12th STD

PUBLIC EXAMINATION - MARCH - 2024

PART - III

Reg. No.

Time Allowed : 3.00 Hours] **PHYSICS** (with answers) **[Maximum Marks : 70**

Instructions : (1) Check the question paper for fairness of printing. If there is any lack of fairness, inform the Hall Supervisor immediately.

(2) Use **Blue** or **Black** ink to write and underline and pencil to draw diagrams.

PART - I

Note : (i) Answer **all** the questions. **(15 × 1 = 15)**

(ii) Choose the most appropriate answer from the given **four** alternatives and write the option code and the corresponding answer.

1. The principle based on which a solar cell operates is :

(a) Photovoltaic action (b) Diffusion
(c) Carrier flow (d) Recombination

2. If the amplitude of the magnetic field is 3×10^{-6}T, then the amplitude of the electric field for a electromagnetic wave is :

(a) 600 Vm^{-1} (b) 100 Vm^{-1}
(c) 900 Vm^{-1} (d) 300 Vm^{-1}

3. A toaster operating at 240 V has resistance of 120 Ω. Its power is :

(a) 240 W (b) 400 W
(c) 480 W (d) 2 W

4. Atomic number of H - like atom with ionization potential 122.4 V for n = 1 is :

(a) 3 (b) 4 (c) 2 (d) 1

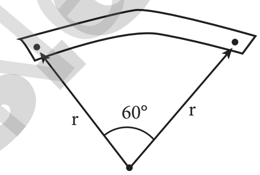
5. The transverse nature of light is shown in :

(a) scattering (b) interference
(c) polarisation (d) diffraction

6. In an oscillating LC circuit, the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic field is :

(a) $\frac{Q}{\sqrt{2}}$ (b) $\frac{Q}{2}$
(c) Q (d) $\frac{Q}{\sqrt{3}}$

7. A bar magnet of length 'l' and magnetic moment 'P_m' is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be :



(a) $\frac{2}{\pi}P_m$ (b) P_m
(c) $\frac{1}{2}P_m$ (d) $\frac{3}{\pi}P_m$

8. The speed of light in an isotropic medium depends on :

(a) the nature of propagation
(b) its intensity
(c) the motion of the source w.r.t. medium
(d) its wavelength

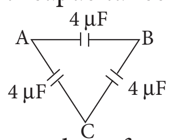
9. In a series RL circuit, the resistance and inductive reactance are the same, Then the phase difference between voltage and current in the circuit is :

(a) $\frac{\pi}{6}$ (b) $\frac{\pi}{4}$ (c) zero (d) $\frac{\pi}{2}$

10. Two identical conducting balls having positive charges q_1 and q_2 are separated by a center to center distance 'r'. If they are made to touch each other and then separated to the same distance, the force between them will be:

(a) more than before
(b) less than before
(c) zero
(d) same as before

11. Three capacitors are connected in triangle as shown in figure. The equivalent capacitance between the points A and C is :



(a) 4 μF (b) 2 μF
(c) 8 μF (d) 6 μF

12. The threshold wavelength for a metal surface whose photoelectric work function is 3.313 eV :

(a) 6000 Å (b) 4125 Å
(c) 2062.5 Å (d) 3750 Å

13. Light transmitted by Nicol prism is :
    (a) plane polarised
    (b) partially polarised
    (c) elliptically polarised
    (d) unpolarised

14. The gravitational waves were theoretically proposed by :
    (a) Albert Einstein
    (b) Conrod Rontgen
    (e) Edward Purcell
    (d) Marie Curie

15. The value of forbidden energy gap for Si at room temperature is :
    (a) 1.1 V (b) 0.7 eV
    (c) 1.1 eV (d) 0.7 V

PART - II

Note : Answer **any six** questions. Question No. **24** is **Compulsory.** **(6 × 2 = 12)**

16. What is meant by hysteresis ?
17. State Malu s' Law.
18. Define Electrostatic Potential.
19. A straight metal wire crosses a magnetic field of flux 4 mWb in a time 0.4 sec. Find the magnitude of the emf induced in the wire.
20. State the applications of Seebeck Effect.
21. The half-life of radioactive sample is 5.01 days. Calculate the decay constant.
22. What are electromagnetic waves ?
23. What is meant by biasing? Mention its types.
24. If the focal length is 150 cm for a lens, what is the power of the lens ?

