\Rightarrow 2\pi rB = \mu_0 I_D \frac{\pi r^2}{\pi R^2} = \frac{\mu_0 I_D r}{2\pi R^2}$$

$$B = \frac{\mu_0 rI}{2\pi R^2}$$

$\because$ Amplitude of B = Maximum value of B

$$= \frac{\mu_0 rI_0}{2\pi R^2} = \frac{\mu_0 r\sqrt{2}\, I_{rms}}{2\pi R^2}$$

$$= \frac{4\pi \times 10^{-7} \times 0.03 \times \sqrt{2} \times 6.9 \times 10^{-6}}{2 \times 3.14 \times (0.06)^2} = 1.6 \times 10^{-11}\,\text{T.}$$ (1 mark)

22. Let a charged particle is moving in the magnetic field with a velocity $\vec{v}$ making angle θ with $\vec{B}$.

The component of $\vec{v}$ along $\vec{B}$ is v cosθ, due to which no force will act on the particle. so it will cover a distance along the magnetic field with a constant speed.
The perpendicular component v sin θ will provide a force,
F = qBvsinθ which provide the necessary centripetal force for the circular motion of the charged particle

$$\therefore \quad Bqv\sin\theta = \frac{m(v\sin\theta)^2}{r}$$

$$\Rightarrow v\sin\theta = \frac{Bqr}{m}$$ (1 mark)

and r = radius of the path = $\frac{mv\sin\theta}{Bq}$

If sin θ = 1, i.e. θ = 90° then $r = \frac{mv}{Bq}$

Under the combined action of both the velocities the charged particle will undergo a linear as well as a circular motion. So the resultant path will be a helix. (2 marks)

SECTION - D

23. (i) Caring, sharing, concern. (1½ marks)
(ii) Polarisation. (1 mark)
(iii) No change in intensity of light. (1½ marks)

SECTION - E

24. **Induced e.m.f:** When the magnetic flux linked with a coil changes, an e.m.f is induced in the coil. This is called induced e.m.f. (1 mark)

Faraday's law of electromagnetic induction:

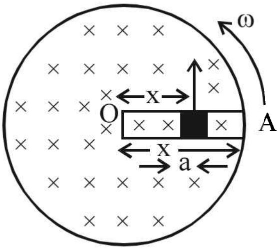
1st Law: When the magnetic flux linked with a coil changes, an e.m.f is induced in the coil. It lasts so long as the change in flux continues.

2nd law: The magnitude of induced e.m.f is directly proportional to the rate of change of magnetic flux linked with the coil. It is in the opposite direction of the change of magnetic flux.

$$e = \frac{d\phi}{dt} \quad \text{[Here proportionality constant = 1]}$$

For a coil of N turns, $e = -N\frac{d\phi}{dt}$ (1 mark)

Induced e.m.f in a rotating rod : Consider a metallic rod of length l, which is rotating with angular velocity ω in a uniform magnetic field B, the plane of rotation being perpendicular to the magnetic field. A rod may be supposed to be formed of a large number of small elements. Consider a small element of length dx at a distance x from centre. If v is the linear velocity of this elements, then area swept out by the element per second = vdx.



∴ E.m.f induced across the ends of the element $= dE = B\frac{dA}{dt} = Bv\,dx$

∵ $v = x\omega$ ∴ $dE = Bx\omega\,dx$

∴ The e.m.f induced across the rod

$$= \varepsilon = \int_0^{\ell} Bx\omega dx = B\omega\int_0^{\ell} xdx = B\omega\left[\frac{x^2}{2}\right]_0^{\ell} = B\omega\left(\frac{\ell^2}{2} - 0\right)$$

∴ $\varepsilon = \frac{1}{2}B\omega\ell^2$ (3 marks)

