SAMPLE PAPER TEST 01 FOR BOARD EXAM 2025

SUBJECT: PHYSICS | **MAX. MARKS : 70**
CLASS : XII | **DURATION: 3 HRS**

General Instructions:

1. There are 33 questions in all. All questions are compulsory
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains sixteen questions, twelve MCQ and four Assertion-Reasoning based questions of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

SECTION – A

Questions 1 to 16 carry 1 mark each.

1. In the process of charging of a capacitor, the current produced between the plates of the capacitor is:

(a) $\mu_0 \frac{d\phi_E}{dt}$ (b) $\frac{1}{\mu_0}\frac{d\phi_E}{dt}$ (c) $\varepsilon_0 \frac{d\phi_E}{dt}$ (d) $\frac{1}{\varepsilon_0}\frac{d\phi_E}{dt}$

where symbols have their usual meanings.

2. The area of a square shaped coil is 10^{-2} m^2. Its plane is perpendicular to a magnetic field of strength 10^{-3} T. The magnetic flux linked with the coil is

(a) 10 Wb (b) 10^{-5} Wb (c) 10^5 Wb (d) 100 Wb

3. A particle of mass m and charge q moving with a uniform velocity $\vec{v} = v_{0x}\hat{i} + v_{0y}\hat{j}$ enters a region with a magnetic field $\vec{B} = B_0\hat{j}$. After some time, an electric field $\vec{E} = E_0\hat{j}$ is also switched on in the region. The resulting path described by the particle will be:

(a) a circle in x-z plane (b) a parabola in x-y plane
(c) a helix with constant pitch (d) a helix with increasing pitch

4. An electron experiences a force $(1.6\times10^{-16} N)\hat{i}$ in an electric field $\vec{E}$. The electric field $\vec{E}$ is :

(a) $(1.0\times10^{3}\frac{N}{C})\hat{i}$ (b) $-(1.0\times10^{3}\frac{N}{C})\hat{i}$ (c) $(1.0\times10^{-3}\frac{N}{C})\hat{i}$ (d) $-(1.0\times10^{-3}\frac{N}{C})\hat{i}$

5. At a certain temperature in an intrinsic semiconductor, the electrons and holes concentration is $1{\cdot}5 \times 10^{16}$ m^{-3}. When it is doped with a trivalent dopant, hole concentration increases to $4{\cdot}5 \times 10^{22}$ m^{-3}. In the doped semiconductor, the concentration of electrons (n_e) will be :

(a) 3×10^6 m^{-3} (b) 5×10^7 m^{-3} (c) 5×10^9 m^{-3} (d) $6{\cdot}75 \times 10^{38}$ m^{-3}

6. A voltage signal is described by:

$$v = V_0 \quad for \quad 0 \le t \le \frac{T}{2}$$

$$= 0 \quad for \quad \frac{T}{2} \le t \le T$$

for a cycle. Its rms value is :

(a) $V_0/\sqrt{2}$ (b) V_0 (c) $V_0/2$ (d) $\sqrt{2}\, V_0$

7. In the wave picture of light, the intensity I of light is related to the amplitude A of the wave as:
(a) $I \propto \sqrt{A}$ (b) $I \propto A$ (c) $I \propto A^2$ (d) $I \propto 1/A^2$

8. An inductor, a capacitor and a resistor are connected in series across an ac source of voltage. If the frequency of the source is decreased gradually, the reactance of :
(a) both the inductor and the capacitor decreases.
(b) inductor decreases and the capacitor increases.
(c) both the inductor and the capacitor increases.
(d) inductor increases and the capacitor decreases.

9. A graph is plotted between the stopping potential (on y-axis) and the frequency of incident radiation (on x-axis) for a metal. The product of the slope of the straight line obtained and the magnitude of charge on an electron is equal to :
(a) h (b) h/c (c) 2h/c (d) h/2c

10. Light of frequency $6{\cdot}4 \times 10^{14}$ Hz is incident on a metal of work function 2·14 eV. The maximum kinetic energy of the emitted electrons is about :
(a) 0·25 eV (b) 0·51 eV (c) 1·02 eV (d) 0·10 eV

11. Which one of the following is not a scalar quantity?
(a) Electric field (b) Voltage (c) Resistivity (d) Power

12. The electromagnetic radiations used to kill germs in water purifiers are called :
(a) Infrared waves (b) X-rays (c) Gamma rays (d) Ultraviolet rays

ASSERTION-REASON BASED QUESTIONS

In the following questions, a statement of assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.
(a) Both Assertion (A) and Reason (R) are true and (R) is the correct explanation of (A).
(b) Both Assertion (A) and Reason (R) are true and (R) is NOT the correct explanation of (A).
(c) Assertion (A) is true and Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false.

13. Assertion (A): The nucleus $^{7}_{3}X$ is more stable than the nucleus $^{4}_{3}Y$.
Reason (R): $^{7}_{3}X$ contains more number of protons.

14. Assertion (A): The internal resistance of a cell is constant.
Reason (R): Ionic concentration of the electrolyte remains same during use of a cell.

15. Assertion (A): When radius of a circular loop carrying a steady current is doubled, its magnetic moment becomes four times.
Reason (R): The magnetic moment of a circular loop carrying a steady current is proportional to the area of the loop.

16. Assertion (A): Thin films such as soap bubble or a thin layer of oil on water show beautiful colours when illuminated by white light.
Reason (R): It is due to interference of sun's light reflected from upper and lower surfaces of the film.

SECTION – B

Questions 17 to 21 carry 2 marks each.

17. The refractive indices of two media A and B are 2 and $\sqrt{2}$ respectively. What is the critical angle for their interface?

18. Explain the property of a p-n junction which makes it suitable for rectifying alternating voltages. Differentiate between a half-wave and a full-wave rectifier.

19. What is meant by the term 'displacement current' ? Briefly explain how this current is different from a conduction current.

20. A wire of length l is in the form of a circular loop A of one turn. This loop is reshaped into loop B of three turns. Find the ratio of the magnetic fields at the centres of loop A and loop B for the same current through them.

21. (a) State Huygens' principle. How did Huygens explain the absence of the backwave?

OR

(b) Use Huygens' principle to show reflection/refraction of a plane wave by (i) concave mirror, and (ii) a convex lens.

SECTION – C

Questions 22 to 28 carry 3 marks each.

22. Draw a diagram to show the variation of binding energy per nucleon with mass number for different nuclei and mention its two features. Why do lighter nuclei usually undergo nuclear fusion ?

23. (a) An ac source $v = v_m \sin\omega t$ is connected across an ideal capacitor. Derive the expression for the (i) current flowing in the circuit, and (ii) reactance of the capacitor. Plot a graph of current i versus ωt.

OR

(b) A series combination of an inductor L, a capacitor C and a resistor R is connected across an ac source of voltage in a circuit. Obtain an expression for the average power consumed by the circuit. Find power factor for (i) purely inductive circuit, and (ii) purely resistive circuit.

24. Explain the roles of diffusion current and drift current in the formation of the depletion layer in a p-n junction diode.

25. Calculate the wavelength of de Broglie waves associated with a proton having (500/1·673) eV energy. How will the wavelength be affected for an alpha particle having the same energy ?

26. What is meant by the term 'mutual inductance' of a pair of coils ? Obtain an expression for the mutual inductance of two long coaxial solenoids, each of length l but having different number of turns N_1 and N_2 and radii r_1 and r_2 ($r_2 > r_1$).