PART - III

Note : Answer **any six** questions. Question No. **33** is **Compulsory.** **(6 × 3 = 18)**

25. Discuss the Beta$^+$ (β^+) decay process with an example.
26. A copper wire of cross-sectional area 0.5 mm^2 carries a current of 0.2 A. If the free electron density of copper wire is 8.4×10^{28} m^{-3}, then compute the drift velocity of free electron.
27. Derive the equation for effective focal length for lenses in contact.
28. Define current sensitivity. State the factors which increase the current sensitivity of a galvanometer.
29. How many photons per second emanate from a 50 mW laser of 640 nm ?
30. Derive the equation for inductance of a solenoid. Assume that the length of the solenoid is greater than its diameter.
31. What are the differences between interference and diffraction?
32. Obtain Gauss law from Coulomb's law.
33. Determine the wavelength of the light emitted from LED, which is made up of GaAsP semiconductor, whose forbidden energy gap is 1.875 eV. Mention the colour of the light emitted (Given $h = 6.6 \times 10^{-34}$ Js).

PART - IV

Note: Answer **all** the questions **(5 × 5 = 25)**

34. (a) Explain about simple microscope and obtain equation for magnification for near point focusing and normal focusing.

    (OR)

    (b) Explain the determination of unknown resistance using metre bridge.

35. (a) Calculate the magnetic field produced at a point along the axis of the current carrying circular coil. Write down the equation of the magnetic field at the center of the coil using Biot-Savart law.

    (OR)

    (b) Derive the equation for angle of deviation produced by a prism and thus obtain the equation for refractive index of material of the prism.

36\. (a) Obtain Einstein's photoelectric equation with necessary explanations.

(OR)

(b) Find out the phase relationship between the voltage and current in a pure inductive circuit. Draw the phasor and wave diagrams.

37\. (a) List out the advantages and limitations of frequency modulation.

(OR)

(b) Explain the Maxwell's modification of Ampere's circuital law.

38\. (a) Calculate the electric field due to a dipole at a point on the axial line

(OR)

(b) What is nuclear reactor? Write note on Moderators, Control rods and Cooling system.

ANSWERS

PART - I

1\. (a) Photovoltaic action

2\. (c) 900 Vm^{-1}

3\. (c) 480 W

4\. (a) 3

5\. (c) polarisation

6\. (a) $\frac{Q}{\sqrt{2}}$

7\. (d) $\frac{3}{\pi}P_m$

8\. (d) its wavelength

9\. (b) $\frac{\pi}{4}$

10\. (a) more than before

11\. (d) 6 μF

12\. (d) 3750 Å

13\. (a) plane polarised

14\. (a) Albert Einstein

15\. (c) 1.1 eV

PART - II

16\. The phenomenon of lagging of magnetic induction behind the magnetising field is called hysteresis. Hysteresis means 'lagging behind'.

17\. When a beam of plane polarised light of intensity I_0 is incident on an analyser, the intensity of light I transmitted from the analyser varies directly as the square of the cosine of the angle θ between the transmission axis of polariser and analyser. This is known as Malus' law.

$$I = I_0 \cos^2 \theta$$

18\. The electric potential at a point P is equal to the work done by an external force to bring a unit positive charge with constant velocity from infinity to the point P in the region of the external electric field $\vec{E}$.

19\. **Given :**

$d\phi_B$ = 4 mWb (or) 4×10^{-3} Wb

Time $dt = 0.4$ s

To find :

The magnetic of induced emf ε = ?

Formula :

$$\varepsilon = \frac{d\Phi}{dt} = \frac{4\times10^{-3}}{0.4} = 10^{-2} \text{ (or) } 10 \text{ mV.}$$

ε = 10 mV.

20\. **(i)** Seebeck effect is used in thermoelectric generators. These thermoelectric generators are used in power plants to convert waste heat into electricity.

(ii) This effect is utilized in automobiles as automotive thermoelectric generators for increasing fuel efficiency.

21. Decay constant

$$\lambda = \frac{0.6931}{T_{1/2}} = \frac{0.6931}{5.01} = 0.1383 \text{ per day}$$

$$\therefore \lambda \text{ for per second} = \frac{0.1383}{60 \times 60 \times 24}$$

$$= \mathbf{1.601 \times 10^{-6}\ s^{-1}}$$

22. Electromagnetic waves are non-mechanical waves which move with speed equals to the speed of light (in vacuum). It is a transverse wave.

23. **(i)** **Biasing** means providing external energy to charge carriers to overcome the barrier potential and make them move in a particular direction.

(ii) The external voltage applied to the *p-n* junction is called bias voltage.

Types: Depending on the polarity of the external source to the *p-n* junction, we have two types of biasing: i) Forward bias ii) Reverse bias.

24. Given, focal length, f = 150 cm = 1.5 m

Equation for power of lens is, $P = \frac{1}{f}$

Substituting the values,

$$P = \frac{1}{1.5\,m} = 0.67D$$

As the power is positive, it is a converging lens.

PART - III

25. **(i)** **β^+ decay:** In β^+ decay, the atomic number is decreased by one and again its mass number remains the same. This decay is represented by ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + e^+ + \nu$

(ii) It implies that the element X becomes Y by giving out an positron and neutrino (ν), In other words for each β^+ decay, a proton in the nucleus X is converted into a neutron a positron (e^+) and a neutrino. It is given by

$$p \rightarrow n + e^+ + \nu$$

(iii) However a single proton (not inside any nucleus) cannot exhibit β^+ decay due to energy conservation, because neutron mass is larger than proton mass. But a single neutron (not inside any nucleus) can exhibit β^- decay.