OR

The instantaneous voltage and current in an LCR circuit are given by, $E = E_0 \sin\omega t$ and $I = I_0 \sin(\omega t - \varphi)$

$$P = \frac{1}{T}\int_0^T EI = \frac{1}{T}\int_0^T E_0 \sin\omega t\, I_0 \sin(\omega t - \varphi)dt$$

$$= \frac{E_0 I_0}{2T}\int_0^T (\sin\omega t(\sin\omega t\cos\varphi - \cos\omega t.\sin\varphi)dt$$

$$= \frac{E_0 I_0}{T}\left[\int_0^T \sin^2\omega t\cos\varphi dt - \int_0^T \sin\omega t.\cos\omega t.\sin\varphi)dt\right]$$

$$= \frac{E_0 I_0}{2T}\left[\int_0^T 2\sin^2\omega t\cos\varphi dt - \int_0^T 2\sin\omega t.\cos\omega t.\sin\varphi)dt\right]$$

$$= \frac{E_0 I_0}{2T}\left[\int_0^T (1 - \cos 2\omega t)\cos\varphi dt - \int_0^T 2\sin\omega t.\cos\omega t.\sin\varphi dt\right]$$

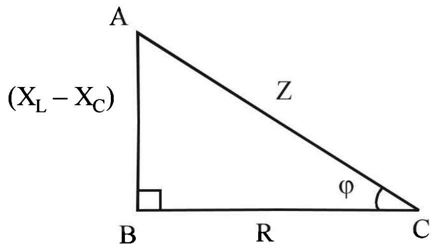
$$\therefore \int_0^T \cos 2\omega t dt = 0 \text{ and } \int_0^T \sin 2\omega t dt = 0$$

$$\therefore P = \frac{E_0 I_0}{2T}.T\cos\varphi = \frac{E_0}{\sqrt{2}}.\frac{I_0}{\sqrt{2}}\cos\varphi$$

$\therefore P = E_{rms} I_{rms} \cos\varphi$, where $\cos\varphi$ is called **power factor.**(3 marks)

From the impedance in angle

$$\cos\varphi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + (x_L - x_C)^2}}$$



For non inductive circuit $X_L = X_C$

$$\therefore \cos\varphi = \frac{R}{R} = 1 \Rightarrow \text{Maximum} \Rightarrow \varphi = 0°$$

For inductive or capacitative circuit,

$\cos\varphi = \cos 90° = 0$

$\therefore P = 0$ (2 marks)

25. (i) When p– and n– type semiconductors are joined in thin wafer form they form a junction. In p– type semiconductor concentration of holes is more and on n – side electrons are in majority, hence due to this gradient both electrons and holes diffuse to the other side leaving behind ionised donor and acceptor atoms which are immobile. As charges diffuse a layer of negative charges (acceptor) is found on p–side and positive charges (donor) on n–side near the junction. This is depletion layer and creates an electric field due to which electrons on p– side move to n–side. This is called drift current. Thus space charge region of either side extends, forming p–n junction. (1½ marks)

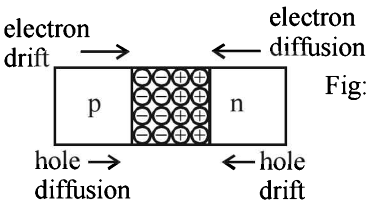
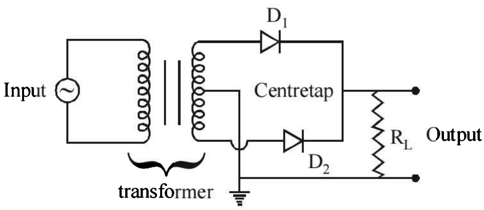
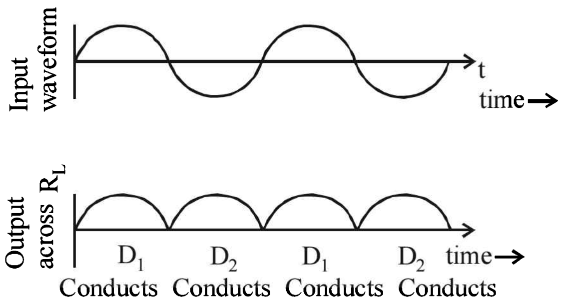


Fig: p–n junction formation process

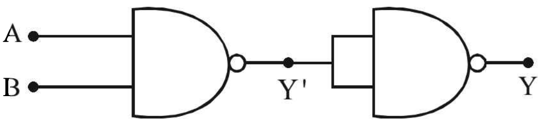
(ii) Here we use two diodes to rectify voltage corresponding to both positive and negative half of the a.c. cycle. Here, the p–side of the two diodes are connected to ends of secondary which is centre tapped in this transformer. For positive half cycle, D_1 is forward biased and conducts and for negative half cycle D_2 conducts. The output across load is a continuously, varying pulse of the shape of half sinusoids.