27. (i) Draw a graph to show the variation of the number of scattered particles detected (N) in Geiger-Marsden experiment as a function of scattering angle (θ).

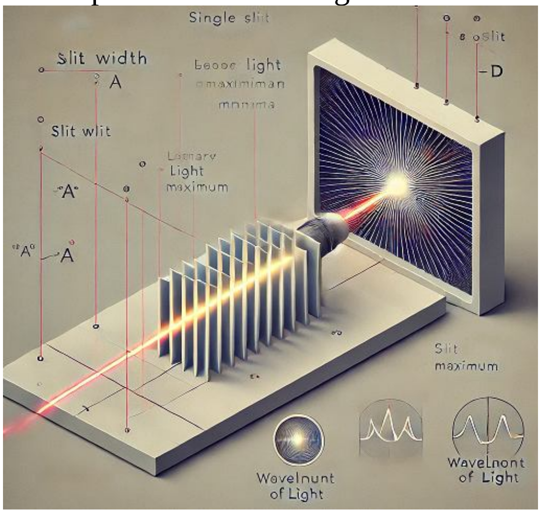
(ii) Discuss briefly two conclusions that can be drawn from this graph and how they lead to the discovery of nucleus in an atom.

28. A potential difference V is applied across a conductor of length l and uniform cross-section area A. How will the (i) electric field E, (ii) drift velocity v_d, and (iii) current density j be affected when (a) V is doubled and (b) l is halved (keeping other factors constant) ?

SECTION – D (Case Study Based Questions)

Questions 29 to 30 carry 4 marks each.

29. Diffraction: Diffraction of light is bending of light around the corners of an object whose size is comparable with the wavelength of light. Diffraction actually defines the limits of ray optics. This limit for optical instruments is set by the wavelength of light. An experimental arrangement is set up to observe the diffraction pattern due to a single slit.



(i) The penetration of light into the region of geometrical shadow is called
(a) polarisation (b) interference (c) diffraction (d) refraction

(ii) To observe diffraction, the size of an obstacle
(a) should be of the same order as wavelength
(b) should be much larger than the wavelength
(c) have no relation to wavelength
(d) should be exactly $l/2$

(iii) Both, light and sound waves produce diffraction. It is more difficult to observe diffraction with light waves because
(a) light waves do not require medium (b) wavelength of light waves is too small
(c) light waves are transverse in nature (d) speed of light is far greater

(iv) Angular width of central maximum of a diffraction pattern of a single slit does not depend upon
(a) distance between slit and source (b) wavelength of light used
(c) width of the slit (d) frequency of light used

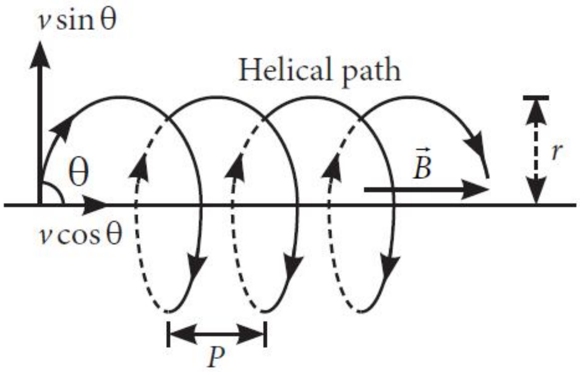
OR

The diffraction effect can be observed in
(a) only sound waves (b) only light waves
(c) only ultrasonic waves (d) sound as well as light waves

30. Helical Motion

The path of a charged particle in magnetic field depends upon angle between velocity and magnetic field.

If velocity v is at angle q to $\vec{B}$, component of velocity parallel to magnetic field (v cosθ) remains constant and component of velocity perpendicular to magnetic field (v sinθ) is responsible for circular motion, thus the charge particle moves in a helical path.



The plane of the circle is perpendicular to the magnetic field and the axis of the helix is parallel to the magnetic field. The charged particle moves along helical path touching the line parallel to the magnetic field passing through the starting point after each rotation.
Radius of circular path is r = mvsin-θ/qB
Hence the resultant path of the charged particle will be a helix, with its axis along the direction of $\vec{B}$ as shown in figure.
(i) When a positively charged particle enters into a uniform magnetic field with uniform velocity, its trajectory can be
(i) a straight line (ii) a circle (iii) a helix.
(a) (i) only (b) (i) or (ii) (c) (i) or (iii) (d) any one of (i), (ii) and (iii)

(ii) Two charged particles A and B having the same charge, mass and speed enter into a magnetic field in such a way that the initial path of A makes an angle of 30° and that of B makes an angle of 90° with the field. Then the trajectory of
(a) B will have smaller radius of curvature than that of A
(b) both will have the same curvature
(c) A will have smaller radius of curvature than that of B
(d) both will move along the direction of their original velocities.

(iii) An electron having momentum 2.4×10^{-23} kg m/s enters a region of uniform magnetic field of 0.15 T. The field vector makes an angle of 30° with the initial velocity vector of the electron. The radius of the helical path of the electron in the field shall be
(a) 2 mm (b) 1 mm (c) √3/2 mm (d) 0.5 mm

(iv) The magnetic field in a certain region of space is given by $\vec{B} = 8.35\times10^{-2}\hat{i}$ T. A proton is shot into the field with velocity $\vec{v} = (2\times10^{5}\hat{i}+4\times10^{5}\hat{j})$ m/s. The proton follows a helical path in the field. The distance moved by proton in the x-direction during the period of one revolution in the yz-plane will be
(Mass of proton = 1.67×10^{-27} kg)
(a) 0.053 m (b) 0.136 m (c) 0.157 m (d) 0.236 m

SECTION – E

Questions 31 to 33 carry 5 marks each.

31. (a) (i) Draw a ray diagram showing the formation of a real image of an object placed at a distance 'v' in front of a concave mirror of radius of curvature 'R'. Hence, obtain the relation for the image distance 'v' in terms of u and R.
(ii) A 1·8 m tall person stands in front of a convex lens of focal length 1 m, at a distance of 5 m. Find the position and height of the image formed.

OR

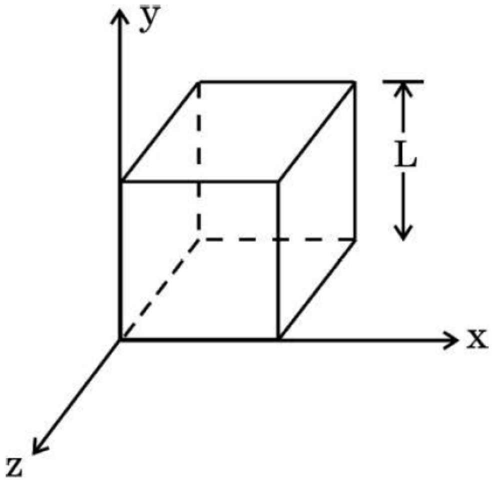
(b) (i) Draw a ray diagram showing refraction of a ray of light through a triangular glass prism. Hence, obtain the relation for the refractive index (μ) in terms of angle of prism (A) and angle of minimum deviation (δ_m).

(ii) The radii of curvature of the two surfaces of a concave lens are 20 cm each. Find the refractive index of the material of the lens if its power is –5·0 D.

32. (a) (i) Define electric flux and write its SI unit.

(ii) Use Gauss' law to obtain the expression for the electric field due to a uniformly charged infinite plane sheet.

(iii) A cube of side L is kept in space, as shown in the figure. An electric field $\vec{E} = (Ax + B)\hat{i}\frac{N}{C}$ exists in the region. Find the net charge enclosed by the cube.