Example : Sodium (${}^{22}_{11}Na$) is converted into neon (${}^{22}_{10}Ne$) through β^+ decay.

$${}^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + e^+ + \nu$$

(iv) The electron or positron which comes out from nuclei during beta decay are not present inside the nuclei but they are produced during the conversion of neutron into proton or proton into neutron inside the nucleus.

26. The relation between drift velocity of electrons and current in a wire of cross sectional area A is

$$v_d = \frac{I}{neA}$$

$$= \frac{0.2}{8.4 \times 10^{28} \times 1.6 \times 10^{-19} \times 0.5 \times 10^{-6}}$$

$$= 0.03 \times 10^{-3} ms^{-1}$$

27. **(i)** Consider two lenses of focal length f_1 and f_2 in contact with each other.

(ii) An object placed at O beyond the focus of the first lens, an image is formed by it at I′.

(iii) This image I′ acts as an object for the second lens and the final image is formed at I.

(iv) lens equation for first lens,

$$\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1} \quad ...(1)$$

lens equation for second lens,

$$\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2} \quad ...(2)$$

Adding the above two equations (1) + (2),

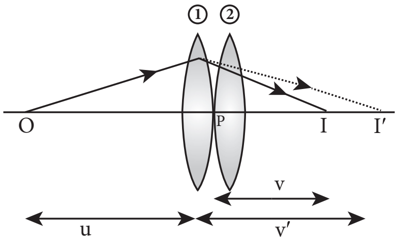
$$\text{By } \frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \quad ...(3)$$

(v) The combination acts as a single lens of focal length f so that for an object at the position O, it forms the image at I then,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad ...(4)$$

By Comparing the (3) & (4)

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$



Lenses in contact

For any number of lenses

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \frac{1}{f_4} + ...$$

Power of the lenses $P = P_1 + P_2 + P_3 + P_4 ...$

28. **Current sensitivity**

It is defined as the deflection produced per unit current flowing through galvanometer.

$$I_s = \frac{\theta}{I} = \frac{NAB}{K} \Rightarrow I_s = \frac{1}{G}$$

The current sensitivity of a galvanometer can be increased by

(i) increasing the number of turns, N
(ii) increasing the magnetic induction, B
(iii) increasing the area of the coil, A
(iv) decreasing the couple per unit twist of the suspension wire, K.

Phosphor - bronze wire is used as the suspension wire because the couple per unit twist is very small.

29. **Given data:**

Wavelength of the laser, $\lambda = 640$ nm

$\lambda = 640 \times 10^{-9}$ m

Power of laser P = 50 mW $= 50 \times 10^{-3}$ W

To find: No. of photons emitted per second N = ?

The energy of a photon $E = h\nu = \frac{hc}{\lambda}$

c - velocity of light $= 3 \times 10^8 \text{ ms}^{-1}$

h - planck constant $= 6.626 \times 10^{-34}$ Js.

P = No. of photons emitted per second × Energy of one photon.

$$P = NE$$

$$N = \frac{P}{E} = \frac{P\lambda}{hc}$$

$$= \frac{50\times10^{-3}\times640\times10^{-9}}{6.626\times10^{-34}\times3\times10^{8}} = \frac{32000\times10^{-9}}{19.878\times10^{-26}}$$

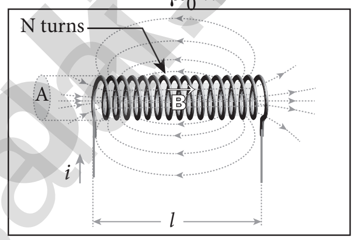
$$= \frac{32}{19.878} \times 10^{26} \times 10^{-9}$$

$$\boxed{N = 1.61 \times 10^{17}\ s^{-1}}$$

30. **(i)** Consider a long solenoid of length l and cross-sectional area A. Let n be the number of turns per unit length ($l > n$).

(ii) When an electric current i is passed through the solenoid, a magnetic field produced inside is almost uniform and is directed along the axis of the solenold as shown in Figure. The magnetic field at any point inside the solenoid is given by

$$B = \mu_0 ni$$



Self-inductance of a long solenoid

(iii) The magnetic flux passing through each turn is

$$\Phi_B = \int_A \vec{B}\cdot d\vec{A} = BA \cos\theta = BA$$

$$= (\mu_0 ni)A \qquad [\text{since } \theta = 0°]$$

(iv) The total magnetic flux linked or flux linkage of the solenoid with N turns (the total number of turns N is given by $N = n\,l$) is

$$N\Phi_B = (nl)(\mu_0 ni)A$$

$$N\Phi_B = (\mu_0 n^2 Al)i \qquad ...(1)$$

$$N\Phi_B = Li \qquad ...(2)$$

Comparing equation (1) and (2), we have

$$L = \mu n^2 Al$$

(v) Inductance depends on the geometry of the solenoid and the medium present inside the solenoid. If the solenoid is filled with a dielectric medium of relative permeability μ_r, then

$$L = \mu n^2 Al \text{ or } L = \mu_0 \mu_r n^2 Al$$

31.

