Sample Question Paper—2025 (Solved)

(Issued by Central Board of Secondary Education, New Delhi)

CLASS – 12th

PHYSICS

Time Allowed : 3 Hours **Maximum Marks : 70**

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.

(3) All the sections are compulsory.

(4) **Section A** contains **sixteen questions, twelve MCQ and four Assertion Reasoning based 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 **two case study-based questions of four marks each** and **Section E** contains **three long answer questions of five marks each.**

(5) There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.

(6) Use of calculators is not allowed.

(7) You may use the following values of physical constants where ever necessary

(*i*) $c = 3 \times 10^8$ m s^{-1}

(*ii*) $m_e = 9 \times 10^{-31}$ kg

(*iii*) $m_p = 1.675 \times 10^{-27}$ kg

(*iv*) $e = 1.6 \times 10^{-19}$ C

(*v*) $\mu_0 = 4\pi \times 10^{-7}$ T,

(*vi*) $h = 6.63 \times 10^{-34}$ J s^{-1},

(*vii*) $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

(*viii*) Avogadro's number = 6.023×10^{23} per gram mole

SECTION – A

[16 × 1 = 16 marks]

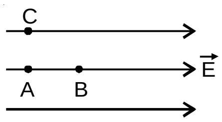
Q. 1. A uniform electric field pointing in positive X-direction exists in a region. Let A be the origin, B be the point on the X-axis at x = + 1 cm and C be the point on the Y-axis at y = + 1 cm. Then the potential at points A, B and C satisfy :

(*a*) $V_A < V_B$ (*b*) $V_A > V_B$

(*c*) $V_A < V_C$ (*d*) $V_A > V_C$.

Ans. (*b*)

The situation is as shown.



The electric potential decreases in the direction of the electric field. Therefore $V_A = V_C$ and $V_A > V_B$.

Q. 2. A conducting wire connects two charged conducting spheres such that they attain equilibrium with respect to each other. The distance of separation between the two spheres is very large as compared to either of their radii. The ratio of the magnitudes of the electric fields at the surfaces of the two spheres is :

(*a*) $\dfrac{r_1}{r_2}$ (*b*) $\dfrac{r_2}{r_1}$

(*c*) $\dfrac{r_2^2}{r_1^2}$ (*d*) $\dfrac{r_1^2}{r_2^2}$.

Ans. (*b*) When equilibrium is attained,

The potential on the surface of bigger sphere = the potential at the surface of the smaller sphere

Therefore

$$\frac{kq_1}{r_1} = \frac{kq_2}{r_2} \Rightarrow \frac{q_1}{q_2} = \frac{r_1}{r_2}$$

Hence electric field will be

$$\frac{E_1}{E_2} = \frac{kq_1}{r_1^2} \times \frac{r_2^2}{kq_2} = \frac{q_1}{q_2} \times \frac{r_2^2}{r_1^2} = \frac{r_1}{r_2} \times \frac{r_2^2}{r_1^2} = \frac{r_2}{r_1}.$$

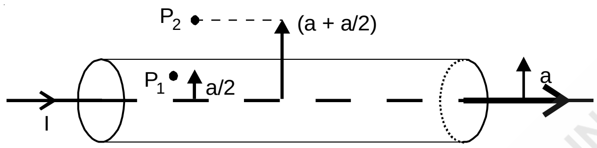
Q. 3. A long straight wire of circular cross section of radius '*a*' carries a steady current I. The current is uniformly distributed across its cross section. The ratio of magnitude of the magnetic field at a point *a*/2 above the surface of wire to that of a point *a*/2 below its surface is :

(*a*) 4 : 1 (*b*) 1 : 1

(*c*) 4 : 3 (*d*) 3 : 4.

Ans. (*c*)

The diagram of the situation is as shown.



At P_2, $B_2 = \dfrac{\mu_0 I}{2\pi\left(\dfrac{3a}{2}\right)} = \dfrac{\mu_0 I}{3\pi a}$

At P_1, $B_1 = \dfrac{\mu_0 (I/4)}{2\pi(a/2)} = \dfrac{\mu_0 I}{4\pi a}$

$$\therefore \quad \frac{B_2}{B_1} = \frac{\left(\dfrac{\mu_0 I}{3\pi a}\right)}{\left(\dfrac{\mu_0 I}{4\pi a}\right)} \Rightarrow \frac{B_2}{B_1} = \frac{4}{3}.$$

Q. 4. The diffraction effect can be observed in :

(*a*) sound waves only

(*b*) light waves only

(*c*) ultrasonic waves only

(*d*) sound waves as well as light waves.

Ans. (*d*) sound waves as well as light waves.

Q. 5. A capacitor consists of two parallel plates, with an area of cross-section of 0.001 m², separated by a distance of 0.0001 m. If the voltage, across the plates varies at the rate of 10^8 V s⁻¹, then the value of displacement current through the capacitor is :

(*a*) 8.85×10^{-3} A (*b*) 8.85×10^{-4} A

(*c*) 7.85×10^{-3} A (*d*) 9.85×10^{-3} A.

Ans. (*a*)

Displacement current through a capacitor connected to time varying current is given as,

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

$\phi_E = EA = VA/d$

Therefore,

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \frac{\varepsilon_0 A}{d} \times \frac{dV}{dt}$$

$$= \frac{8.8 \times 10^{-12} \times 0.001}{0.0001} \times 10^8$$

$I_D = 8.85 \times 10^{-3}$ A.

Q. 6. In a series LCR circuit, the voltage across the resistance, capacitance and inductance is 10 V each. If the capacitance is short circuited the voltage across the inductance will be :

(*a*) 10 V (*b*) $10\sqrt{2}$ V

(*c*) $\dfrac{10}{\sqrt{2}}$ V (*d*) 20 V.

Ans. (*c*)

When all the components are connected

$I R = I X_C = I X_L = 10$ V

In series current is same, therefore

$R = X_C = X_L$

The circuit is in resonance, therefore

$Z = R$

$V_S = I Z = I R = 10$ V

So, the source voltage is also 10 V

When the capacitor is short circuited then

$$Z = \sqrt{R^2 + (X_L)^2} = \sqrt{R^2 + R^2} = R\sqrt{2} \text{ ohm}$$

Hence

$$V_L = I X_L = \frac{V}{Z} \times R = \frac{10}{R\sqrt{2}} \times R = \frac{10}{\sqrt{2}} \text{ V}$$

Q. 7. Correct match of column I with column II is :

C-I (Waves)	C-II Production
(1) Infra Red	(P) Rapid vibration of electrons in aerials.
(2) Radio	(Q) Electrons in atoms emit light when the move from higher energy level to lower energy level.
(3) Light	(R) Klystron valve
(4) Microwave	(S) Vibration of atoms and molecules.

(*a*) 1-P, 2-R, 3-S, 4-Q
(*b*) 1-S, 2-P, 3-Q, 4-R
(*c*) 1-Q, 2-P, 3-S, 4-R
(*d*) 1-S, 2-R, 3-P, 4-Q.

Ans. (*b*)

Q. 8. The distance of closest approach of an alpha particle is *d* when it moves with a speed V towards a nucleus. Another alpha particle is projected with higher energy such that the new distance of the closest approach is *d*/2. What is the speed of projection of the alpha particle in this case ?

(*a*) V / 2 (*b*) $\sqrt{2}$ V
(*c*) 2 V (*d*) 4 V.

Ans. (*b*)

The distance of closest approach is given by

$$d = \frac{1}{4\pi\varepsilon_o}\frac{2Ze^2}{E_K} = \frac{1}{4\pi\varepsilon_o}\frac{2Ze^2}{\frac{1}{2}mV^2}$$

Therefore $d \propto \frac{1}{V^2}$

Now $d_1 = d$ and $d_2 = d/2$, also $V_1 = V$ and $V_2 = ?$

Hence

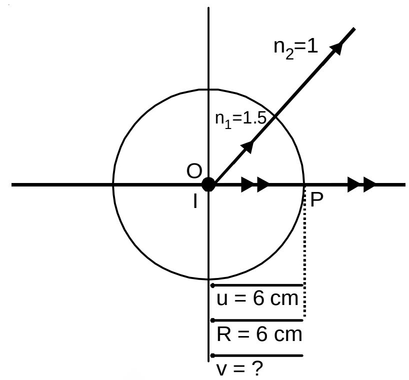
$$\frac{d_1}{d_2} = \frac{V_2^2}{V_1^2} \Rightarrow V_2 = V_1\sqrt{\frac{d_1}{d_2}} = V\sqrt{\frac{d}{d/2}} = \sqrt{2}V.$$

Q. 9. A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of virtual image from the surface of the sphere is :

(*a*) 2 cm (*b*) 4 cm
(*c*) 6 cm (*d*) 12 cm.

Ans. (*c*)

The diagram is as shown.



Distances to be measured from the pole P. Given $n_2 = 1$, $n_1 = 1.5$, R = – 6 cm, u = – 6 cm
Using the equation for object lies in the denser medium

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

$$\frac{1}{v} - \frac{1.5}{-6} = \frac{1-1.5}{-6}$$

$$\frac{1}{v} = -\frac{3}{12} + \frac{1}{12} = -\frac{1}{6}$$

v = – 6 cm.

Q. 10. Colours observed on a CD (Compact Disk) is due to :

(*a*) Reflection (*b*) Diffraction
(*c*) Dispersion (*d*) Absorption.

Ans. (*b*)

This is due to the diffraction taking place between the very fine lines on the CD.

Q. 11. The number of electrons made available for conduction by dopant atoms depends strongly upon :

(*a*) doping level
(*b*) increase in ambient temperature
(*c*) energy gap
(*d*) options (*a*) and (*b*) both.

Ans. (*a*)

More the doping, more are the number of electrons available.

Q. 12. If copper wire is stretched to make its radius decrease by 0.1%, then the percentage change in its resistance is approximately.

(*a*) – 0.4% (*b*) +0.8%
(*c*) +0.4% (*d*) +0.2%.

Ans. (*c*)

When a wire is stretched its volume remains constant-

R = ρL/A

$$R = \frac{\rho L}{A} \times \frac{A}{A} = \frac{\rho V}{A^2} = \frac{\rho V}{\pi^2 r^4} \Rightarrow R \propto \frac{1}{r^4}$$

Hence, $\frac{dR}{R} = 4\frac{dr}{r} = 4 \times 0.1 = 0.4\ \%$

Resistance of wire is increased by 0.4 percent.

For Questions 13 to 16, two statements are given–one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

(*a*) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.
(*b*) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
(*c*) If Assertion is true but Reason is false.
(*d*) If both Assertion and Reason are false.

Q. 13. Assertion (A) : On increasing the current sensitivity of a galvanometer by increasing the number of turns may not necessarily increase its voltage sensitivity.

Reason (R) : The resistance of the coil of the galvanometer increases on increasing the number of turns.

Ans. (*a*)

The voltage sensitivity is given by

$$\frac{\theta}{V} = \frac{\text{current sensitivity}}{R}$$

When we increase current sensitivity by increasing the number of turns, then resistance of coil also increases.

So increasing current sensitivity does not necessarily imply that voltage sensitivity will increase. As the voltage sensitivity is given by $\frac{\theta}{V} = \frac{\text{current sensitivity}}{R}$

$\therefore$ if current sensitivity increases and R also increases by different amounts, then voltage sensitivity may increase or decrease.