OR

(b) (i) Define electric potential at a point and write its SI unit.

(ii) Two capacitors are connected in series. Derive an expression of the equivalent capacitance of the combination.

(iii) Two point charges + q and –q are located at points (3a, 0) and (0, 4a) respectively in x-y plane. A third charge Q is kept at the origin. Find the value of Q, in terms of q and a, so that the electrostatic potential energy of the system is zero.

33. (a) (i) Write the principle and explain the working of a moving coil galvanometer. A galvanometer as such cannot be used to measure the current in a circuit. Why ?

(ii) Why is the magnetic field made radial in a moving coil galvanometer ? How is it achieved ?

OR

(b) (i) Derive an expression for magnetic field on the axis of a current carrying circular loop.

(ii) Write any two points of difference between a diamagnetic and a paramagnetic substance.

SAMPLE PAPER TEST 01 FOR BOARD EXAM 2025

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CLASS : XII **DURATION: 3 HRS**

General Instructions:

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2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains sixteen questions, twelve MCQ and four Assertion-Reasoning based questions of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

SECTION – A

Questions 1 to 16 carry 1 mark each.

1. In the process of charging of a capacitor, the current produced between the plates of the capacitor is:

(a) $\mu_0 \frac{d\phi_E}{dt}$ (b) $\frac{1}{\mu_0}\frac{d\phi_E}{dt}$ (c) $\varepsilon_0 \frac{d\phi_E}{dt}$ (d) $\frac{1}{\varepsilon_0}\frac{d\phi_E}{dt}$

where symbols have their usual meanings.

Ans: (c) $\varepsilon_0 \frac{d\phi_E}{dt}$

2. The area of a square shaped coil is 10^{-2} m^2. Its plane is perpendicular to a magnetic field of strength 10^{-3} T. The magnetic flux linked with the coil is

(a) 10 Wb (b) 10^{-5} Wb (c) 10^5 Wb (d) 100 Wb

Ans: (b) 10^{-5} Wb

3. A particle of mass m and charge q moving with a uniform velocity $\vec{v} = v_{0x}\hat{i} + v_{0y}\hat{j}$ enters a region with a magnetic field $\vec{B} = B_0\hat{j}$. After some time, an electric field $\vec{E} = E_0\hat{j}$ is also switched on in the region. The resulting path described by the particle will be:

(a) a circle in x-z plane (b) a parabola in x-y plane
(c) a helix with constant pitch (d) a helix with increasing pitch

Ans: (d) a helix with increasing pitch

4. An electron experiences a force $(1.6\times10^{-16} N)\hat{i}$ in an electric field $\vec{E}$. The electric field $\vec{E}$ is :

(a) $(1.0\times10^3 \frac{N}{C})\hat{i}$ (b) $-(1.0\times10^3 \frac{N}{C})\hat{i}$ (c) $(1.0\times10^{-3} \frac{N}{C})\hat{i}$ (d) $-(1.0\times10^{-3} \frac{N}{C})\hat{i}$

Ans: (b) $-(1.0\times10^3 \frac{N}{C})\hat{i}$

5. At a certain temperature in an intrinsic semiconductor, the electrons and holes concentration is $1{\cdot}5 \times 10^{16}$ m^{-3}. When it is doped with a trivalent dopant, hole concentration increases to $4{\cdot}5 \times 10^{22}$ m^{-3}. In the doped semiconductor, the concentration of electrons (n_e) will be :

(a) 3×10^6 m^{-3} (b) 5×10^7 m^{-3} (c) 5×10^9 m^{-3} (d) $6{\cdot}75 \times 10^{38}$ m^{-3}

Ans: (c) 5×10^9 m^{-3}

6. A voltage signal is described by:

$$v = V_0 \quad for \quad 0 \le t \le \frac{T}{2}$$

$$= 0 \quad for \quad \frac{T}{2} \le t \le T$$

for a cycle. Its rms value is :

(a) $V_0/\sqrt{2}$ (b) V_0 (c) $V_0/2$ (d) $\sqrt{2}\, V_0$

Ans: (a) $V_0/\sqrt{2}$

7. In the wave picture of light, the intensity I of light is related to the amplitude A of the wave as:

(a) $I \propto \sqrt{A}$ (b) $I \propto A$ (c) $I \propto A^2$ (d) $I \propto 1/A^2$

Ans: (c) $I \propto A^2$

8. An inductor, a capacitor and a resistor are connected in series across an ac source of voltage. If the frequency of the source is decreased gradually, the reactance of :

(a) both the inductor and the capacitor decreases.
(b) inductor decreases and the capacitor increases.
(c) both the inductor and the capacitor increases.
(d) inductor increases and the capacitor decreases.

Ans: (b) inductor decreases and the capacitor increases.

9. A graph is plotted between the stopping potential (on y-axis) and the frequency of incident radiation (on x-axis) for a metal. The product of the slope of the straight line obtained and the magnitude of charge on an electron is equal to :

(a) h (b) h/c (c) 2h/c (d) h/2c

Ans: (a) h

10. Light of frequency $6{\cdot}4 \times 10^{14}$ Hz is incident on a metal of work function 2·14 eV. The maximum kinetic energy of the emitted electrons is about :

(a) 0·25 eV (b) 0·51 eV (c) 1·02 eV (d) 0·10 eV

Ans: (b) 0·51 eV

11. Which one of the following is not a scalar quantity?

(a) Electric field (b) Voltage (c) Resistivity (d) Power

Ans: (a) Electric field

12. The electromagnetic radiations used to kill germs in water purifiers are called :

(a) Infrared waves (b) X-rays (c) Gamma rays (d) Ultraviolet rays

Ans: (d) Ultraviolet rays

ASSERTION-REASON BASED QUESTIONS

In the following questions, a statement of assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.

(a) Both Assertion (A) and Reason (R) are true and (R) is the correct explanation of (A).
(b) Both Assertion (A) and Reason (R) are true and (R) is NOT the correct explanation of (A).
(c) Assertion (A) is true and Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false.

13. Assertion (A): The nucleus ${}^{7}_{3}X$ is more stable than the nucleus ${}^{4}_{3}Y$.

Reason (R): ${}^{7}_{3}X$ contains more number of protons.

Ans: (c) Assertion (A) is true, but Reason (R) is false

14. Assertion (A): The internal resistance of a cell is constant.
Reason (R): Ionic concentration of the electrolyte remains same during use of a cell.
Ans: (d) Assertion (A) is false and Reason (R) is also false.

15. Assertion (A): When radius of a circular loop carrying a steady current is doubled, its magnetic moment becomes four times.
Reason (R): The magnetic moment of a circular loop carrying a steady current is proportional to the area of the loop.
Ans: (a) Both Assertion(A) and Reason (R) are true and Reason(R) is the correct explanation of the Assertion (A)

16. Assertion (A): Thin films such as soap bubble or a thin layer of oil on water show beautiful colours when illuminated by white light.
Reason (R): It is due to interference of sun's light reflected from upper and lower surfaces of the film.
Ans: (a) Both Assertion(A) and Reason (R) are true and Reason(R) is the correct explanation of the Assertion (A)

SECTION – B

Questions 17 to 21 carry 2 marks each.