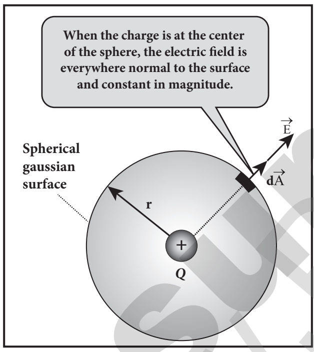
	Interference	Diffraction
1.	Equally spaced bright and dark fringes	Central bright is double the size of other fringes
2.	Equal intensity for all bright fringes	Intensity falls rapidly for higher order fringes
3.	Large number of fringes are obtained	Less number of fringes are obtained

32. **(i)** A positive point charge Q is surrounded by an imaginary sphere of radius r. Total electric flux through the closed surface of the sphere

$$\Phi_E = \oint \vec{E}.d\vec{A} = \oint E\,dA\cos\theta \quad ...(1)$$

(ii) The electric field of the point charge is directed radially outward at all points on the surface of the sphere. Therefore, the direction of the area element $d\vec{A}$ is along the electric field $\vec{E}$ and $\theta = 0°$.

$$\therefore \Phi_E = \oint E\,dA \quad \text{since } \cos 0° = 1 \quad ...(2)$$



E is uniform on the surface of the sphere,

$$\because \oint dA = 4\pi r^2$$

$$\therefore \varphi_E = 4\pi r^2 E \text{ and } E = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{r^2}$$

$$\Phi_E = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{r^2} \times 4\pi r^2 = 4\pi\frac{1}{4\pi\varepsilon_0}Q$$

$$\Phi_E = \frac{Q}{\varepsilon_0} \quad ...(3)$$

The equation (3) is called as Gauss's law.

33. **Solution :**

$$E_g = \frac{hc}{\lambda}$$

Therefore, $\lambda = \frac{hc}{E_g} = \frac{6.6\times10^{-34}\times3\times10^8}{1.875\times1.6\times10^{-19}}$

$= 660$ nm

The wavelength 660 nm corresponds to red colour light.

PART - IV

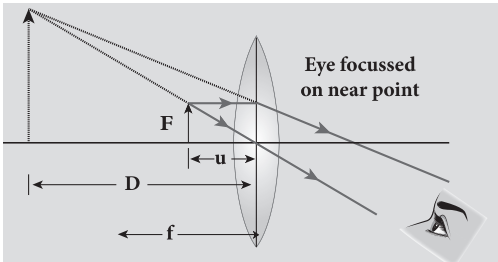
34.(a) **(i)** A simple microscope is a single magnifying (convex) lens of small focal length which must produce an erect, magnified and virtual image of the object.

(ii) Hence, the object must be placed within the focal length f (between the points F and P) on one side of the lens and viewed through the other side of it.

(a) **Near point focusing :** The eye is least strained when image is formed at near point, i.e. 25 cm. The near point is also called as least distance of distinct vision. The object distance u should be less than f. The image distance is the near point D. The magnification m of this lens is given by the equation, $m = \frac{v}{u}$

Substituting, $v = -D$ and $u = -u$, as both the distances are measured to the left of the lens. Hence,

$$m = \frac{-D}{-u} \Rightarrow m = \frac{D}{u}$$



Near point focusing

(b) We can also write the equation for magnification m in terms of focal length f by using lens equation,

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

in equation $m = \frac{v}{u}$ we get $m = 1 - \frac{v}{f}$

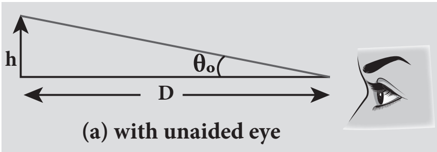
Substituting $v = -D$ gives, $m = 1 + \frac{D}{f}$

This is the magnification for near point focusing.