Q. 14. Assertion (A) : In a hydrogen atom, there is only one electron but its emission spectrum shows many lines.

Reason (R) : In a given sample of hydrogen there are many atoms each containing one electron; hence many electrons in different atoms may be in different orbits so many transitions from higher to lower orbits are possible.

Ans. (*a*)

Electrons in different orbits will give out radiation of different frequencies when they fall into lower energy levels.

Q. 15. Assertion (A) : Nuclei having mass number about 60 are least stable.

Reason (R) : When two more light nuclei are combined into a heavier nucleus then the binding energy per nucleon will decrease.

Ans. (*d*)

Nuclei having mass number 60 are more stable. When two smaller nuclei fuse the binding energy per nucleon increase.

Q. 16. Assertion (A) : de Broglie's wavelength of a freely falling body keeps decreasing with time.

Reason (R) : The momentum of the freely falling body increases with time.

Ans. (*a*)

De-Broglie wavelength is given by $\lambda = \frac{h}{p}$

where *p* is the momentum. When a body falls its velocity and hence its momentum keeps on increasing. Thus, de-Broglie wavelength will keep on falling.

SECTION – B

[5 × 2 = 10 marks]

Q. 17. A platinum surface having work function 5.63 eV is illuminated by a mono-chromatic source of 1.6×10^{15} Hz. What will be the minimum wavelength associated with the ejected electron ?

Ans. Given $\phi = 5.63\text{ eV} = 5.63 \times 1.6 \times 10^{-19}$ J,

$\nu = 1.6 \times 10^{15}$ Hz, λ = ?

We know that

$$E = h\nu - \phi = \frac{hc}{\lambda}$$

Hence

$$\lambda = \frac{hc}{h\nu - \phi}$$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{6.63\times10^{-34}\times1.6\times10^{15}-5.63\times1.6\times10^{-19}}$$

Or $\lambda = 12.7 \times 10^{-7}$ m.

Q. 18. (I) In Young's double-slit experiment using monochromatic light of wavelength λ, the intensities of two sources is I. What is the intensity of light at a point where path difference between wavefront is $\lambda/4$?

OR

(II) A beam of light consisting of two wavelengths, 4000 Å and 6000 Å, is used to obtain interference fringes in a Young's double-slit experiment. What is the least distance from the central maximum where the dark fringe is obtained ? (d = 10 mm, D = 1 m These values are not given in the question)

Ans. (I) $x = \lambda/4$, therefore phase difference will be

$$\phi = \frac{2\pi}{\lambda}\times\frac{\lambda}{4}=\frac{\pi}{2}$$

Given $I_1 = I_2 = I$

Using the expression

$$I_R = I_1 + I_2 + 2\sqrt{I_1I_2}\ \cos\phi = I + I + 2\sqrt{I^2}$$

$$\cos\frac{\pi}{2} = 21$$

OR

(II) Given $\lambda_1 = 4000 \times 10^{-10} = 4 \times 10^{-7}$ m

and $\lambda_2 = 6000 \times 10^{-10} = 6 \times 10^{-7}$ m

Distance of dark fringe from the central maxima

$$y = (2n + 1)\frac{D\lambda}{2d}$$

For first dark fringe $n = 0$, therefore distance of first dark fringe

$$y = \frac{D\lambda}{2d}$$

For $\lambda_1 = 4000$ Å $= 4 \times 10^{-7}$ m, the distance of the first dark fringe is

$$y_1 = \frac{D\lambda_1}{2d} = \frac{1\times4\times10^{-7}}{2\times10^{-2}} = 2 \times 10^{-5} \text{ m}$$

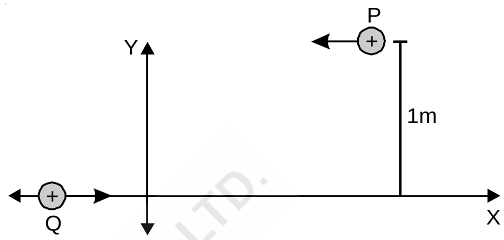
For $\lambda_2 = 6000$ Å $= 6 \times 10^{-7}$ m, the distance of the first dark fringe is

$$y_1 = \frac{D\lambda_1}{2d} = \frac{1\times6\times10^{-7}}{2\times10^{-2}} = 3 \times 10^{-5} \text{ m}$$

The first dark fringes will coincide at a point distance equal to the LCM of y_1 and y_2

$= 6 \times 10^{-5}$ m.

Q. 19. P and Q are two identical charged particles each of mass 4×10^{-26} kg and charge 4.8×10^{-19} C each moving with the same speed of 2.4×10^{5} m s^{-1} as shown in the figure. The two particles are equidistant (0.5 m) from the vertical Y-axis. At some instant, a magnetic field B is switched on so that the two particles undergo head-on collision.



Find—

(I) the direction of the magnetic field and

(II) the magnitude of the magnetic field applied in the region.

Ans. Given $m_1 = m_2 = 4 \times 10^{-26}$ kg,

$q_1 = q_2 = 4.8 \times 10^{-19}$ C, $v = 2.4 \times 10^{5}$ m s^{-1}

(I) The particles P and Q are equidistant (0.5 m) from the vertical Y-axis. This means that the magnetic field must be directed along the X-axis, perpendicular to the line connecting the two particles, in order to cause a head-on collision *i.e.,* perpendicular and into the plane of the paper.

(II) For a head-on collision to take place, the radius of the path of each particle should be equal to 0.5 m.

Now the radius of the circular path followed by the two particles will be

$$r = \frac{mv}{Bq} \Rightarrow B = \frac{mv}{Bq}$$

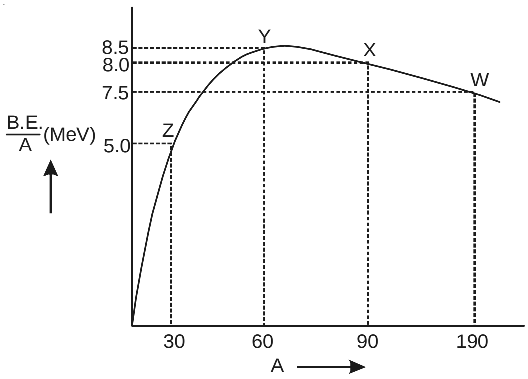
$$\text{Or } B = \frac{4\times10^{-26}\times2.4\times10^{5}}{0.5\times4.8\times10^{-19}} = 0.04 \text{ T.}$$

Q. 20. Binding energy per nucleon vs mass number curve for nuclei is shown in the figure. W, X, Y and Z are four nuclei indicated on the curve. Identify which of the following nuclei is most likely to undergo

(*i*) Nuclear Fission

(*ii*) Nulear Fusion.

Justify your answer.



Ans. (*i*) Nuclear fission – W

Reason: As W has binding energy per nucleon less than Y and X and nucleus is larger. Its binding energy per nucleon is also small, thus it will split into smaller nuclei to increase its binding energy per nucleon and in the process become stable.

(*ii*) Nuclear fusion – Z

Reason: As Z has binding energy per nucleon more than Y and X and nucleus is smaller. Also its binding energy per nucleon is small. Thus to stabilize itself it fuses to increase its binding energy per nucleon.

Q. 21. What should be the radius 'r' of nearest possible orbits of satellite to mass 'm' revolving around the planet of mass 'M' as per Bohr Postulates in terms of m, M, G, h where G is Gravitational constant and h is Planck's constant.

Ans. By Bohr's theory the angular momentum of an electron is given by

$$L = mvr = \frac{nh}{2\pi} \qquad ...(i)$$

$$\text{Or } v^2 = \left(\frac{nh}{2\pi mr}\right)^2 \qquad ...(ii)$$

For the satellite to move in an orbit around the earth, the gravitational force of attraction between the earth and the satellite provides the necessary centripetal force, therefore we have

$$\frac{mv^2}{r} = \frac{GMm}{r^2} \text{ or}$$

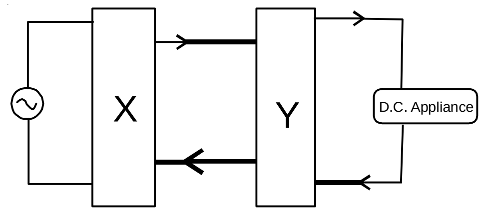
$$v^2 = \frac{GM}{r} \qquad ...(iii)$$

$$\text{Or } r = \frac{n^2h^2}{4\pi^2m^2GM}.$$

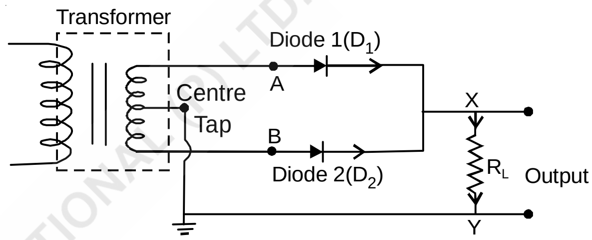
SECTION – C

[7 × 3 = 21 marks]

Q. 22. (I) Identify the circuit elements X and Y as shown in the given block diagram and draw the output waveforms of X and Y.



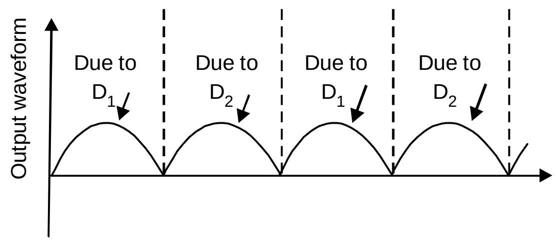
(II) If the centre tapping is shifted towards Diode D_1 as shown in the diagram, draw the output waveform of the given circuit.



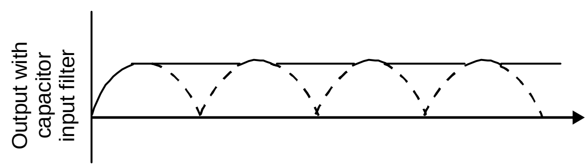
Ans. (I) X = Full wave rectifier

Y = Filter circuit

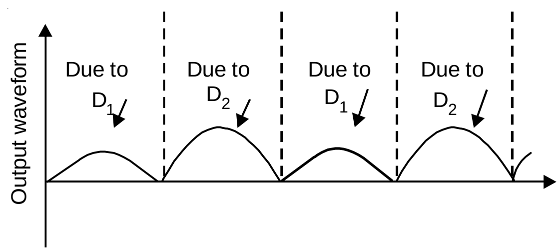
Output waveform of X



Output waveform of Y



(II) If the centre tap is shifted towards D_1, the output of D_1 will decrease, as less ac voltage will be fed to it.



Q. 23. Find the expression for the capacitance of a parallel place capacitor of plate area A and plate separation *d* when (I) a dielectric slab of thickness *t* and (II) a metallic slab of thickness *t*, where (t<d) are introduced one by one between the plates of the capacitor. In which case would the capacitance be more and why?

Ans. (I) Let t be the thickness of the dielectric such that $t < d$, where d is the distance between the plates.