17. The refractive indices of two media A and B are 2 and √2 respectively. What is the critical angle for their interface?
Ans: From Snell 's law:-

$$\mu_A \sin i_c = \mu_B \sin 90^0 \Rightarrow 2 \times \sin i_c = \sqrt{2} \times 1$$

$$\Rightarrow \sin i_c = \frac{\sqrt{2}}{2} = \frac{1}{\sqrt{2}} = \sin 45^0 \Rightarrow i_c = 45^0$$

Alternatively: $\Rightarrow \sin i_c = \frac{1}{{}^B\mu_A} = \frac{1}{\sqrt{2}} = \sin 45^0 \Rightarrow i_c = 45^0$

18. Explain the property of a p-n junction which makes it suitable for rectifying alternating voltages. Differentiate between a half-wave and a full-wave rectifier.
Ans: When a junction diode has an alternating voltage placed across it, only when the diode is forward biased can current flow. The junction diode's ability to correct alternating current can be used. This is accomplished through the use of a rectifier circuit. It exhibits high resistance when reverse-biased and low resistance when forward-biased.
The half-wave rectifier gives output only for half of the input cycle .The full-wave rectifier gives output for both the halves of the input cycles.
Alternatively:- If output waveform of both the rectifiers shown diagrammatically, then full credit to be given.

19. What is meant by the term 'displacement current' ? Briefly explain how this current is different from a conduction current.
Ans: Displacement current: It is the current that arises due to the rate of change of electric field/flux.

Alternatively:- $I_d = \varepsilon_0 \left(\frac{d\phi_E}{dt} \right)$

Alternatively: The term with units of current to explain the continuity of current in a region.
Difference:
Displacement current is due to change in electric flux. Conduction current is due to flow of electrons.

Alternatively: $I_d = \varepsilon_0\left(\frac{d\phi_E}{dt}\right)$, $I_c = \frac{dq}{dt}$

20. A wire of length l is in the form of a circular loop A of one turn. This loop is reshaped into loop B of three turns. Find the ratio of the magnetic fields at the centres of loop A and loop B for the same current through them.

Ans: Ratio of magnetic fields at the centres of loop A & loop B:

$$B = \frac{\mu_0 NI}{2r}$$

$$I = 2\pi r;\ \ 2\pi r_A = 3(2\pi r_B) \Rightarrow r_B = \frac{r_A}{3}$$

$$\frac{B_A}{B_B} = \frac{\mu_0 N_A I}{2r_A} \div \frac{\mu_0 N_B I}{2r_B} = \frac{\mu_0 N_A I}{2r_A} \times \frac{2r_B}{\mu_0 N_B I} = \frac{N_A r_B}{N_B r_A} = \frac{1}{3} \times \frac{1}{3} = \frac{1}{9}$$

21. (a) State Huygens' principle. How did Huygens explain the absence of the backwave?

Ans: Statement: Each point of the wavefront is the source of secondary disturbance in all directions.

Common tangent to all the secondary wavelets gives new position of the wavefront.

Explanation: Light energy cannot travel in backward direction.

Alternatively:

It was an adhoc assumption .

Alternatively:

For back wave: $I = \frac{1}{2}(1 + \cos\theta)$

at θ =180º ; contribution is zero.

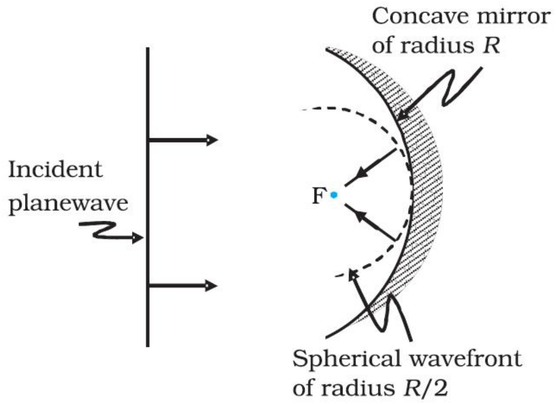
Alternatively:

Amplitude of secondary wavelets is maximum in forward direction and zero in backward in direction.

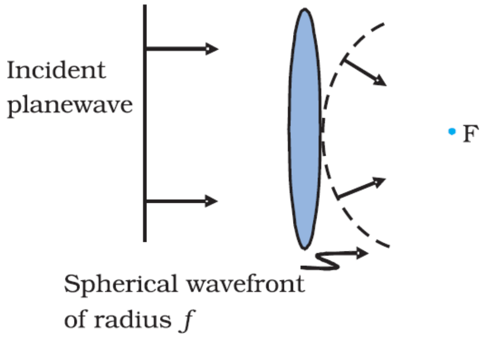
OR

(b) Use Huygens' principle to show reflection/refraction of a plane wave by (i) concave mirror, and (ii) a convex lens.

Ans: (i) Diagram for concave mirror



(ii) Diagram for convex lens

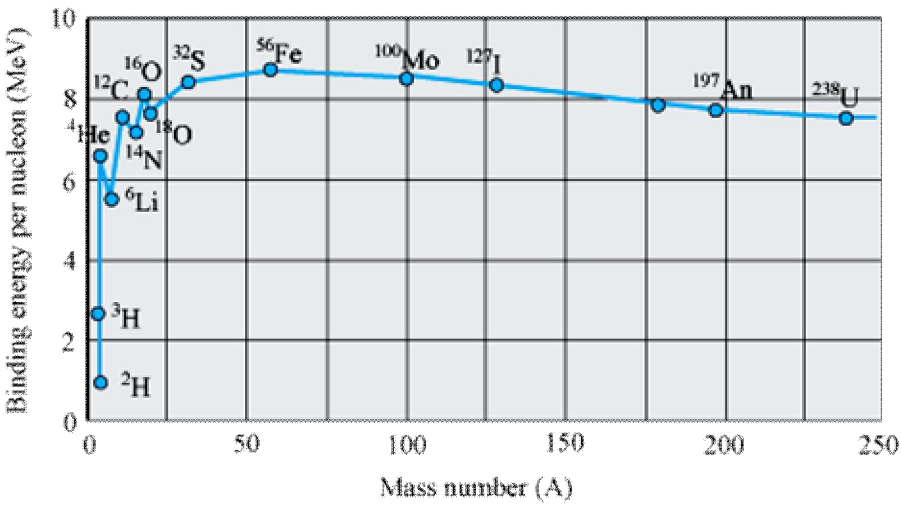


SECTION – C

Questions 22 to 28 carry 3 marks each.

22. Draw a diagram to show the variation of binding energy per nucleon with mass number for different nuclei and mention its two features. Why do lighter nuclei usually undergo nuclear fusion ?

Ans:



Features of diagram (any two)

1. Binding energy per nucleon is practically independent of atomic number for nuclei of middle mass number (30 <A < 170)

2. The curve has maximum of about 8.75 MeV for A= 56 and has a value of 7.6 MeV for A= 238

3. Binding energy per nucleon is lower for both light nuclei (A<30) and heavy nuclei (A>170)

Two lighter nuclei fuse together to form heavier nuclei as the binding energy per nucleon of fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. Thus the final system is more tightly bound than initial system.

23. (a) An ac source v = v_m sinωt is connected across an ideal capacitor. Derive the expression for the (i) current flowing in the circuit, and (ii) reactance of the capacitor. Plot a graph of current i versus ωt.