Normal focusing :

(i) The eye is most relaxed when the image is formed at infinity. The focusing is called normal focusing when the image is formed at infinity.

$$\left(m = \frac{h'}{h}\right).$$



(ii) The angular magnification is defined as the ratio of angle θ_i subtended by the image with aided eye to the angle θ_0 subtended by the object with unaided eye.

$$m = \frac{\theta_i}{\theta_0}$$

For unaided eye shown in Figure (a),

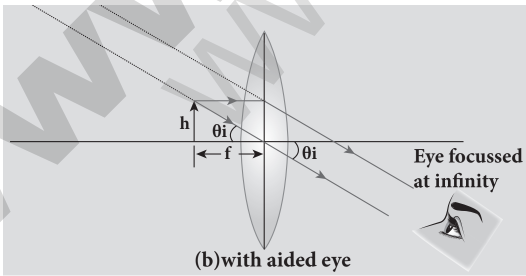
$$\tan\theta_0 \approx \theta_0 = \frac{h}{D}$$

For aided eye shown in Figure (b),

$$\tan\theta_i \approx \theta_i = \frac{h}{f}$$

The angular magnification is,

$$m = \frac{\theta_i}{\theta_0} = \frac{h/f}{h/D} \Rightarrow m = \frac{D}{f}$$



Normal focusing

(iii) This is the magnification for normal focusing.

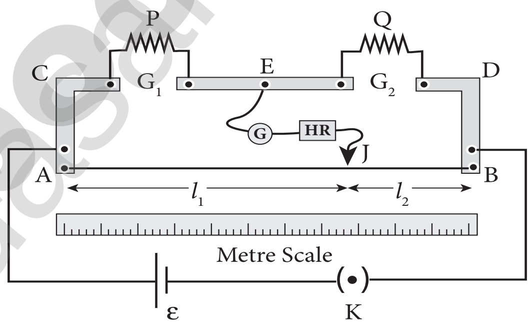
(OR)

(b) **(i)** The meter bridge is another form of Wheatstone's bridge. It consists of a uniform wire of manganin AB of one meter length. This wire is stretched along a metre scale on a wooden board between two copper strips C and D. Between these two copper strips another copper strip E is mounted to enclose two gaps G_1 and G_2.

(ii) An unknown resistance P is connected in G_1 and a standard resistance Q is connected in G_2.

(iii) A jockey is connected to the terminal E on the central copper strip through a galvanometer (G) and a high resistance (HR).

(iv) A Lechlanche cell and a key (K) are connected between the ends of the bridge wire.



Metre bridge

(v) Let the position of jockey at the wire be at J.

(vi) The resistances corresponding to AJ and JB of the bridge wire form the resistances R and S of the Wheatstone's bridge. Then for the bridge balance

$$\frac{P}{Q} = \frac{R}{S} = \frac{r.AJ}{r.JB} \quad ...(1)$$

where r is the resistance per unit length of wire.

$$\frac{P}{Q} = \frac{AJ}{JB} = \frac{l_1}{l_2} \quad ...(2)$$

$$P = Q\frac{l_1}{l_2} \quad ...(3)$$

(vii) The bridge wire is soldered at the ends of the copper strips. These are called end resistances.

(viii) The specific resistance or resistivity ρ can be calculated using the relation.

Resistance $= \rho \frac{l}{A}$

By rearranging the above equation, we get

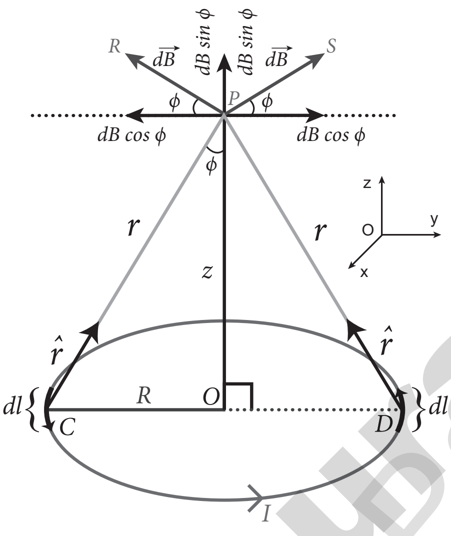
$$\rho = \text{Resistance} \times \frac{A}{l} \quad ...(4)$$

If P is the unknown resistance equation (4) becomes,

$$\rho = P\frac{\pi a^2}{l}$$

35. (a) **(i)** Consider a current carrying circular loop of radius R and let I be the current flowing through the wire in the direction.

(ii) The magnetic field at a point P on the axis of the circular coil at a distance z from the centre of the coil O is computed by taking two diametrically opposite line elements of the coil each of length $d\vec{l}$ at C and D. Let $\vec{r}$ be the vector joining the current element $(Id\vec{l})$ at C and the point P.



Magnetic field due to current-carrying circular loop

(iii) According to Biot-Savart's law, the magnetic field at P due to the current element at C is

$$d\vec{B} = \frac{\mu_\circ}{4\pi}\frac{Id\vec{l} \times \hat{r}}{r^2}$$

The magnitude of is $d\vec{B}$ is

$$dB = \frac{\mu_\circ}{4\pi}\frac{Idl\sin\theta}{r^2} = \frac{\mu_\circ}{4\pi}\frac{Idl}{r^2}$$

where θ is the angle between $Id\vec{l}$ and $\vec{r}$. Here θ = 90°.