Now net electric field between the plates is

$E = E_0 - E_i$. ...(1)

But $\frac{E_0}{E} = K$, therefore $\frac{E_0}{K} = E$ ...(2)

Now electric potential difference between the two plates is

V = (field outside the dielectric × distance of this field) + (field within the dielectric × thickness of the dielectric)

$V = E_0 (d - t) + Et = E_0 (d - t) + E_0 t / K$

$= E_0 (d - t + t / K)$ ...(3)

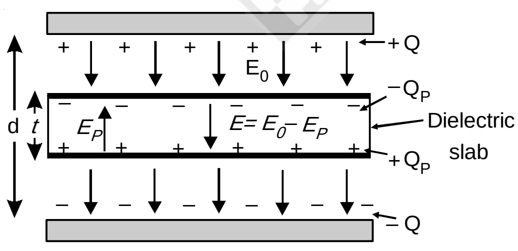
But $E_0 = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$, therefore

$$V = \frac{Q \times (d - t + t/K)}{A\varepsilon_0} \quad ...(4)$$

Therefore

$$C = \frac{Q}{V} = Q \times \frac{A\varepsilon_0}{Q \times (d - t + t/K)} = \frac{A\varepsilon_0}{(d - t + t/K)}$$

$$\text{or } C = \frac{\varepsilon_0 A}{d + t\left(\frac{1}{K} - 1\right)} \quad ...(5)$$



(II) For a mettallic slab K = ∞

Therefore, we have

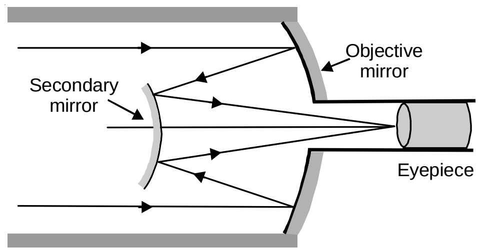
$$C = \frac{\varepsilon_0 A}{d + t\left(\frac{1}{\infty} - 1\right)} = \frac{\varepsilon_0 A}{d - t}$$

It is more in case of a metallic slab.

Q. 24. (I) Draw a ray diagram for the formation of image by a Cassegrain telescope.

(II) Why these types of telescopes are preferred over refracting type telescopes. (Write 2 points)

Ans. (I) The ray diagram is as shown.



(II) (*i*) No chromatic aberration: Because reflected light doesn't disperse by wavelength, reflecting telescopes don't suffer from chromatic aberration, which is the appearance of coloured fringes around stars.

(*ii*) Shorter tube: For the same diameter, reflecting telescopes have shorter tubes than refracting telescopes, which reduces the cost of the tube.

(*iii*) Easter to build : Large mirros are easier and cheaper to build than large lenses.

(*iv*) Easier to mount : The back of the mirror can be used to attach to the mount.

(*v*) Less mechanical support : Because mirrors weigh less than lenses, reflecting telescopes require less mechanical support.

(*vi*) Spherical aberration can be minimized : Parabolic mirrors can be used to minimize spherical aberration.

(*vii*) Only one-side of the objective needs to the perfect: Because light reflects off the objective instead of passing through it, only one side of the objective needs to be perfect.

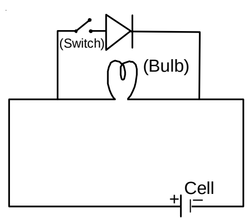
(Any two)

Q. 25. (I) Draw the energy bank diagram for P-type semiconductor at (*i*) T = 0 K and (*ii*) room temperature.

(II) In the given diagram considering an ideal diode, in which condition will the bulb glow

(*a*) when the switch is open

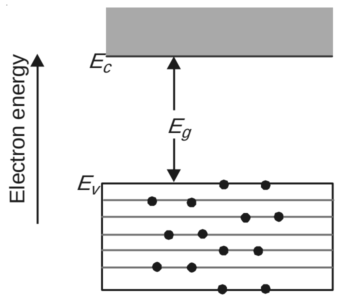
(*b*) when the switch is closed.



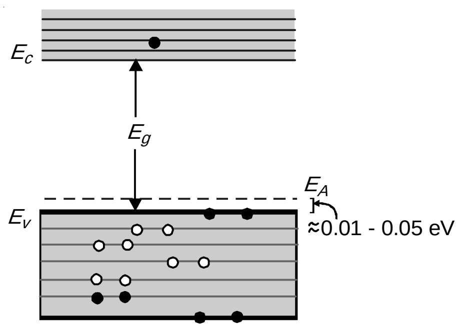
Justify your answer.

Ans. (I) The ray diagrams are as shown.

(*i*) At T = 0 K



(*ii*) At room temperature



(II) When switch is open, there will be no current through the diode. The entire current will pass through the bulb. When switch is closed, diode will be forward biased and current will by-pass the bulb.

Q. 26. A boy is holding a smooth, hollow and non-conducting pipe vertically with charged spherical ball of mass 10 g carrying a charge of +10 mC inside it, which is free to move along the axis of the pipe. The boy is moving the pipe from East to West direction in the presence of magnetic field of 2 T. With what minimum velocity, should the boy move the pipe such that the ball does not move along the axis ? Also, determine the direction of the magnetic field.

Ans. Given

B = 2 T, q = 10 mC = 10 × 10^{-3} C = 10^{-2} C, m = 10^{-2} kg, g = 9.8 m s^{-2},

The magnetic force on the ball is given by

$F_m = Bqv \sin\theta$

For the ball to remain stationary, the magnetic force must balance the gravitational force:

$F_g = mg$

In equilibrium

$F_m = F_g$

$B\,q\,v \sin\theta = m\,g$

Or $v = \dfrac{mg}{Bq\sin\theta}$

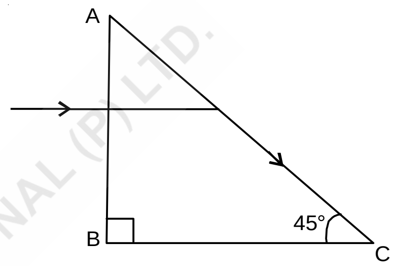
For minimum velocity sin θ should be maximum *i.e.,* sin θ = 1

Therefore, $v = \dfrac{mg}{Bq} = \dfrac{10^{-2} \times 9.8}{2 \times 10^{-2}} = 4.9 \text{ m s}^{-1}$

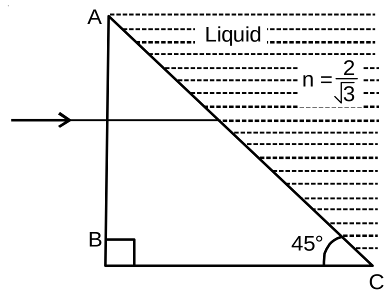
As the magnetic force will act upwards, then by Fleming's left hand rule the magnetic field will be from South to North.

Q. 27. A light ray entering a right-angled prism undergoes refraction at the face AC as shown in Fig. 1.

(I) What is the refractive index of the material of the prism in Fig. 1 ?



(II) (*a*) If the side AC of the above prism is now surrounded by a liquid of refractive index $\frac{2}{\sqrt{3}}$ as shown in Fig. 2, determine if the light ray continues to graze along the interface AC or undergoes total internal reflection or undergoes refraction into the liquid.



(*b*) Draw the ray diagram to represent the path followed by the incident ray with the corresponding angle values.

(Given, $\sin^{-1}\left(\frac{\sqrt{2}}{\sqrt{3}}\right)$ = 54.6°).

Ans. (I) Since, the light ray enters perpendicular to the face AB, the angle of incidence on face AC will be 45° because the prism is a right angled isosceles prism.

Thus, i_c = 45° as the ray grazes the side AC
Now for face AC

$$\sin i_C = \frac{1}{n} \Rightarrow n = \frac{1}{\sin i_C} = \frac{1}{\sin 45°} = \sqrt{2}$$

(*ii*) (*a*) In fig 2, the face AC is surrounded by a liquid of refractive index $\frac{2}{\sqrt{3}}$ therefore, this will change the refractive index of the prism. The new refractive index will become

$$_L n_g = \frac{_a n_g}{_a n_L} = \frac{\sqrt{2}}{2/\sqrt{3}} = \frac{\sqrt{3}}{\sqrt{2}}$$

Hence, the critical angle now becomes

$$\sin i_C = \frac{1}{_L n_g} \Rightarrow \sin i_C = \frac{\sqrt{2}}{\sqrt{3}} \Rightarrow i_C = \sin^{-1}\left(\frac{\sqrt{2}}{\sqrt{3}}\right)$$

= 54.6°

Since, the angle of incidence on the surface AC is 45°, which is less than the critical angle for the given pair of media (glass and the liquid), the ray neither undergoes grazing along surface AC, nor does it suffer total internal reflection.

Instead the ray will undergo refraction at the surface AC and pass into the liquid.

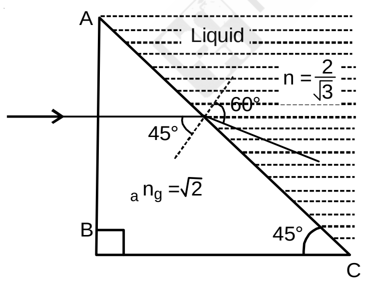
For refracting interface AC, by Snell's law we have

$$_a n_g \sin i = {_a n_L} \sin r$$

$$\sqrt{2} \times \sin 45° = \frac{2}{\sqrt{3}} \times \sin r \Rightarrow \sin r = \frac{\sqrt{3}}{2}$$

Or r = 60°

The ray diagram is as shown.



Q. 28. (I) State Gauss's theorem in electrostatics. Using this theorem, derive an expression for the electric field due to an infinitely long straight wire of linear charge density λ.

Or

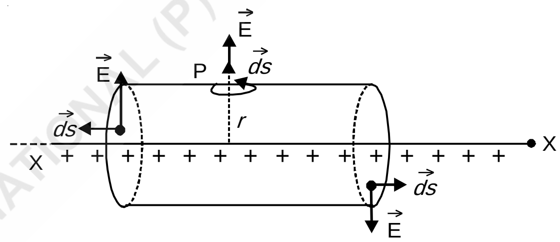
(II) (*a*) Define electric flux and write its SI unit.

(*b*) Use Gauss's law to obtain the expression for the electric field due to a uniformly charged infinite plane sheet of charge.

Ans. (I) It states, "The net electric flux through any Gaussian surface is equal to $\frac{1}{\varepsilon_0}$ times the net electric charge enclosed by the surface

Mathematically, $\phi = \oint \vec{E}.d\vec{A} = \frac{q_{en}}{\varepsilon_0}$

Consider an infinitely long, thin wire charged + vely and having uniform linear charge density λ. Draw a circular cylinder of radius r and arbitrary length l coaxial with the rod as shown Fig. Then this circular cylinder is our Gaussian surface. Since the Gaussin surface must be closed, the two end caps are part of the Gaussian surface.