Ans: (i) $V_m \sin\omega t = \dfrac{q}{C}$

$$I = \frac{dq}{dt} = \frac{d}{dt}(CV_m \sin\omega t)$$

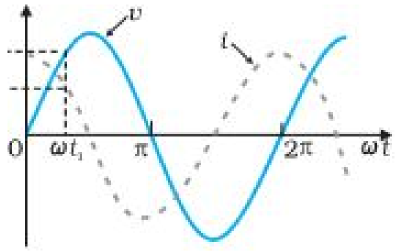
$$\Rightarrow I = \omega CV_m \cos\omega t$$

Alternatively:- $I = \dfrac{V_m}{1/\omega C}\cos\omega t = I_m \sin\left(\omega t + \dfrac{\pi}{2}\right)$

(ii) $I = \frac{V_m}{1/\omega C} \sin\left(\omega t + \frac{\pi}{2}\right) = I_m \sin\left(\omega t + \frac{\pi}{2}\right)$

Comparing with $I_m = \frac{V_m}{1/\omega C}$

Reactance of the capacitor; $Xc = \frac{1}{\omega C}$



OR

(b) A series combination of an inductor L, a capacitor C and a resistor R is connected across an ac source of voltage in a circuit. Obtain an expression for the average power consumed by the circuit. Find power factor for (i) purely inductive circuit, and (ii) purely resistive circuit.

Ans: Instantaneous Power;

$P = VI = (V_m \sin \omega t) \times I_m \sin(\omega t + \phi)$

$\Rightarrow P = \frac{V_m I_m}{2}[\cos\phi - \cos(2\omega t + \phi)]$

The average power over a cycle is given by the average of the two terms in the R.H.S of equation (1). It is only the second term which is time dependent. Its average is zero (the positive half of the cosine cancels the negative half).

Therefore, $P_{avg} = \frac{V_m I_m}{2}\cos\phi = \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}\cos\phi$

$\Rightarrow P_{avg} = V_{rms} I_{rms} \cos\phi$

Alternatively:-

If the expression is deduced using integration, then full credit to be given.

(i) Power factor for purely inductive circuit, $\phi = \frac{\pi}{2} \Rightarrow \cos\phi = 0$

(ii) Power factor for purely resistive circuit; $\phi = 0 \Rightarrow \cos\phi = 1$

24. Explain the roles of diffusion current and drift current in the formation of the depletion layer in a p-n junction diode.

Ans: During the formation of p-n junction ,and due to the concentration gradient across p-,and n-sides, holes diffuse from p-side to n-side (p → n) and electrons diffuse from n-side to p-side(n → p).When an electron diffuses from (n → p), it leaves behind an ionized donor(positive charge) on n-side which is immobile. Similarly, when a hole diffuses from (p → n) due to the concentration gradient, it leaves behind an ionised acceptor (negative charge) which is immobile. This space–charge region on either side of the junction together is known as depletion region.

As a result, an electric field is developed across the junction. Due to this field, an electron on p-side of the junction moves to n-side and a hole on n-side of the junction moves to p-side. The motion of charge carriers due to the electric field is called drift. Initially, diffusion current is large and drift current is small.

As the diffusion process continues, the electric field strength & hence drift current increases. This process continues till diffusion & drift current becomes equal.

25. Calculate the wavelength of de Broglie waves associated with a proton having (500/1·673) eV energy. How will the wavelength be affected for an alpha particle having the same energy ?

Ans: $\lambda = \frac{h}{\sqrt{2mK}}$

$$K = \left(\frac{500}{1.673}\right)eV = \frac{500 \times 1.6 \times 10^{-19}}{1.673} J$$

$$\Rightarrow \lambda = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 1.673 \times 10^{-27} \times \left(\frac{500 \times 1.6 \times 10^{-19}}{1.673}\right)}} = 1.65 \times 10^{-12} m$$

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

For α particle; $m_\alpha = 4m_p$

$$\Rightarrow \lambda_\alpha = \frac{\lambda_p}{2}$$

26. What is meant by the term ‘mutual inductance’ of a pair of coils ? Obtain an expression for the mutual inductance of two long coaxial solenoids, each of length *l* but having different number of turns N_1 and N_2 and radii r_1 and r_2 ($r_2 > r_1$).

Ans: Mutual Inductance-It is the magnetic flux in the secondary coil due to the flow of unit current in the primary coil.

Alternatively:

It is the emf induced in the secondary coil when rate of change of current in the primary coil is unity.

Expression for Mutual Inductance:

Let N_1 and N_2 be the total number of turns of coils S_1 & S_2, respectively.

When a current I_2 is set up through S_2, it in turn sets up a magnetic flux through S_1

$\Rightarrow N_1\phi_1 = M_{12}I_2$ ---------(1)

M_{12} is the mutual inductance of solenoid S_1 w.r.t. S_2.

Magnetic field due to I_2 in S_2 = $\mu_0\left(\frac{N_2}{l}\right)I_2$

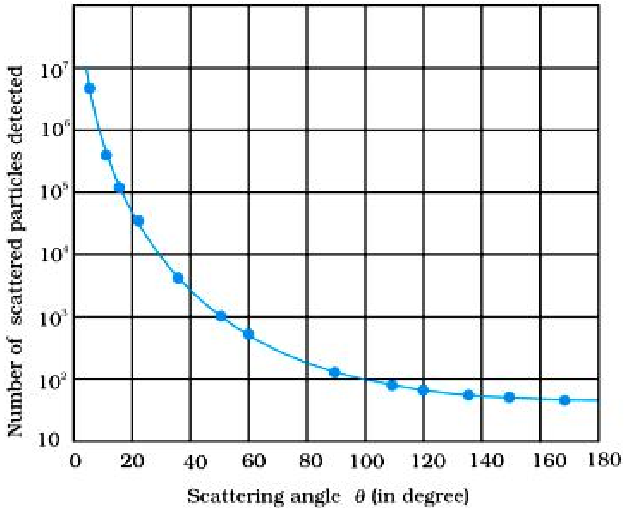
$$\Rightarrow N_1\phi_1 = (N_1)(\pi r_1^2)\mu_0\left(\frac{N_2}{l}\right)I_2$$

From equation (1) & equation (2), we get $M_{12} = \frac{\mu_0 N_1 N_2 \pi r_1^2}{l}$

27. (i) Draw a graph to show the variation of the number of scattered particles detected (N) in Geiger-Marsden experiment as a function of scattering angle (θ).

(ii) Discuss briefly two conclusions that can be drawn from this graph and how they lead to the discovery of nucleus in an atom.

Ans: (i)



(ii)- The entire positive charge and most of the mass of the atom are concentrated in a small space.

-Many of the α-particles pass through the foil. It means that they do not suffer any collisions.

To deflect the α-particle backwards, a large repulsive force is required, which is provided only if the greater part of the mass of the atom & its positive charge were concentrated tightly at its centre. This lead to the discovery of the nucleus in the atom.

28. A potential difference V is applied across a conductor of length l and uniform cross-section area A. How will the (i) electric field E, (ii) drift velocity v_d, and (iii) current density j be affected when (a) V is doubled and (b) *l* is halved (keeping other factors constant) ?

Ans: (a) (i) Electric field is given by $E = \frac{V}{l} \Rightarrow E' = \frac{2V}{l} = 2E$

So, When V is doubled, Electric field is doubled.

(ii) drift velocity is given by $v_d = \left(\frac{eE}{m}\right)\tau = \frac{e\tau}{m}\left(\frac{V}{l}\right) \Rightarrow v_d' = \frac{e\tau}{m}\left(\frac{2V}{l}\right) = 2\frac{e\tau}{m}\left(\frac{V}{l}\right) = 2v_d$

So, When V is doubled, drift velocity is doubled.