(iv) The magnetic field $d\vec{B}$ due to each current element is resolved into two components; dBcosϕ along y-direction and dBsinϕ along z-direction. The horizontal components cancel out while the vertical components (dBsinϕ $\hat{k}$) alone contribute to the net magnetic field $\vec{B}$ at the point P.

$$\vec{B} = \int d\vec{B} = \int dB \sin\phi \hat{k}$$

$$= \frac{\mu_0 I}{4\pi} \int \frac{dl}{r^2} \sin\phi \hat{k}$$

From ΔOCP,

$$\sin\phi = \frac{R}{(R^2 + z^2)^{1/2}} \text{ and } r^2 = R^2 + z^2$$

Substituting these in the above equation, we get

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{R}{(R^2 + z^2)^{3/2}} \hat{k} \left(\int dl\right)$$

If we integrate the line element from 0 to $2\pi r$, we get the net magnetic field $\vec{B}$ at point P due to the current-carrying circular loop.

$$\vec{B} = \frac{\mu_0 I}{2} \frac{R^2}{(R^2 + z^2)^{3/2}} \hat{k}$$

If the circular coil contains N turns, then the magnetic field is

$$\vec{B} = \frac{\mu_0 NI}{2} \frac{R^2}{(R^2 + z^2)^{3/2}} \hat{k}$$

The magnetic field at the centre of the coil is

$$\vec{B} = \frac{\mu_0 NI}{2R} \hat{k} \quad \text{since } z = 0$$

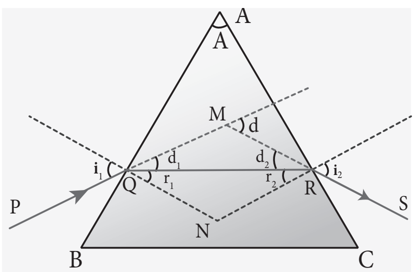
(OR)

(b) **Angle of deviation produced by prism:**

(i) Let light ray PQ is incident on one of the refracting faces of the prism. The angles of incidence and refraction at the first face AB are i_1 and r_1.

(ii) The angle between the direction of incident ray and the emergency ray is called the angle of deviation d in a prism.

(iii) The two normals drawn at the point of incidence Q and at the point of emergence R meet at point N. The incident ray and the emergent ray meet at a point M.



Refraction through prism

The angle of deviation d_1 at the surface AB is,

$$\angle RQM = d_1 = i_1 - r_1 \quad ...(1)$$

The angle of deviation d_2 at the surface AC is,

$$\angle QRM = d_2 = i_2 - r_2 \quad ...(2)$$

Total angle of deviation d produced is,

$$d = d_1 + d_2 \quad ...(3)$$

$$d = (i_1 - r_2) - (r_1 + r_2)$$

Substituting for d_1 and d_2,

$$d = (i_1 - r_1) + (i_2 - r_2)$$

After rearranging,

$$d = (i_1 + i_2) - (r_1 + r_2) \quad ...(4)$$

(iv) Therefore, the sum of the other angles of the quadrilateral is 180°.

$$\angle A + \angle QNR = 180° \quad ...(5)$$

From the triangle ΔQNR,

$$r_1 + r_2 + \angle QNR = 180°$$

Comparing these two equations (4) and (5) we get,

$$r_1 + r_2 = A \quad ...(6)$$

Substituting this in equation (4) for angle of deviation,

$$d = i_1 + i_2 - A \quad ...(7)$$

Refractive index of the material of the prism.

At minimum deviation, $i_1 = i_2 = i$ and $r_1 = r_2 = r$

Now, the equation (7) becomes,

$$D = i_1 + i_2 - A = 2i - A \text{ (or) } i = \frac{(A + D)}{2}$$

The equation (6) becomes,

$$r_1 + r_2 = A \Rightarrow 2r = A \text{ (or) } r = \frac{A}{2}$$

Substituting i and r in Snell's law,

$$n = \frac{\sin i}{\sin r}$$

$$n = \frac{\sin\left(\frac{A + D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

The above equation is used to determine the refractive index of the material of the prism.

36. (a) **(i)** When a photon of energy $h\nu$ is incident on a metal surface, it is completely absorbed by a single electron and the electron is ejected.

(ii) In this process, a part of the photon energy is used in overcoming the potential barrier of the metal surface (photoelectric work function ϕ_0) and the remaining energy as the kinetic energy of the ejected electron. From the law of conservation of energy,

$$h\nu = \phi_0 + \frac{1}{2}mv^2 \quad ...(1)$$

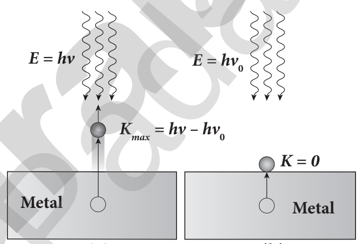
(iii) where m is the mass of the electron and v its velocity.