For the cylinderical part of the Gaussian surface, $\vec{E}$ is constant in magnitude and perpendicular to the surface at each point. Furthermore, the flux through the ends of the Gaussian cylinder is zero since $\vec{E}$ is parallel to these surfaces, i.e., there is no normal component of electric field at these faces. Therefore, by the definition of electric flux we have

$$\phi = E \times A \quad ...(1)$$

where A is the curved surface area of the cylinder

or $$\phi = E \times 2\pi rL \quad ...(2)$$

By Gauss's law the electric flux is given by

$$\phi = \frac{q}{\varepsilon_0} = \frac{\lambda L}{\varepsilon_0} \quad ...(3)$$

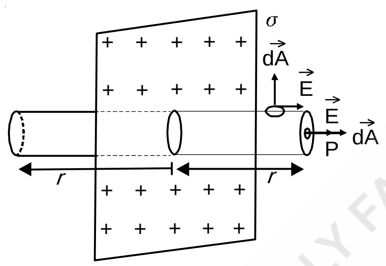
From equation **2** and **3** we have

$$E \times 2\pi rL = \frac{\lambda L}{\varepsilon_0} \quad ...(4)$$

or $$E = \frac{\lambda}{2\pi\varepsilon_0 r} = 2k\frac{\lambda}{r} \quad ...(5)$$

(II) (*a*) It is defined as the total number of electric field lines crossing a given area. The electric flux can be found by multiplying the component of electric field in the direction of the area vector (or perpendicular to the area) with the area of the closed surface. Its SI unit is N m^2 C^{-1}.

(*b*) Let σ be the uniform surface charge density i.e. the charge per unit surface area of an infinite plane sheet of charge. From symmetry, the electric field is perpendicular to the plane of the sheet, and that the direction of $\vec{E}$ on one side of the plane must be opposite to its direction on the other side as shown in figure. Let us choose a Gaussian surface in the form of a cylinder with the ends of area A. The charged sheet ABCD passes through the middle of the cylinder's length, so that the cylinder's ends are equidistant from the sheet. The electric field has a normal component at each end of the cylinder and no normal component along the curved surface of the cylinder. As a result the electric flux is linked with only the result, the electric flux is linked with only the ends and not the curved surface.



Therefore, by the definition of electric flux, the flux linked with the Gaussian surface is given by

ϕ = EA + EA = 2EA ...(1)

But by Gauss's law

$$\phi = \frac{q}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0} \quad ...(2)$$

From equations **1** and **2** we have

$$2EA = \frac{\sigma A}{\varepsilon_0} \quad ...(3)$$

$$E = \frac{\sigma}{2\varepsilon_0} \quad ...(4)$$

This gives the electric field due to an infinite plane sheet of charge.

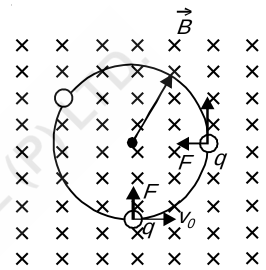
SECTION – D

[2 × 4 = 08 marks]

Q. 29. Case Study Based Question :

Motion of Charge in Magnetic Field

An electron with speed $v_0 << c$ moves in a circle of radius r_0 in a uniform magnetic field. This electron is able to traverse a circular path as the magnetic force acting on the electron is perpendicular to both v_0 and B as shown in the figure. This force continuously deflects the particle sideways without changing its speed and the particle will move along a circle perpendicular to the field. The time required for one revolution of the electron is T_0.



(*i*) If the speed of the electron is now doubled to $2v_0$. The radius of the circle will change to

(*a*) $4r_0$ (*b*) $2r_0$ (*c*) r_0 (*d*) $r_0/2$.

Ans. (*b*)

The radius of the circular loop is given by

$r = \frac{mv}{Bq}$, if v is doubled *r* also doubles.

(*ii*) If $v = 2v_0$, then the time required for one revolution of the electron (T_0) will change to

(*a*) 4 T_0 (*b*) 2 T_0 (*c*) T_0 (*d*) $T_0/2$.

Ans. (*c*)

$$T = \frac{2\pi r}{v} = \frac{2\pi(2r_0)}{2v_0} = T_0$$

(*iii*) A charged particle is projected in a magnetic field $\vec{B} = (2\hat{i} + 4\hat{j}) \times 10^2 T$. The acceleration of the particle is found to be $\vec{a} = (x\hat{i} + 2\hat{j})ms^{-2}$. Find the value of *x*.

(*a*) 4 m s^{-2} (*b*) –4 m s^{-2}

(*c*) –2 m s^{-2} (*d*) 2 m s^{-2}.

Ans. Incomplete question

(*iv*) If the given electron has a velocity not perpendicular to B, then trajectory of the electron is :

(*a*) straight line (*b*) circular
(*c*) helical (*d*) zig-zag.

Ans. (*c*)

If the electron enters a magnetic field at any other angle rather than 0°, 180° or 90° it will follow a helical path.

Or

If this electron of charge (e) is moving parallel to uniform magnetic field with constant velocity v, the force acting on the electron is :

(*a*) Bev (*b*) Be/v (*c*) B/ev (*d*) Zero.

Ans. (*d*)

Force acting on the electron

F = Bev sin θ

Here θ = 0°

Therefore

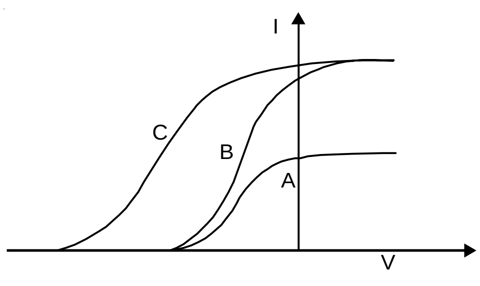
F = 0.

Q. 30. Case Study Based Question :
Photoelectric effect

It is the phenomenon of emission of electrons from a metallic surface when light of a suitable frequency is incident on it. The emitted electrons are called photoelectrons. Nearly all metals exhibits this effect with ultravoilet light but alkali metals like lithium, sodium, potassium, caesium etc. show this effect even with visible light. It is an instantaneous process i.e. photoelectrons are emitted as soon as the light is incident on the metal surface. The number of photoelectrons emitted per second is directly proportional to the intensity of the incident radiation.

The maximum kinetic energy of the photoelectrons emitted from a given metal surface is independent of the intensity of the incident light and depends only on the frequency of the incident light. For a given metal surface, there is a certain minimum value of the frequency of the incident light below which emission of photoelectrons does not occur.

(*i*) In a photoelectric experiment plate current is plotted against anode potential.



(*a*) A and B will have same intensities while B and C will have different frequencies.
(*b*) B and C will have different intensities while A and B will have different frequencies.
(*c*) A and B will have different intensities while B and C will have equal frequencies.
(*d*) B and C will have equal intensities while A and B will have same frequencies.

Ans. (*d*)

For same intensity, photoelectric current will be same and for same frequency stopping potential will be same.

(*ii*) Photoelectrons are emitted when a zinc plate is

(*a*) Heated (*b*) hammered
(*c*) Irradiated by ultraviolet light
(*d*) subjected to a high pressure

Ans. (*c*)

The frequency of the incident radiation should be higher than the threshold frequency of the given metal.

(*iii*) The threshold frequency for photoelectric effect on sodium corresponds to a wavelength of 500 nm. Its work function is about.

(*a*) 4×10^{-19} J (*b*) 1 J
(*c*) 2×10^{-19} J (*d*) 3×10^{-19} J.

Ans. (*a*)

$$\phi = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{500 \times 10^{-9}} = 4 \times 10^{-19} \text{ Js}$$

(*iv*) The maximum kinetic energy of photoelectrons emittted from a surface when photons of energy 6 eV fall on it is 4 eV. The stopping potential is :

(*a*) 2 V (*b*) 4 V
(*c*) 6 V (*d*) 10 V.

Ans. K = eV_0 = 4 eV

Therefore V_0 = 4 V

Or

The minimum energy required to remove an electron from a substance is called its

(*a*) work function
(*b*) kinetic energy
(*c*) stopping potential
(*d*) potential energy.

Ans. (*a*)

SECTION – E

[3 × 5 = 15 marks]

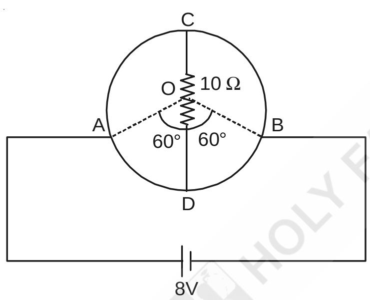
Q. 31. (I) (*a*) Write two limitations of Ohm's law. Plot their I-V characteristics.

(*b*) A heating element connected across a battery of 100 V having an internal resistance of 1 Ω draws an initial current of 10 A at room temperature 20.0° which settles after a few seconds to a steady value. What is the power consumed by battery itself after the steady temperature of 320.0 °C is attained ? Temperature coefficient of resistance averaged over the temperature range involved is 3.70 × 10^{-4} $^{-1}$C°.

Or

(II) (*a*) Using Kirchhoff's laws obtain the equation of the balanced state in Wheatstone bridge.

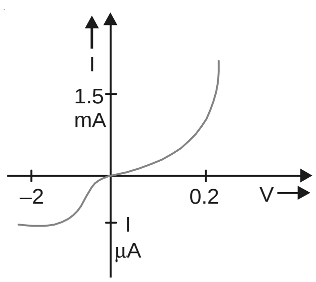
(*b*) A wire of uniform cross-section and resistance of 12 ohm is bent in the shape of circle as shown in the figure. A resistance of 10 ohms is connected to diametrically opposite ends C and D. A battery of emf 8V is connected between A and B. Determine the current flowing through arm AD.



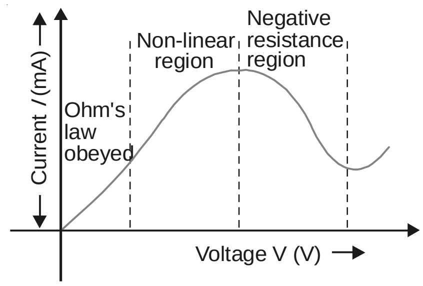
Ans. (I) (*a*) The limitations are

(*i*) The relation between V and I depends upon the sign of V (Graph 1)

(*ii*) The relation between V and I is not unique *i.e.,* there is more than one value of V for the same value of current I. (Graph 2)



Graph 1



Graph 2

(*b*) Given V = 100 V, r = 1 Ω, I_{20} = 10 A, T_0 = 20.0 °C, T = 320.0 °C

$\alpha = 3.70 \times 10^{-4}$ °C^{-1}

At room temperature 20.0 °C, current is given by

$$I_{20} = \frac{\varepsilon}{R_0 + r}$$

Therefore,

$$R_0 = \frac{\varepsilon}{I_{20}} - r = \frac{100}{10} - 1 = 9\ \Omega$$

Now change in temperature

320 – 20 = 300 °C

Therefore R at 320.0 °C

$R = R_0\,(1 + \alpha\Delta T)$

Or R = 9(1 + 3.7 × 10^{-4} × 300)

R = 10 ohm

Hence power consumed by the battery

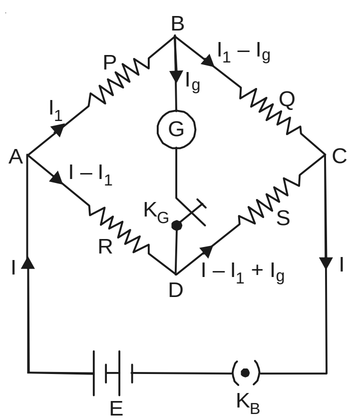
$P = I^2 R$

$$P = \left(\frac{\varepsilon}{R + r}\right)^2 \times r = \left(\frac{100}{10 + 1}\right)^2 \times 1 = 82.64\ W$$

Or

(II) (*a*) The Wheatstone bridge and the current distribution is as shown.