(2 marks)

(iii) If output Y' of NAND is connected to input of NOT gate (made from NAND gate by joining two inputs) then we get AND gate.



A	B	Y'	Y
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1

(1½ marks)

OR

(i) Reverse current is due to flow of minority carriers. As the reverse bias voltage increases, electric field at the junction increases. At $V = V_Z$ (breakdown) electric field strength is enough to pull valence electrons from p–side to n–side. This is field emission of electrons (or field ionisation) which leads to high current. The electric field required is ~ 10^6 V/m. (2 marks)

(ii) Voltage drop across p-n junction = 0.6V, emf of battery = 1.5 V
Let R = max. resistance used in series with p-n junction
max. current = 6 mA
Using Ohm's law, $IR + 0.6 = 1.5$
$\Rightarrow IR = 1.5 - 0.6 = 0.9$

$$\Rightarrow R = \frac{0.9}{I} = \frac{0.9}{6 \times 10^{-3}} = 150\Omega.$$ (3 marks)

26. (i) (a) From the fringe width expression,

$$\beta = \frac{\lambda D}{d}$$

With the decrease in separation between two slits, the fringe width β increases. (1 mark)

(b) For interference fringes to be seen, $\frac{s}{S} \leq \frac{\lambda}{d}$

Condition should be satisfied

where, s = size of the source and d = distance of the source from the plane of two slits.

As the source-slit-width increase, fringe pattern gets less and less sharp.

When the source-slit is so wide, the above condition does not satisfied and the interference pattern disappears. (1 mark)

(c) The interference pattern due to different colour component of white light overlap. The central bright fringes for different colours are at the same position. Therefore, centre fringes are white. And on the either side of the central fringe (i.e., central maxima), coloured bands will appear.

The fringe closed on either side of central white fringe is red and the farthest will be blue. After a few fringes, no clear fringes patterns is seen. (1 mark)

(ii) Intensity at point is given by

$I = 4I' \cos^2 \phi/2$

where, ϕ = phase difference,

I' = intensity produced by each one of the individual sources.

At central maxima, $\phi = 0$, the intensity at the central maxima, $I = I_0 = 4I'$

or $\quad I' = \frac{I_0}{4}$ ...(i)

As path difference = $\frac{\lambda}{3}$

Phase difference, $\phi' = \frac{2\pi}{\lambda} \times$ Path difference

$$= \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$$

Now, intensity at this point,

$$I'' = 4I' \cos^2 \frac{1}{2}\left(\frac{2\pi}{3}\right) = 4I' \cos^2 \frac{\pi}{3} = 4I \times \frac{1}{4} = I'$$

or $\quad I'' = \frac{I_0}{4}$ [From equ (i)] (2 marks)

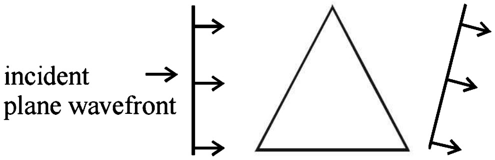
OR

(i) A polaroid is a material which consists of long chain molecules aligned in a particular direction. If an unpolarised light wave is incident on such a polaroid then electric vector along the direction of aligned molecules get absorbed and the light wave is linearly polarised. (1 mark)

Polaroids are used to control the intensity of light in sunglasses, window panes and aeroplanes etc. They are also used in photographic cameras and 3D movie cameras. (1 mark)

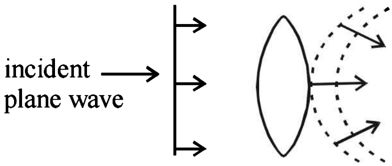
(ii) Refraction of a plane wave form by

(a) A thin prism.



(1½ marks)

(b) A convex lens



(1½ marks)