(iv) At some frequency ν_0 of incident radiation, the photo electrons are just ejected with almost zero kinetic energy (Figure b). Then the equation (1) becomes

i.e. $h\,\nu_0 = \phi_0$

(v) where ν_0 is the threshold frequency. By rewriting the equation (1), we get

$$h\nu = h\nu_0 + \frac{1}{2}mv^2 \quad ...(2)$$



Emission of photoelectrons

(vi) The equation (2) is known as Einstein's photoelectric equation. If the electron does not lose energy by internal collisions, then it is emitted with maximum kinetic energy K_{max}. Then $K_{max} = \frac{1}{2} mv^2_{max}$

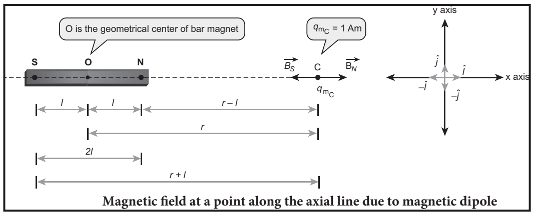
where v_{max} is the maximum velocity of the electron ejected. The equation (1) is rearranged as follows:

$$K_{max} = h\nu - \phi_0$$

(OR)

(b) **AC current containing only an inductor:**

(i) Consider a circuit containing a pure inductor of inductance L connected across an alternating voltage source (Figure).



AC circuit with inductance

The alternating voltage is given by the equation.

$v = V_m \sin \omega t$ ...(1)

(ii) The alternating current flowing through the inductor induces a self-induced emf or back emf in the circuit. The back emf is given by

Back emf, $\varepsilon = -L\dfrac{di}{dt}$

By applying Kirchoff's loop rule to the purely inductive circuit, we get

$$v + \varepsilon = 0$$

$$V_m \sin \omega t = L\frac{di}{dt}$$

$$di = \frac{V_m}{L} \sin \omega t \, dt$$

Integrating both sides, we get

$$i = \frac{V_m}{L}\int \sin \omega t \, dt$$

$$i = \frac{V_m}{L\omega}(-\cos \omega t) + \text{constant}$$

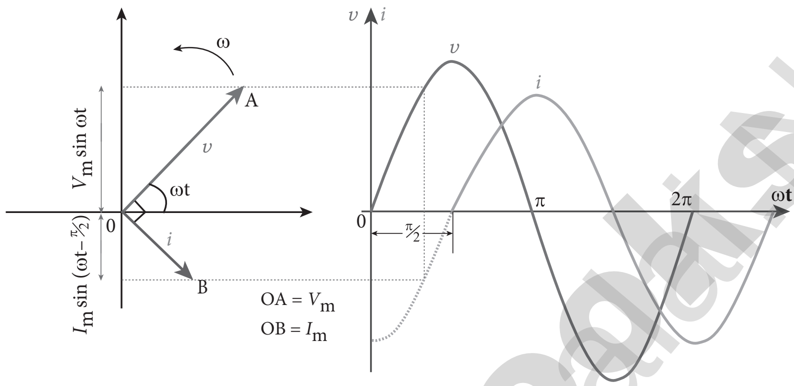
$$\left[\begin{array}{l} \cos \omega t = \sin\left(\frac{\pi}{2} - \omega t\right) \\ -\sin\left(\frac{\pi}{2} - \omega t\right) = \sin\left(\omega t - \frac{\pi}{2}\right) \end{array}\right]$$

From equation (2) it is evident that the current lags the applied voltage by $\frac{\pi}{2}$.

$$i = \frac{V_m}{\omega L} \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$\text{(or)} \quad i = I_m \sin\left(\omega t - \frac{\pi}{2}\right) \quad ...(2)$$

where $\frac{V_m}{\omega L} = I_m$ the peak value of the alternating current in the circuit.



Phasor diagram and wave diagram for AC circuit with L

37. (a) **Advantages of FM:**

(i) In FM, there is a Large decrease in noise. It leads to an increases in signal-noise ratio.

(ii) The operating range is quite large.

(iii) The transmission efficiency is very high as all the transmitted power is useful.

(iv) FM bandwidth covers the entire frequency range which humans can hear. Due to this, FM radio has better quality compared to AM radio.

Limitations of FM :

(i) FM requires a much wider channel.

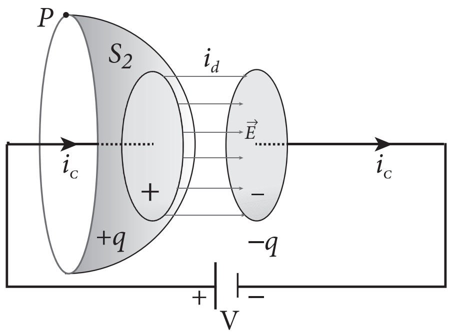
(ii) FM transmitters and receivers are more complex and costly.