(iii) Current density is given by $J = \frac{I}{A} = \frac{V}{RA} \Rightarrow J' = \frac{2V}{RA} = 2J$

So, When V is doubled, current density is doubled.

(b) (i) Electric field is given by $E = \frac{V}{l} \Rightarrow E' = \frac{V}{l/2} = \frac{2V}{l} = 2E$

So, When *l* is halved, Electric field is doubled.

(ii) drift velocity is given by $v_d = \left(\frac{eE}{m}\right)\tau = \frac{e\tau}{m}\left(\frac{V}{l}\right) \Rightarrow v_d' = \frac{e\tau}{m}\left(\frac{V}{l/2}\right) = 2\frac{e\tau}{m}\left(\frac{V}{l}\right) = 2v_d$

So, When *l* is halved, drift velocity is doubled.

(iii) Current density is given by $J = \frac{I}{A} = \frac{V}{RA} = \frac{V}{A}\left(\frac{A}{\rho l}\right) = \frac{V}{\rho l} \Rightarrow J' = \frac{V}{\rho l/2} = 2\frac{V}{\rho l} = 2J$

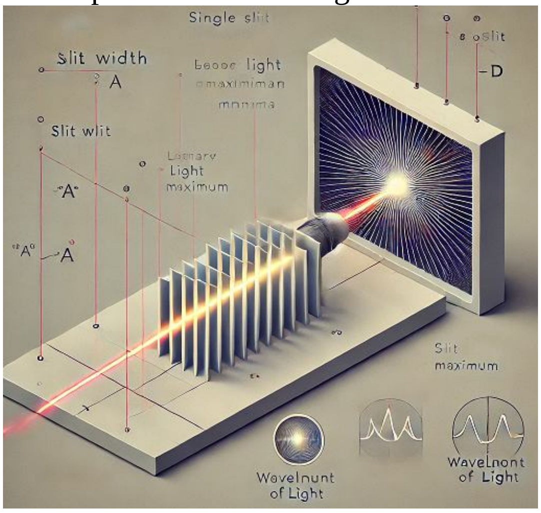
So, When *l* is halved, current density is also doubled.

SECTION – D (Case Study Based Questions)

Questions 29 to 30 carry 4 marks each.

29. Diffraction: Diffraction of light is bending of light around the corners of an object whose size is comparable with the wavelength of light. Diffraction actually defines the limits of ray optics.

This limit for optical instruments is set by the wavelength of light. An experimental arrangement is set up to observe the diffraction pattern due to a single slit.



(i) The penetration of light into the region of geometrical shadow is called
(a) polarisation (b) interference (c) diffraction (d) refraction

(ii) To observe diffraction, the size of an obstacle
(a) should be of the same order as wavelength
(b) should be much larger than the wavelength
(c) have no relation to wavelength
(d) should be exactly $l/2$

(iii) Both, light and sound waves produce diffraction. It is more difficult to observe diffraction with light waves because
(a) light waves do not require medium (b) wavelength of light waves is too small
(c) light waves are transverse in nature (d) speed of light is far greater

(iv) Angular width of central maximum of a diffraction pattern of a single slit does not depend upon
(a) distance between slit and source (b) wavelength of light used
(c) width of the slit (d) frequency of light used

OR

The diffraction effect can be observed in
(a) only sound waves (b) only light waves
(c) only ultrasonic waves (d) sound as well as light waves

Ans. (i) (c) The bending of light around the corners is known as diffraction of light. So, the light penetrates into the region of geometrical shadow.
(ii) (a) To observe diffraction, the size of obstacle should be of the same order as that of the wavelength.
(iii) (b) It is more difficult to observe diffraction with light waves because wavelength of light waves is far too smaller compared to that of sound waves.
(iv) (a) Angular width, $\theta = \dfrac{\lambda}{d} = \dfrac{c}{\nu d}$
Hence, angular width depend upon wavelength of light used, width of slit and frequency of light used.

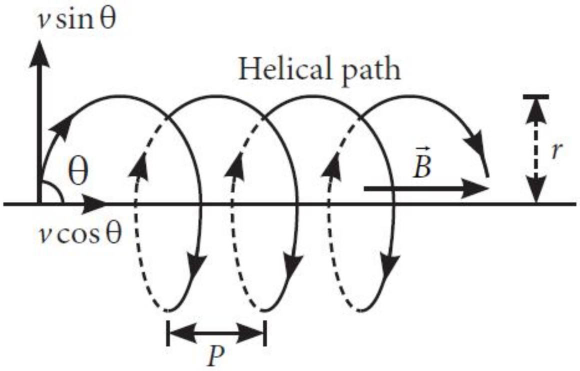
OR

(d) The diffraction effect can be observed in sound as well as in light waves.

30. Helical Motion

The path of a charged particle in magnetic field depends upon angle between velocity and magnetic field.

If velocity v is at angle q to $\vec{B}$, component of velocity parallel to magnetic field (v cosθ) remains constant and component of velocity perpendicular to magnetic field (v sinθ) is responsible for circular motion, thus the charge particle moves in a helical path.



The plane of the circle is perpendicular to the magnetic field and the axis of the helix is parallel to the magnetic field. The charged particle moves along helical path touching the line parallel to the magnetic field passing through the starting point after each rotation.
Radius of circular path is r = mvsin-θ/qB
Hence the resultant path of the charged particle will be a helix, with its axis along the direction of $\vec{B}$ as shown in figure.
(i) When a positively charged particle enters into a uniform magnetic field with uniform velocity, its trajectory can be
(i) a straight line (ii) a circle (iii) a helix.
(a) (i) only (b) (i) or (ii) (c) (i) or (iii) (d) any one of (i), (ii) and (iii)

(ii) Two charged particles A and B having the same charge, mass and speed enter into a magnetic field in such a way that the initial path of A makes an angle of 30° and that of B makes an angle of 90° with the field. Then the trajectory of
(a) B will have smaller radius of curvature than that of A
(b) both will have the same curvature
(c) A will have smaller radius of curvature than that of B
(d) both will move along the direction of their original velocities.

(iii) An electron having momentum 2.4×10^{-23} kg m/s enters a region of uniform magnetic field of 0.15 T. The field vector makes an angle of 30° with the initial velocity vector of the electron. The radius of the helical path of the electron in the field shall be
(a) 2 mm (b) 1 mm (c) √3/2 mm (d) 0.5 mm

(iv) The magnetic field in a certain region of space is given by $\vec{B} = 8.35\times10^{-2}\hat{i}$ T. A proton is shot into the field with velocity $\vec{v} = (2\times10^5\hat{i} + 4\times10^5\hat{j})$ m/s. The proton follows a helical path in the field. The distance moved by proton in the x-direction during the period of one revolution in the yz-plane will be
(Mass of proton = 1.67×10^{-27} kg)
(a) 0.053 m (b) 0.136 m (c) 0.157 m (d) 0.236 m
Ans.