Now applying Kirchhoff's loop rule to the closed loop **ABDA** we have



$- I_1P - I_gG + (I - I_1)\,R = 0$ ...(1)

Again applying Kirchhoff's loop rule to closed loop BCDB we have

$-(I_1 - I_g)\,Q + (I - I_1 + I_g)\,X + I_gG = 0$ ...(2)

The value of P, Q, R and X are so adjusted that the galvanometer gives zero deflection. This means that both B and D will be at the same potential and hence no current will flow through the galvanometer. *i.e.*, $I_g = 0$. In this situation, the Wheatstone bridge is said to be balanced. Putting $I_g = 0$ in equations 1 and 2 we have

$- I_1P + (I - I_1)\,R = 0$ ...(3)

and $- I_1Q + (I - I_1)\,X = 0$ ...(4)

Rewriting the above two equations we have

$I_1P = (I - I_1)\,R$ ...(5)

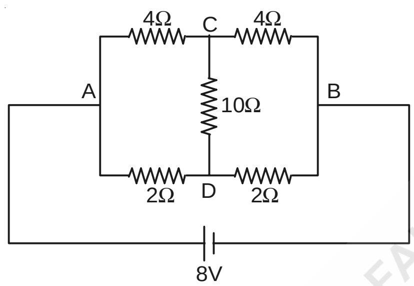
and $I_1Q = (I - I_1)\,X$ ...(6)

Dividing the above equations we have

$$\frac{P}{Q} = \frac{R}{X} \quad ...(7)$$

The above expression gives the condition for the balance of a Wheatstone bridge.

(*b*) The circuit is a balanced Wheatstone bridge and is redrawn as shown.



Here $R_{AC} = R_{BC}$

$R_{AD} = R_{BD}$

Now $R_{DAC} = R_{DBC} = 12/2 = 6\ \Omega$

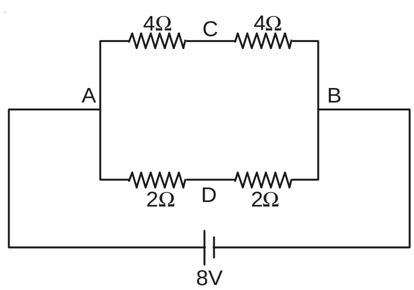
Now resistance

$$R_{AD} = R_{BD} = R_{DAC} \times \frac{60}{180} = \frac{R_{DAC}}{3} = \frac{6}{3} = 2\ \Omega$$

Therefore resistance

$R_{AC} = R_{BC} = R_{DAC} - R_{AD} = 6 - 2 = 4\ \Omega$

The Wheatstone bridge is in the balance state. Therefore, it reduces to



Now $R_{ADB} = 2 + 2 = 4\ \Omega$

Therefore current through arm AD = current through arm ADB

$I = V/R_{ADB} = 8/4 = 2$ A

Q. 32. (I) Explain briefly, with the help of a labelled diagram, the basic principle of the working of an ac generator. In an ac generator, coil of N turns and area A is rotated at an angular velocity *ω* in a uniform magnetic field B. Derive an expression for the instantaneous value of the emf induced in coil. What is the source of energy generation in this device ?

Or

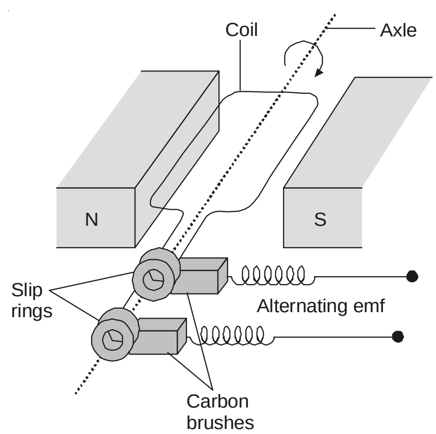
(II) (*a*) With the help of a diagram, explain the principle of a device which changes a low ac voltage into a high voltage. Deduce the expression for the ratio of secondary voltage to the primary voltage in term of the ratio of the number of turns of primary and secondary winding. For an ideal tranformer, obtain the ratio of primary and secondary currents in terms of the ratio of the voltages in the secondary and primary coils.

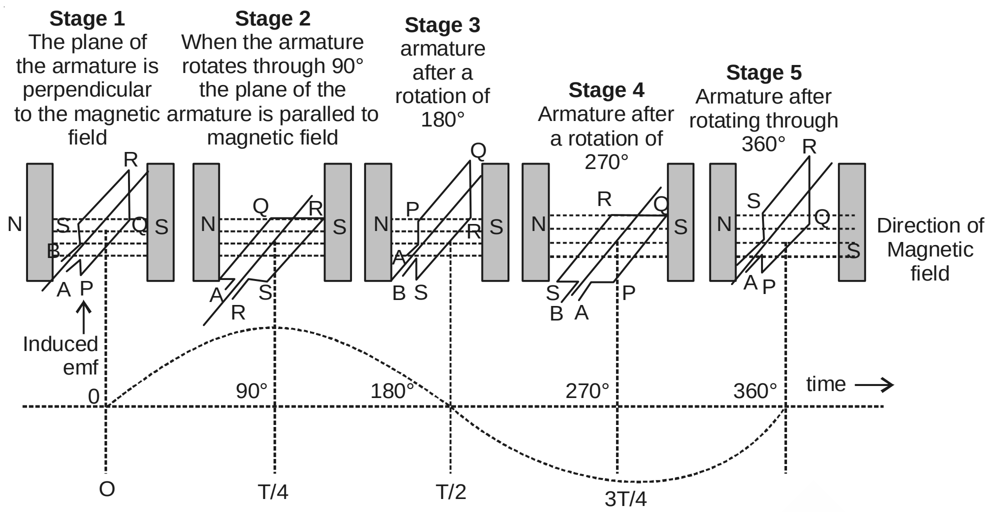
(*b*) Write any two sources of the energy losses, which occur in actual transformers.

(*c*) A step-up transformer converts a low input voltage into a high output voltage. Does it violate law of conservation of energy ? Explain.

Ans. (I) Principle : It is based on the principle of electromagnetic induction. When a coil is rotated about an axis perpendicular to the direction of uniform magnetic field, an induced emf is produced across it.

A labelled diagram of an ac generator is shown below.





Suppose at time $t = 0$, the plane of the loop is perpendicular to B. As the loop rotates from position $t = 0$ to position $t = T/2$, the induced emf changes from zero to maximum value and then becomes zero again as shown in the diagram. For angles 0° and 180° the instantaneous rate of magnetic flux is zero, hence induced emf is zero. As the loop moves from position $t = T/2$ to position $t = T$, the emf again changes from zero to maximum value and then again becomes zero. But this time it reverses its direction. For angle 90° and 270° maximum magnetic flux is linked with the coil hence the emf is a maximum. Thus the output of the ac generator varies sinusoidally with time. The induced emf does not depend upon the shape of the loop, but depends only upon the area of the loop.

Consider an armature of the ac generator having n turns and placed in a uniform magnetic field B.

Suppose at any instant t the normal to the plane of the coil makes an angle θ with the direction of the magnetic field. If ω is the uniform angular velocity with which, the coil rotates then $\theta = \omega t$.

The flux through the loop equals its area A multiplied by $B_\perp = B\cos\theta$, the component of magnetic field B perpendicular to the area, hence

$$\phi = nBA\cos\phi = nBA\cos\omega t \qquad ...(1)$$

where n is the number of turns in the armature.

By Faraday's flux rule,

$$\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}\, nBA\cos\omega t$$

$$= -nBA\frac{d}{d\phi}\cos\omega t = -nBA(-\omega\sin\omega t) \qquad ...(2)$$

or $\varepsilon = nBA\omega\sin\omega t$

The induced emf is maximum when $\sin\omega t$ = maximum = 1, therefore the maximum induced emf is given by $\varepsilon_0 = nBA\omega$ ...(3)

The current in the external load is given by

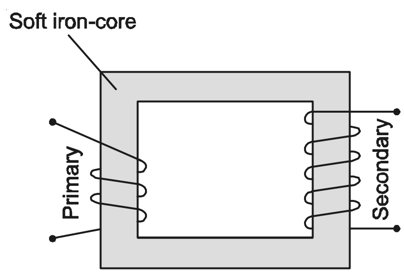
$$i = \frac{\varepsilon_0 \sin\omega t}{R} = i_0 \sin\omega t$$

Here i_0 is the peak value of the current

Or

(II) (*a*) The device is a transformer.

The diagram is a shown.



It works on the principle of mutual induction *i.e.,* whenever magnetic flux linked with the primary changes, an emf is induced in the secondary coil.

Let the resistance of the windings be neglected and let us assume that all the magnetic field lines be confined to the iron core. As such at any time, the magnetic flux ϕ is same in each turn of the primary and secondary windings. Let N_P be the number of turns in primary and N_S be the number of turns in the secondary. When the magnetic flux changes, because of the changing currents in the two coils, the resulting induced emf's across the primary and the secondary are

$$\varepsilon_P = -N_P\frac{d\phi}{dt} \text{ and } \varepsilon_S = -N_S\frac{d\phi}{dt} \quad ...(1)$$

The flux per turn ϕ is the same in both the primary and the secondary so equation 1 shows that the induced emf per turn in the same in each. The ratio of the primary emf ε_S is therefore equal at any instant to the ratio of the primary to secondary turns;

$$\frac{\varepsilon_p}{\varepsilon_s} = \frac{N_p}{N_s} \quad ...(2)$$

Since ε_P and ε_S both oscillate with the same frequency as the ac source, therefore equation 2 also gives the ratio of the amplitudes or of the rms values of the induced emf's. If the windings have zero resistance, the induced emf's ε_P and ε_S are equal to the terminal voltages across the primary and the secondary respectively; hence

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \quad ...(3)$$

By choosing the appropriate turns ratio $\frac{N_s}{N_p} = r$, called transformation ratio, we can obtain any desired secondary voltage from a given primary voltage.

If there are no energy losses in the process of transformation then

instantaneous output power = instantaneous input power or

$$V_S I_S = V_P I_P$$

or $$\frac{V_p}{V_s} = \frac{I_s}{I_p} \quad ...(4)$$

from equation (3) and (4)

we have $$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s} = r \quad ...(5)$$

(*b*) The two sources of energy losses are eddy current losses and flux leakage losses.

(*c*) There is no violation of the principle of the conservation of energy in the step up transformer. When output voltage increases the output current decreases automatically keeping the power the same.

Q. 33. (I) (*a*) A giant refracting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece of focal length 1.0 cm is used, what is angular magnification of the telescope is normal adjustment ?

(*b*) 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.

Or

(II) A compound microscope consists of an objective lens of focal length 2.0 cm and an eyepiece of focal length 6.25 cm separately by a distance of 15 cm. How far from the objective should an object be placed in order to obtain the final image at

(*a*) the least distance of distinct vision (25 cm) and

(*b*) infinity ?

What is the magnifying power of the microscope in each case ?

Ans. (I) (*a*) Given f_0 = 15 m, f_e = 10 cm = 0.01 m, M = ?