(iii) In FM reception, less area is covered compared to AM.

(OR)

(b) **(i)** Ampere's circuital law is $\oint \vec{B} \cdot d\vec{s} = \mu_0 I$

Modification by J.C Maxwell on Ampere's circuital law.



Applying Gauss's law between the plates of the capacitor

(ii) Due to external source applied between the plates, the increasing current flowing through the capacitor produce an increasing electric field between the plates.

(iii) This change in electric field between the capacitor plate produce a current between the plates.

(iv) The time varying electric flux between the plate of the capacitor produce a current known as displacement current.

By Gauss Law $\Phi_E = \oint_s \vec{E}.d\vec{A} = EA = \frac{q}{\varepsilon_0}$

Change in electric flux

$$\frac{d\Phi_E}{dt} = \frac{1}{\varepsilon_0}\frac{dq}{dt}$$

$$\frac{dq}{dt} = \varepsilon_0 \frac{d\Phi_E}{dt}$$

$$\therefore\ i_d = \varepsilon_0 \frac{d\Phi_E}{dt}$$

i_d is the displacement current.

(v) The displacement current is defined as the current which comes into play in the region in which the electric field and the electric flux are changing with time.

(vi) So, Maxwell modified Ampere's Law

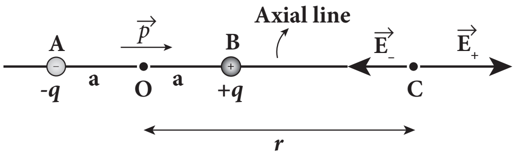
$$\oint \vec{B}.\vec{dl} = \mu_0 i_c = \mu_0 \in_0 \frac{d\phi_E}{dt} \qquad \therefore i = i_c + i_d$$

$i^l \rightarrow$ total current

The above equation is known as Ampere - Maxwell law. When current is constant, $i_d = 0$.

38. (a) **(i)** **Electric field due to an electric dipole at points on the axial line :**

Consider an electric dipole placed on the x-axis. A point C is located at a distance of r from the midpoint of the dipole on the axial line.



The electric field at a point 'C' due to $+q$ is

$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} \text{ along BC}$$

The electric field at a point 'C' due to $-q$ is

$$\vec{E}_- = -\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p} \text{ along CA}$$

The total electric field at point C is calculated using the superposition principle of the electric field.

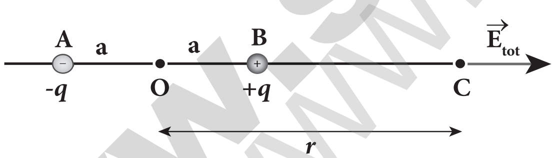
$$\vec{E}_{tot} = \vec{E}_+ + \vec{E}_-$$

at 'C' using superpostion principle

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p} \quad ...(1)$$

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}q\left(\frac{4ra}{(r^2-a^2)^2}\right)\hat{p} \quad ...(2)$$

Note that the total electric field is along $\vec{E}_+$, since $+q$ is closer to C than $-q$.



If the point C is very far away from the dipole (r >> a). Then under this limit the term $(r^2-a^2)^2 \approx r^4$. Substituting this into equation(2), we get

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\left(\frac{4aq}{r^3}\right)\hat{p} \quad (r >> a)$$

since $2aq\,\hat{p} = \vec{p}$

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3} \quad (r >> a)$$

$$\vec{E}_{tot} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3} \qquad (r >> a)$$

If the point C is chosen on the left side of the dipole, the total electric field is still in the direction of $\vec{p}$.

(OR)

(b) **Nuclear reactor :**

Nuclear reactor is a device in which the nuclear fission takes place in a self-sustained controlled manner and the energy produced is used either for research purpose or for power generation. The first nuclear reactor was built in the year 1942 at Chicago, USA by physicist Enrico Fermi.

Moderators:

The moderator is a material used to convert fast neutrons into slow neutrons. Usually the moderators are chosen in such a way that they must be very light nuclei having mass comparable to that of neutrons.

Most of the reactors use heavy water (D_2O) and graphite as moderators.

Control rods :

The control rods are used to adjust the reaction rate. During each fission, on an average 2.5 neutrons are emitted and in order to have the controlled chain reactions, only one neutron is allowed to cause another fission and the remaining neutrons are absorbed by the control rods.

If the average number of neutrons produced per fission is equal to one, then reactor is said to be in critical state. In fact, all the nuclear reactors are maintained in critical state by suitable adjustment of control rods. If it is greater than one, then reactor is said to be in super-critical and it may explode sooner or may cause massive destruction.

Cooling system :

The cooling system removes the heat generated in the reactor core. Ordinary water, heavy water and liquid sodium are used as coolant since they have very high specific heat capacity and have large boiling point under high pressure.

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