(i) (d)

(ii) (a): Using, $qvB\sin\theta = \frac{mv^2}{r}$

$r \propto \frac{1}{\sin\theta}$ for the same values of m, v, q and B

$\therefore \quad \frac{r_A}{r_B} = \frac{\sin 90°}{\sin 30°} = 2$ or $r_A = 2r_B$ or $r_B < r_A$

(iii) (d): The radius of the helical path of the electron in the uniform magnetic field is

$$r = \frac{mv_\perp}{eB} = \frac{mv\sin\theta}{eB} = \frac{(2.4\times10^{-23}\text{ kg m/s})\times\sin 30°}{(1.6\times10^{-19}\text{ C})\times 0.15\text{ T}}$$

$$= 5\times10^{-4}\text{ m} = 0.5\times10^{-3}\text{ m} = 0.5\text{ mm}$$

(iv) (c): Here, $\vec{B} = 8.35\times10^{-2}\hat{i}$ T

$\vec{v} = 2\times10^5\hat{i} + 4\times10^5\hat{j}$ m/s , $m = 1.67\times10^{-27}$ kg

Pitch of the helix (*i.e.*, the linear distance moved along the magnetic field in one rotation) is given by

Pitch of the helix $= \frac{2\pi m v_\parallel}{qB}$

$$= \frac{2\times3.14\times1.67\times10^{-27}\times2\times10^5}{1.6\times10^{-19}\times8.35\times10^{-2}} = 0.157\text{ m}$$

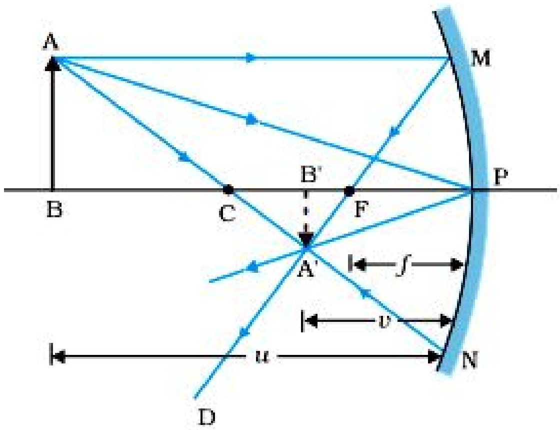
SECTION – E

Questions 31 to 33 carry 5 marks each.

31. (a) (i) Draw a ray diagram showing the formation of a real image of an object placed at a distance ‘v’ in front of a concave mirror of radius of curvature ‘R’. Hence, obtain the relation for the image distance ‘v’ in terms of u and R.

(ii) A 1·8 m tall person stands in front of a convex lens of focal length 1 m, at a distance of 5 m. Find the position and height of the image formed.

Ans: (i)



From Fig. the two right-angled triangles A′B′F and MPF are similar. (For paraxial rays, MP can be considered to be a straight line perpendicular to CP.)

Therefore, $\frac{B'A'}{PM} = \frac{B'F}{FP} \Rightarrow \frac{B'A'}{BA} = \frac{B'F}{FP} (\because PM = AB)$ -----(i)

Since ∠ APB = ∠ A′PB′, the right angled triangles A′B′P and ABP are also similar.

Therefore, $\frac{B'A'}{BA}=\frac{B'P}{BP}$ -----(ii)

Comparing equations (i) and (ii), we get

$$\frac{B'F}{FP}=\frac{B'P-FP}{FP}=\frac{B'P}{BP} \quad \text{-----(iii)}$$

B′ P = – v, FP = – f, BP = – u;

Using these in Eq.(iii) we get $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}=\frac{2}{R}$

Alternatively:- If the result derived by any other method, full credit to be given.

(ii) For lens: $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

Here, u = - 5m; f = +1m

$$\frac{1}{v}-\frac{1}{-5}=\frac{1}{+1}\Rightarrow\frac{1}{v}+\frac{1}{5}=1\Rightarrow\frac{1}{v}=1-\frac{1}{5}=\frac{4}{5}$$

$$\Rightarrow v=\frac{5}{4}m=1.25m$$

⇒ I = (- 0.25) × (1.8)

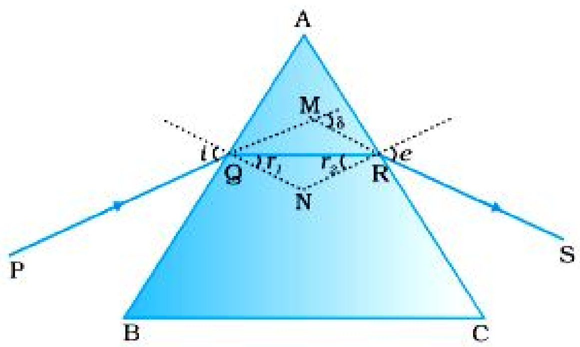
⇒ I = - 0.45 m

OR

(b) (i) Draw a ray diagram showing refraction of a ray of light through a triangular glass prism. Hence, obtain the relation for the refractive index (μ) in terms of angle of prism (A) and angle of minimum deviation (δ_m).

(ii) The radii of curvature of the two surfaces of a concave lens are 20 cm each. Find the refractive index of the material of the lens if its power is –5·0 D.

Ans: (i)



In the quadrilateral AQNR, two of the angles (at the vertices Q and R) are right angles. Therefore, the sum of the other angles of the quadrilateral is 180º.

∠A + ∠QNR = 180º

From the triangle QNR, $r_1 + r_2$ + ∠QNR = 180º

Comparing these two equations, we get

$r_1 + r_2$ = A -------(i)

The total deviation δ is the sum of deviations at the two faces,

$\delta = (i - r_1) + (e - r_2)$ that is, $\delta = i + e - A$ -------(ii)

When $\delta = \delta_m$; $i = e$ & $r_1 = r_2$

From (i); 2r = A or r = A/2

From (ii); $\delta_m = 2i - A$ or $i=\frac{A+\delta_m}{2}$

$$\mu=\frac{\sin i}{\sin r}=\frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

(ii) Given; P = - 5D

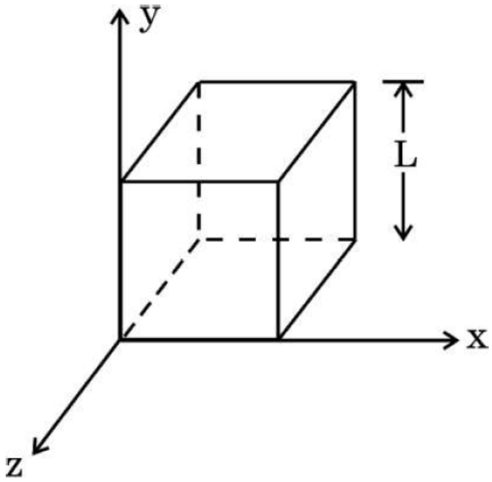
f (in cm) = 100/(- 5) = -20 cm

Using Lens Maker's formula ; $\frac{1}{f}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$

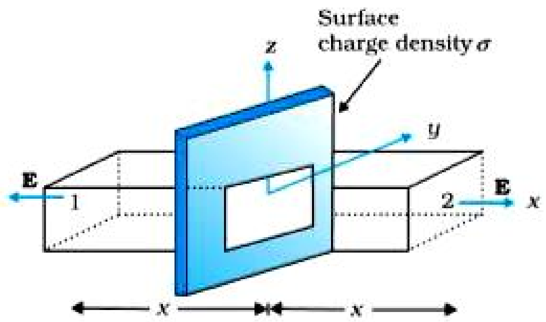
$\Rightarrow \frac{1}{-20}=(\mu-1)\left[\frac{1}{-20}-\frac{1}{+20}\right]$

$\Rightarrow \frac{1}{-20}=(\mu-1)\left[-\frac{1}{10}\right] \Rightarrow \mu-1=\frac{1}{2} \Rightarrow \mu=\frac{3}{2}=1.5$

32. (a) (i) Define electric flux and write its SI unit.
(ii) Use Gauss' law to obtain the expression for the electric field due to a uniformly charged infinite plane sheet.
(iii) A cube of side L is kept in space, as shown in the figure. An electric field $\vec{E}=(Ax+B)\hat{i}\frac{N}{C}$ exists in the region. Find the net charge enclosed by the cube.