Dm = 3.48×10^6 m, $r = 3.8 \times 10^8$ m,

Using $$M = \frac{f_0}{f_e} = \frac{15}{0.01} = 1500$$

Angle subtended by moon at the objective of the telescope

$$\alpha = \frac{D_m}{r} = \frac{3.48\times10^6}{3.8\times10^8}$$

Therefore angle subtended by the image

$$\beta = M \times \alpha = 1500 \times \frac{3.48\times10^6}{3.8\times10^8}$$

(*b*) If I be the linear size of the image then

$$I = \beta \times f_e = \frac{3.48\times10^6\times1500}{3.8\times10^8} \times 0.01$$

$= 13.7 \times 10^{-2}$ m

Or I = 13.7 cm.

Or

Given f_0 = 2.0 cm, f_e = 6.25 cm, L = 15 cm, u_O = ?, v_e = – 25 cm, u_e = ?

Using the formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ *or* $\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$

we have $\frac{1}{u_e} = \frac{1}{25} - \frac{1}{6.25} = -\frac{1}{5}$ or u_e = – 5 cm

Hence $v_0 = L - u_e$ = 15 – 5 = 10 cm

Now applying lens formula for objective lens

we have $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ *or* $\frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0}$

Or $\frac{1}{u_0} = \frac{1}{10} - \frac{1}{2} = \frac{1-5}{10} = \frac{4}{10}$ or

u_0 = – 2.5 cm

Now $M = -\frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right) = -\frac{10}{-2.5}\left(1 + \frac{25}{6.25}\right) = 20$

(*b*) When the final image is formed at infinity.

$v_e = \infty$, u_e = ?

Using the formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ *or* $\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$

we have $\frac{1}{u_0} = \frac{1}{\infty} - \frac{1}{6.25} = -\frac{1}{6.25}$ or u_e = – 6.25 cm

Hence $v_0 = L - u_e$ = 15 – 6.25 = 8.75 cm

Now applying lens formula for objective lens

we have $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ *or* $\frac{1}{u_0} = \frac{1}{v_0} - \frac{1}{f_0}$

Or $\frac{1}{u_0} = \frac{1}{8.25} - \frac{1}{2} = \frac{2-8.75}{17.5} = -\frac{6.75}{17.5}$

or u_0 = – 2.59 cm

Now $M = \frac{v_0}{u_0} \times \frac{D}{f_0} = -\frac{8.75}{-2.59}\left(\frac{25}{6.25}\right)$ = 13.5

MODEL ANSWERS

2024–25
Solved

PHYSICS
CLASS-12th

Holy Faith New Style Sample Paper—1

(Based on the Latest Design & Syllabus issued by C.B.S.E.)

CLASS – 12th

PHYSICS

Time allowed : 3 hours **Maximum Marks : 70**

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.

(3) All the sections are compulsory.

(4) **Section A** contains **sixteen questions, twelve MCQ and four Assertion Reasoning based 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 **two case study-based questions of four marks each** and **Section E** contains **three long answer questions of five marks each.**

(5) There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.

(6) Use of calculators is not allowed.

(7) You may use the following values of physical constants where ever necessary

(*i*) $c = 3 \times 10^8$ m s^{-1}

(*ii*) $m_e = 9 \times 10^{-31}$ kg

(*iii*) $m_p = 1.675 \times 10^{-27}$ kg

(*iv*) $e = 1.6 \times 10^{-19}$ C

(*v*) $\mu_0 = 4\pi \times 10^{-7}$ T,

(*vi*) $h = 6.63 \times 10^{-34}$ J s^{-1},

(*vii*) $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

(*viii*) Avogadro's number = 6.023×10^{23} per gram mole

SECTION – A

Q. 1. Two charged spheres are separated by 2 mm. Which of the following would yield the greatest attractive force ?

(*a*) $+2q$ and $-2q$ (*b*) $+2q$ and $+2q$

(*c*) $-2q$ and $-2q$ (*d*) $-1q$ and $-4q$.

Ans. (*a*) $+2q$ and $-2q$.

Q. 2. The electric potential on the axis of an electric dipole at a distance '*r*' from its centre is V. Then the potential at a point at the same distance on its equatorial line will be :

(*a*) 2V (*b*) – V

(*c*) V/2 (*d*) Zero.

Ans. (*d*) Zero.

Q. 3. By increasing the temperature, the specific resistance of a conductor and semiconductor :

(*a*) increases for both
(*b*) decreases for both
(*c*) increases, decreases
(*d*) decreases for both.

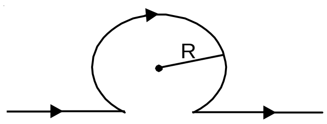
Ans. (*c*) increases, decreases.

Q. 4. Biot-Savart law indicates that the moving electrons (velocity v) produce a magnetic field B such that :

(*a*) $B \perp v$ (*b*) $B \parallel v$
(*c*) it obeys the inverse cube law
(*d*) it is along the line-joining the electron and point of observation.

Ans. (*a*) $B \perp v$

Q. 5. The strength of the magnetic field at the centre of the circular coil is :



(*a*) $\frac{\mu_0 I}{R}\left(1-\frac{1}{\pi}\right)$ (*b*) $\frac{\mu_0 I}{\pi R}$
(*c*) $\frac{\mu_0 I}{2R}\left(1-\frac{1}{\pi}\right)$ (*d*) $\frac{\mu_0 I}{2R}\left(1+\frac{1}{\pi}\right)$

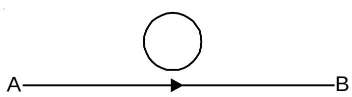
Ans. (*c*) $\frac{\mu_0 I}{2R}\left(1-\frac{1}{\pi}\right)$.

Q. 6. A wire of length L has a magnetic moment M. It is then bent into a semi-circular arc. The now magnetic moment is :

(*a*) M (*b*) ML
(*c*) $2M\pi$ (*d*) $M\pi$

Ans. (*c*) $2M\pi$.

Q. 7. The current flows from A to B is increasing as shown in the figure. The direction of the induced current in the loop is :



(*a*) clockwise (*b*) anticlockwise
(*c*) straight line
(*d*) no induced e.m.f. produced.

Ans. (*a*) clockwise.

Q. 8. Which of the following statement is NOT true about the properties of electromagnetic waves ?

(*a*) These waves do not require any material medium for their propagation
(*b*) Both electric and magnetic field vectors attain the maxima and minima at the same time.
(*c*) The energy in an electromagnetic wave is divided equally between electric and magnetic fields
(*d*) Both electric and magnetic field vectors are parallel to each other.

Ans. (*d*) Both electric and magnetic field vectors are parallel to each other.

Q. 9. A coil of metal wire is kept stationary in a non-uniform magnetic field :

(*a*) An emf and current both are induced in the coil
(*b*) Current but not EMF is induced in the coil
(*c*) An emf but not current is induced in the coil
(*d*) Neither an EMF nor current is induced in the coil.

Ans. (*d*) Neither an EMF nor current is induced in the coil.

Q. 10. The magnifying power of an astronomical telescope is 8 and the distance between the two lenses in 54 cm. The focal length of eye lens and objective lens will be respectively :

(*a*) 6 cm and 48 cm (*b*) 48 cm and 6 cm
(*c*) 8 cm and 64 cm (*d*) 64 cm and 8 cm.

Ans. (*a*) 6 cm and 48 cm

Q. 11. Find the incorrect statements(s) about the photoelectric effect

(*a*) There is no significant time delay between the absorption of a suitable radiation and the emission of electrons
(*b*) Einstein analysis gives a threshold frequency above which no electron can be emitted
(*c*) The maximum kinetic energy of the emitted photoelectrons is proportional to the frequency of incident radiation
(*d*) The maximum kinetic energy of electrons does not depend on the intensity of radiation.

Ans. (*b*) Einstein analysis gives a threshold frequency above which no electron can be emitted.

Q. 12. A set of atoms in an excited state decay.

(*a*) in general, to any of the states with lower energy

(*b*) into a lower state only when excited by an external electric field

(*c*) all together simultaneously into a lower state

(*d*) to emit photons only when they collide.

Ans. (*a*) in general, to any of the states with lower energy.

Question number 13 to 16 are Assertion (A) and Reason (R) type questions.

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

(*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A)

(*c*) (A) is true but (R) is false

(*d*) (A) is false and (R) is also false.

Q. 13. Assertion (A) : A pure semiconductor has negative temperature coefficient of resistance.

Reason (R) : In a semiconductor on raising the temperature, more charge carriers are released, conductance increases and resistance decreases.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A).

Q. 14. Assertion (A) : According to Huygen's principle, no backward wave-front is possible.

Reason (R) : Amplitude of the secondary wavelet is proportional to $(1 + \cos \theta)$ where θ is the angle between the ray at the point of consideration and the direction of the secondary wavelet.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

Q. 15. Assertion (A) : In process of photoelectric emission, all emitted electrons do not have the same kinetic energy.

Reason (R) : If radiation falling on the photosensitive surface of metal consists of different wavelengths then energy acquired by electrons absorbing photons of different wavelengths shall be different.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

Q. 16. Assertion : The change in potential energy of a two-charge system is independent of the choice of zero potential energy reference.

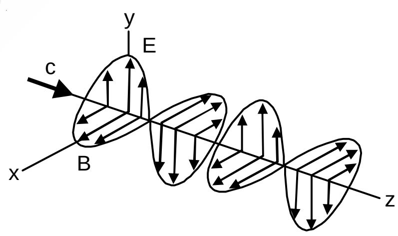
Reason : The potential energy of a charge may decrease when it moves opposite to an electric field.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A)

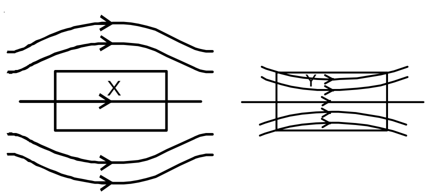
SECTION – B

Q. 17. Draw a sketch of a plane electromagnetic wave propagating along the z-direction. Depict clearly the directions of electric and magnetic fields varying sinusoidally with z.

Ans. The sketch is as shown below :



Q. 18. A uniform magnetic field gets modified as shown below when two specimens X and Y are placed in it.



(*i*) Identify the two specimens X and Y.

(*ii*) State the reason for the behaviour of the field lines in X and Y.

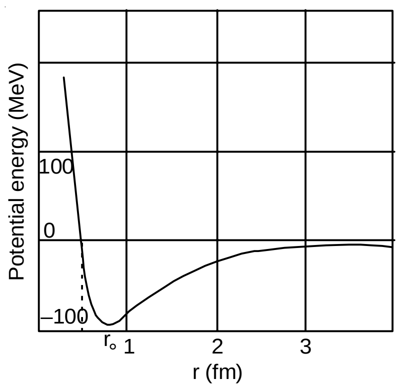
Ans. (*i*) X is a diamagnetic substance and Y is a paramagnetic/ferromagnetic substance.

(*ii*) This is because the permeability of a diamagnetic substance is less than one and that of a paramagnetic/ferromagnetic substance is greater than one.

Q. 19. Draw a plot of the potential energy of a pair of nucleons as a function of their

separation. Write two important conclusions that you can draw regarding the nature of nuclear forces.