Ans: (i) $\phi=\vec{E}.\vec{A}$
Alternatively: Electric flux is the number of electric field lines passing through an area normally.
S.I. unit of electric flux Nm^2/C or V-m.
(ii)



From Gauss's law:- $\phi=\oint \vec{E}.\vec{dA}=\frac{q}{\varepsilon_0} \Rightarrow 2EA=\frac{\sigma A}{\varepsilon_0}$

$\Rightarrow E=\frac{\sigma}{2\varepsilon_0}$

Alternatively: If the shape of the Gaussian surface is taken cylindrical, full credit to be given.

(iii) $\phi_L = Eds\cos 180^0 = -Eds = -BL^2$

$\phi_R = Eds\cos 0^0 = Eds = (AL+B)L^2 = AL^3 + BL^2$

Net flux = $\phi_L + \phi_R = AL^3 + BL^2 - BL^2 = AL^3$

$\Rightarrow$ Net flux = $= AL^3 = \frac{q}{\varepsilon_0} \Rightarrow q = AL^3\varepsilon_0$

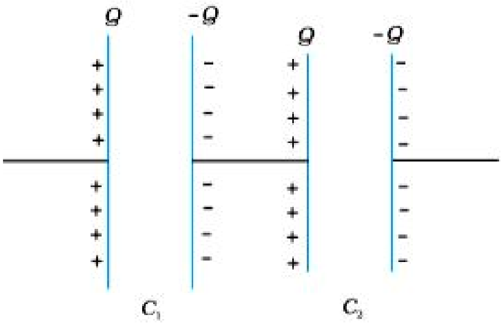
OR

(b) (i) Define electric potential at a point and write its SI unit.
(ii) Two capacitors are connected in series. Derive an expression of the equivalent capacitance of the combination.
(iii) Two point charges + q and –q are located at points (3a, 0) and (0, 4a) respectively in x-y plane. A third charge Q is kept at the origin. Find the value of Q, in terms of q and a, so that the electrostatic potential energy of the system is zero.
Ans: Ans: (b) (i) Electrical Potential – Electrostatic potential at any point in a region with electrostatic field is the work done in bringing a unit positive charge (without acceleration) from infinity to that point.
Alternatively:-

$$V = \frac{Work\ \ Done}{q}$$

$$V = -\int \vec{E}.\vec{dl}$$

S.I. unit of electrostatic potential is volt.
Alternatively:-
S.I. unit is J/C.



$$V = V_1 + V_2 = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\Rightarrow \frac{Q}{C_{eq.}} = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right) \Rightarrow \frac{1}{C_{eq.}} = \frac{1}{C_1} + \frac{1}{C_2}$$

(iii) Potential energy of the system = $K\left[\frac{Q(-q)}{4a} + \frac{Qq}{3a} - \frac{q^2}{5a}\right]$

Potential energy of the system = 0

$$\Rightarrow K\left[\frac{Q(-q)}{4a} + \frac{Qq}{3a} - \frac{q^2}{5a}\right] = 0 \Rightarrow \frac{-Q}{4a} + \frac{Q}{3a} - \frac{q}{5a} = 0$$

$$\Rightarrow \frac{Q}{12} - \frac{q}{5} = 0 \Rightarrow \frac{Q}{12} = \frac{q}{5} \Rightarrow Q = +\frac{12q}{5}$$

33. (a) (i) Write the principle and explain the working of a moving coil galvanometer. A galvanometer as such cannot be used to measure the current in a circuit. Why ?
(ii) Why is the magnetic field made radial in a moving coil galvanometer ? How is it achieved ?
Ans: (i) Principle – When a rectangular loop carrying current I is placed in a uniform magnetic field, it experiences a torque.
Working:-
When a current flows through the coil of a galvanometer, a torque acts on it.
$\tau = NiAB\sin\theta$
For radial magnetic field; $\sin\theta = 1$

The spring provides a counter or restoring torque $k\phi$.

$k\phi = NiAB$

In equilibrium; $\phi = \left(\frac{NAB}{k}\right)i$

Galvanometer cannot be used as such to measure current because:

-It has large resistance and hence will change the value of current in the circuit.

-It is a sensitive device.

(Any one of the above)

(ii) The magnetic field is made radial in a moving coil galvanometer so that the magnetic dipole moment ($\vec{m}$) is always perpendicular to the magnetic field ($\vec{B}$) Hence, $\sin\theta = 1$ always

Alternatively: The magnetic field is made radial in a moving coil galvanometer to make the scale linear. It is achieved by using curved magnetic poles.

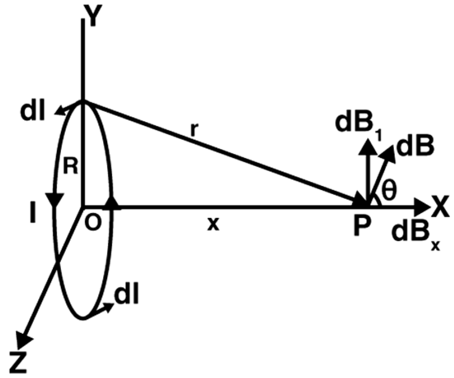
Alternatively:-By using soft iron cylindrical core.

OR

(b) (i) Derive an expression for magnetic field on the axis of a current carrying circular loop.

(ii) Write any two points of difference between a diamagnetic and a paramagnetic substance.

Ans: (i)



$$dB = \frac{\mu_0}{4\pi}\frac{I|dl \times r|}{r^3}$$

$$\Rightarrow dB = \frac{\mu_0 idl \sin 90^0}{4\pi(x^2+R^2)} = \frac{\mu_0}{4\pi}\frac{idl}{(x^2+R^2)}$$

We resolve dB into vertical and horizontal components.

Now all the vertical components cancel out each other and so only the horizontal components survive, which results in the net magnetic field at P in the horizontal direction.

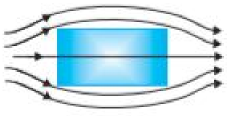
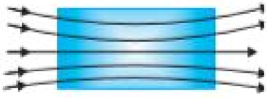
Net magnetic field = $\int dB_x = \int dB\cos\theta = \frac{\mu_0}{4\pi}\int \frac{idl}{(x^2+R^2)} \times \frac{R}{(x^2+R^2)^{1/2}}$

$$= \frac{\mu_0}{4\pi}\frac{iR}{(x^2+R^2)^{3/2}}\int dl = \frac{\mu_0 iR}{4\pi(x^2+R^2)^{3/2}}(2\pi R)$$

$$Net \;\; B = B_x\hat{i} = \frac{\mu_0 iR^2}{2(x^2+R^2)^{3/2}}\hat{i}$$

(ii) Differences

Diamagnetic Materials	Paramagnetic Materials
(i) Susceptibility is between -1 and 0.	(i) Susceptibility is a small positive number.(slightly greater than zero.)
(ii) Relative permeability is between 0 and 1.	(ii) Relative permeability is slightly greater than 1.
(iii) μ < μo	(iii) μ > μo
(iv) Tendency to move from stronger to weaker part of external magnetism.	(iv) Tendency to move from region of weak to strong magnetic field.

(v) is repelled by a magnet.	(v) is weakly attracted by a magnet.
(vi) Field inside the material is reduced.	(vi) Field inside is slightly enhanced.
(vii) 	(vii) 

Any two of the above mentioned differences.

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