Ans. The plot is as shown.



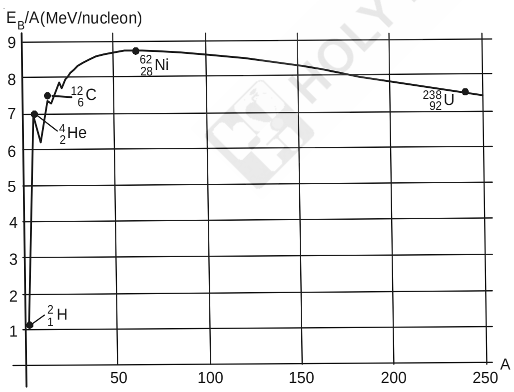
(*i*) It shows that the nuclear force is a saturated force.

(*ii*) It shows that for distances larger than 0.8 fm the force is attractive and is repulsive if the distance is less than this.

Or

Draw a plot of the binding energy per nucleon as a function of mass number for a large number of nuclei $2 \leq A \leq 240$. How do you explain the constancy of binding energy per nucleon in the range $30 < A < 170$ using the, property that nuclear force is short-ranged ?

Ans. The graph is as shown below.



Consider a particular nucleon inside a sufficiently large nucleus. It will be under the influence of only some of its neighbours, which come within the range of the nuclear force. If any other nucleon is at a distance more than the range of the nuclear force from the particular nucleon it will have no influence on the binding energy of the nucleon under consideration. If we increase A by adding nucleons they will not change the binding energy of a nuclei inside. Since most of the nucleons in a large nucleus reside inside and not on the surface, the change in binding energy per nuclei would be small. The binding energy per nucleon is thus constant.

Q. 20. 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 ? Justify your answer.

Ans. We know that

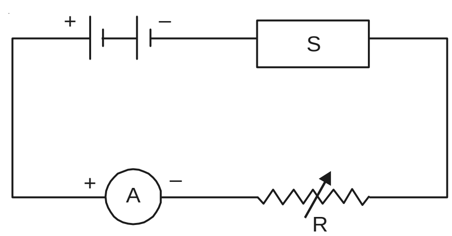
$$\frac{1}{f} = \left(\frac{\mu_m}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{\mu_m}{\mu_w} = \frac{1.25}{1.33} = 0.98$$

The value of $(\mu - 1)$ is negative and 'f' will be negative. So it will behave like a diverging lens.

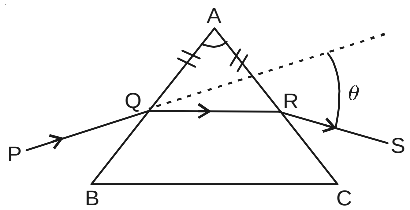
Q. 21. The diagram below shows a piece of pure semiconductor S in series with a variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter (A) constant when semi-conductor S is heated ? Give reason.



Ans. When a semiconductor is heated, its resistance decreases. As a result, the total resistance of the circuit will decrease. In order to maintain constant current flow the total resistance of the circuit must remain constant. Hence, the external resistance has to be increased to compensate for the decrease of resistance of the semiconductor.

SECTION – C

Q. 22. A ray PQ incident on the refracting face BA is refracted in the prism BAC as shown in the figure and emerges from the other refracting face AC as RS such that AQ = AR. If the angle of prism A = 60° and refractive index of material of prism is $\sqrt{3}$, calculate angle θ



Ans. Here As AQ = AR, therefore QR is parallel to BC, hence prism is in minimum deviation position.

$A = 60°,\ \theta = d_m = ?,\ n = \sqrt{3}$

Using $n = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$ Or

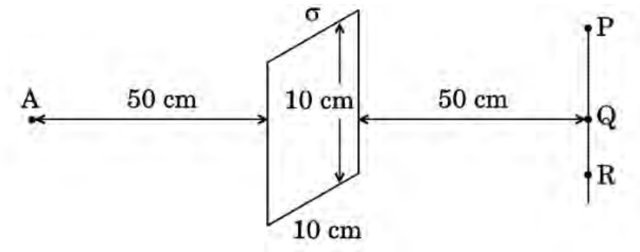
$$\sqrt{3} = \frac{\sin\left(\dfrac{60+\delta_m}{2}\right)}{\sin\left(\dfrac{60}{2}\right)} = \frac{\sin\left(\dfrac{60+\delta_m}{2}\right)}{\sin 30}$$

$$\text{or } \frac{\sqrt{3}}{2} = \sin\left(\frac{60+\delta_m}{2}\right)$$

Solving θ = 60°

Q. 23. (*a*) A uniformly charged large plane sheet has charge density σ = (1/18π) × 10^{-15} C m^{-2}. Find the electric field at point A which is 50 cm from the sheet.

(*b*) Consider a straight line with three points P, Q and R, placed 50 cm from the charged sheet onthe right side as shown in the figure. At which of these points, does the magnitude of the electric field due to the sheet remain the same as that at point A and why ?

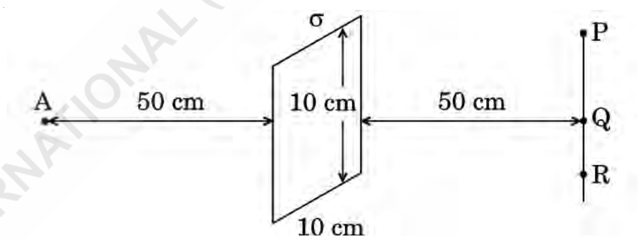


Ans. (*a*) The electric field is given by

$$E = \frac{\sigma}{2\varepsilon_0} = \frac{10^{-15}}{18\pi \times 2 \times 8.854 \times 10^{-12}}$$

$E = 10^{-6}$ N C^1 away from the sheet.

(*b*) At Point Q : Because at 50 cm, the charge sheet acts as a finite sheet and thus the magnitude remains the same towards the middle region of the planar sheet.



Q. 24. A particle of charge '*q*' and mass '*m*', moving with velocity $\vec{v}$ subjected to a uniform magnetic field B perpendicular to its velocity. Show that the particle describes a circular path. Obtain expression for the radius of the circular path of the particle.

Ans. If the angle between v and B is 90° then the force is given by F = $q\ v$ B. This force is perpendicular to both the velocity vector and the magnetic field vector, hence the particle will move in a circular path with a constant speed $\vec{v}$ (though directions of $\vec{F}$ and $\vec{v}$ will change from point to point, but their magnitude will remain same). The necessary centripetal force for circular motion will be provided by the Lorentz magnetic force. Let m be the mass of the charged particle and r the radius of the circular path, then the necessary centripetal force is given by $\frac{mv^2}{r}$. Hence for the circular motion of the charged particle we have :

$$\frac{mv^2}{r} = q\,v\,B \text{ or } r = \frac{mv}{Bq}$$

Q. 25. An alternating voltage of 220 V is applied across a device X, a current of 0.25 A flows, which lags behind the applied voltage in phase by $\pi/2$ radian. If the same voltage is applied across another device Y, the same current flows but now it is in phase with the applied voltage.

(*i*) Name the devices X and Y

(*ii*) Calculate the current flowing in the circuit when the same voltage is applied across the series combination of X and Y.

Ans. Device X = Inductor

Device Y = Resistor

Given I = 0.25 A, V = 220 V, X_L = ? , R = ? , I = ?

Now X_L and R are equal and are given by

$$X_L = R = \frac{220}{0.25} = 880\Omega$$

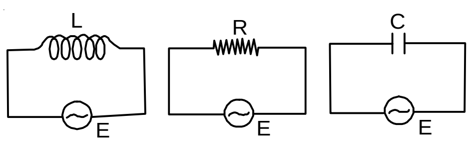
Hence impedance of the circuit

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{2\,(880)^2} = 1244.5\Omega$$

Therefore current through the combination is

$$I = \frac{V}{Z} = \frac{220}{1244.5} = 0.177 \text{ A.}$$

Q. 26. Figure (a), (b) and (c) show three ac circuit in which equal currents are flowing. If the frequency of emf be increased, how will the current be affected in these circuits ? Give reason for your answer.



(a) (b) (c)

Ans. There will be no change in the current in figure *b* as the resistance of the resistor does not depend upon the frequency of the applied ac. The reactance of the inductor in figure a is given by $X_L = 2pfL$. An increase in frequency increases the value of inductive reactance. This decreases the current through the circuit.

The reactance of the capacitor in figure *c* is given by $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$. An increase in frequency decreases the value of capacitive reactance. This increases the current through the circuit.

Or

In a step-up voltage transformer, explain giving reasons, the following facts :

(*a*) The output current is less than the input current.

(*b*) The iron core is laminated.

(*c*) The input power is more than the output power.

Ans. (*a*) A transformer does not transform the power. In an ideal transformer the input and the output power is same. Since P = V I , therefore in a step-up transformer when the voltage is increased the current decrease accordingly.

(*b*) This is done to reduce the losses due to eddy currents.

(*c*) The practical transformers are not ideal. Hence the output power is less than the input power due to various losses.

Q. 27. Light of intensity 'I' and frequency '*v*' is incident on a photosensitive surface and causes photoelectric emission. What will be the effect on anode current when

(*i*) the intensity of light is gradually increased.

(*ii*) the frequency of incident radiation is increased, and

(*iii*) the anode potential is increased ? In each case, all other factors remain the same.

Explain, giving justification in each case.

Ans. (*i*) Anode current will increase with increase of intensity as more the intensity of light, more is the number of photons and hence more number of photoelectrons are ejected.

(*ii*) No effect as frequency of light affects the maximum K.E. of the emitted photoelectrons.

(*iii*) Anode current will increase with anode potential as more anode potential will accelerate the electrons more till it attains a saturation value and get them collected at the anode at a faster rate.

Or

Find the ratio of the de Broglie wavelengths associated with an alpha particle and a proton, if both

(*a*) have the same speeds,

(*b*) have the same kinetic energy

(*c*) are accelerated through the same potential difference.

Ans. Let m be the mass of the proton and e the charge on it. Then the mass of alpha particle $m_a = 4\,m$ and $q_a = 2e$

(*a*) The de-Broglie wavelength of a particle of mass m moving with a velocity v is given by

$$\lambda = \frac{h}{mv}$$

$$\frac{\lambda_\alpha}{\lambda_P} = \frac{h}{m_a v} \times \frac{m_P v}{h} = \frac{m_P}{m_a} = \frac{m}{4m} = \frac{1}{4}$$

(*b*) The de-Broglie wavelength of a particle of mass m moving with a kinetic energy K is given by

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

$$\frac{\lambda_a}{\lambda_P} = \frac{h}{\sqrt{2m_aK}} \times \frac{\sqrt{2m_PK}}{h} = \sqrt{\frac{m_P}{m_a}} = \sqrt{\frac{m}{4m}} = \frac{1}{2}$$

(*c*) The de-Broglie wavelength of a particle of mass m accelerated through the same potential difference V is given by

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

$$\frac{\lambda_a}{\lambda_P} = \frac{h}{\sqrt{2m_aq_aV}} \times \frac{\sqrt{2m_Pq_PV}}{h} = \sqrt{\frac{m \times e}{4m \times 2e}} = \frac{1}{2\sqrt{2}}$$

Q. 28. The photon emitted during the de-excitation from the 1st excited level to the ground state of hydrogen atom is used to irradiate a photo cathode of a photocell, in which stopping potential of 5V is used. Calculate the work function of the cathode used.

Ans. The energy of the photon is given by

E = hν = – 3.4 – (– 13.6) = 10.2 eV

Now stopping potential, V_0 = 5 V, hence eV_0 = 5 eV

Now using the equation $eV_0 = h\nu - \phi$ we have

5 = 10.2 – ϕ

Or ϕ = 10.2 – 5 = 5.2 eV

SECTION – D

Questions number 29 to 30 are case study-based questions.

Read the following paragraph and answer the questions.

Q. 29. A number of optical devices and instruments have been designed and developed such as periscope, binoculars, microscopes and telescopes utilising the reflecting and refracting properties of mirrors, lenses and prisms. Most of them are in common use. Our knowledge about the formation of images by the mirrors and lenses is the basic requirement for understanding the working of these devices.

(*i*) An astronomical telescope of magnifying power 7 consists of the two thin lenses 40 cm apart, in normal adjustment. The focal lengths of the lenses are :

(*a*) 5 cm, 35 cm (*b*) 7 cm, 35 cm

(*c*) 17 cm, 35 cm (*d*) 5 cm, 30 cm.

Ans. (*a*)

M = f_o / f_e = 7

$f_o = 7\,f_e$

In normal adjustment distance between lenses

L = $f_o + f_e$ = 40

Or 7 $f_e + f_e$ = 40

Or

f_e = 40/8 = 5 cm

$f_o = 7\,f_e = 7 \times 5$ = 35 cm.

Or

An astronomical telescope has a magnifying power of 10 D. In normal

adjustment, distance between the objective and eyepiece is 22 cm. The focal length of objective lens is :

(*a*) 25 cm (*b*) 10 cm
(*c*) 15 cm (*d*) 20 cm.

Ans. (*d*) M = 10, L = 22 cm

As $m = f_o / f_e$, $10 = f_e / f_o$

$f_o = 10 f_e$

Also $L = f_o + f_e = 22$

$10 f_e + f_e = 22$

$f_e = 22/11 = 2$ cm

$f_o = 10 f_e = 10 \times 2 = 20$ cm.

(ii) **In astronomical telescope compare to eyepiece, objective lens has**

(*a*) negative focal length
(*b*) zero focal length
(*c*) small focal length
(*d*) large focal length.

Ans. (*d*)

Objective has a large focal length.

(iii) **To see stars, we use**

(*a*) compound microscope
(*b*) simple microscope
(*c*) Endoscope
(*d*) astronomical telescope.

Ans. (*d*)

Astronomical telescope is used to see stars.

Or

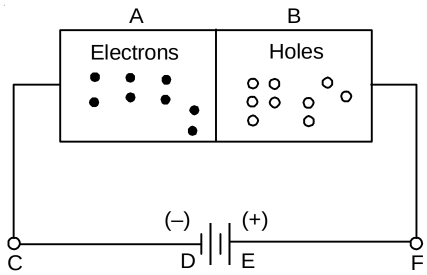
For large magnifying power of astronomical telescope.

(*a*) $f_o << f_e$ (*b*) $f_o = f_e$
(*c*) $f_o >> f_e$ (*d*) none of these.

Ans. (*c*)

$f_o >> f_e$.

Q. 30. A p-n junction is the key to all semiconductor devices. When such a junction is made, a depletion layer is formed consisting of immobile ion-cores devoid of their electrons or holes. This is responsible for a junction potential barrier. By changing the external applied voltage, junction barrier can be changed. In forward bias, the barrier is decreased while the barrier increases in reverse bias. Hence, the forward bias current is more (mA) while it is very small (μA) in reverse biased junction diode. The given figure shows a germanium semiconductor device.



(i) **The section A represents in the diagram ?**

(*a*) P-type (*b*) N-type
(*c*) Intrinsic semiconductor
(*d*) None of these.

Ans. (*b*)

As the majority carriers are electrons.

(ii) **The biasing, shown in the diagram, is**

(*a*) Forward bias (*b*) Reverse bias
(*c*) Both A and B (*d*) No biasing.

Ans. (*b*)

N-type is connected to the negative and P-type to the positive.

(iii) **When a forward bias is applied to a p-n junction, it**

(*a*) raises the potential barrier
(*b*) reduces the majority carrier current to zero
(*c*) lowers the potential barrier
(*d*) None of these.

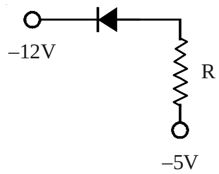
Ans. (*c*)

The forward bias opposes the potential barrier.

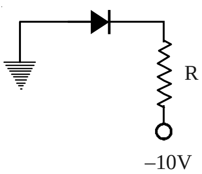
Or

In which of the following figures, the pn diode is reverse biased ?

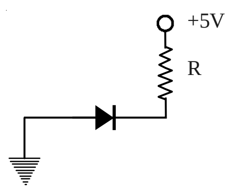
(*a*)



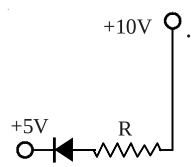
(*b*)



(*c*)



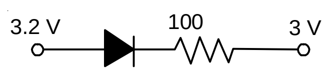
(*d*)



Ans. (*c*)

P-type is connected to a lower potential.

(iv) **What is the current through the ideal diode shown in the figure ?**



(*a*) 2 mA (*b*) 2 A
(*c*) 3 mA (*d*) 3.2 mA.

Ans. (*a*)

$$I = \frac{(3.2-3)}{100} = 2 \times 10^{-3} \text{ A.}$$

SECTION – E

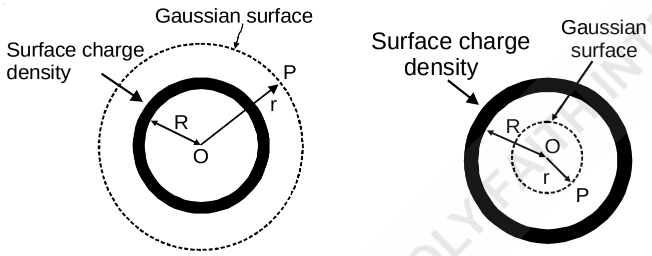
Q. 31. Using Gauss's law, obtain expressions for the electric field (*i*) inside, and (*ii*) outside a positively charged spherical shell.

(*b*) Show graphically variation of the electric field as a function of the distance r from the centre of the sphere.

(*c*) A square plane sheet of side 10 cm is inclined at an angle of 30° with the direction of a uniform electric field of 200 NC^{-1}. Calculate the electric flux passing through the sheet.

Ans. Case 1. At a point outside the spherical shell

In order to find the electric field at a point P outside the shell let us consider a Gaussian surface in the form of a sphere of radius *r* (*r* >> R) .



(*a*) (*b*)

By symmetry we find that the electric field acts radically outwards and has a normal component at all points on the Gaussian sphere. Therefore by definition of electric flux we have

ϕ = E × A where A is the surface area of the Gaussian sphere therefore

$\phi = E \times 4\pi r^2$ ...(1)

But by Gauss's law

$$\phi = \frac{Q}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0} = \frac{\sigma \times 4\pi R^2}{\varepsilon_0} \quad ...(2)$$

from equations 1 and 2 it follows that

$$E \times 4\pi r^2 = \frac{Q}{\varepsilon_0} \text{ or } E \times 4\pi r^2 = \frac{\sigma \times 4\pi R^2}{\varepsilon_0} \quad ...(3)$$

$$\text{or } E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \text{ and } E = \frac{\sigma R^2}{\varepsilon_0 r^2} \quad ...(4)$$

It follows from equation 4 that the electric field due to a spherical shell outside it is same as that due to a point charge. Therefore for points lying outside the spherical shell the shell behaves as if the entire charge is concentrated at the centre.

CASE 2: At a point on the spherical shell

In this case the Gaussian surface will have the same radius as that of the shell. Therefore R can replace *r* in equation 4.

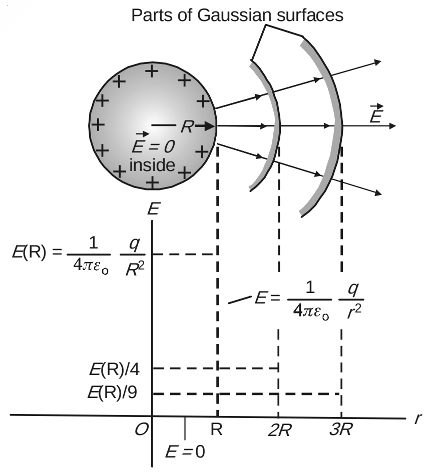
$$\text{Hence } E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2} \text{ and } E = \frac{\sigma}{\varepsilon_0}$$

CASE 3: At a point inside the spherical shell

In this case the Gaussian surface drawn inside the shell does not enclose any charge hence

$$E \times 4\pi r^2 = \frac{\theta}{\varepsilon_0} \text{ or } \mathbf{E = 0}$$

(*b*)



(*c*) Given

r = 10 cm = 0.1m

Electric field 'E' = 200 N C^{-1}

The angle between the sheet and electric field 30°

The angle between the electric field and normal to the plane sheet *q* = 90 – 30 = 60°

Electric flux ϕ = EA cos θ

$\phi = 200 \times (0.1)^2 \times \cos 60° = 1 \text{ N m}^2 \text{ C}^{-1}$

Or

(*i*) Obtain an expression for the potential energy of an electric dipole placed in a uniform electric field.

(ii) Three capacitors of capacitance C_1, C_2 and C_3 are connected in series to a source of V volt. Show that the total energy stored in the combination, of capacitors is equal to sum of the energy stored in individual capacitors.

(iii) A capacitor of capacitance C is connected across a battery. After charging the battery is disconnected and the separation between the plates is doubled. How will (i) the capacitance of the capacitor, and (ii) and electric field between the plates be affected ? Justify your answer.

Ans. (i) The torque acting on the dipole in a uniform electric field tends to align it in the direction of the electric field. If the dipole is moved against this torque, work will have to be done. This work is stored in the dipole as its potential energy. If q is the angle between the dipole moment and the electric field, then the torque acting on the dipole is given by

$$r = p\text{E} \sin\theta \qquad .....(1)$$

Suppose the dipole is rotated through an infinitesimally small angle $d\theta$ against the torque then the small work done is

$$d\text{W} = r\, d\theta = p\text{E} \sin\theta\, d\theta \qquad ......(2)$$

The net work done in rotating the dipole from its initial position θ_1 to its final position θ_2 is given by

$$\text{W} = \int_{\theta_1}^{\theta_2} p\text{E}\sin\theta\, d\theta = p\text{E}\,|-\cos\theta|_{\theta_1}^{\theta_2}$$

or $$\text{W} = p\text{E}\,(\cos\theta_1 - \cos\theta_2) \qquad .....(3)$$

This work done is stored in the dipole in the form of its potential energy. Hence

$$\text{U} = p\text{E}\,(\cos\theta_1 - \cos\theta_2) \qquad .....(4)$$

(ii) Suppose three capacitors of capacitances C_1, C_2 and C_3 are connected in series, then

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Since in series the charge on each capacitor is same therefore the energy stored in the parallel combination is

$$U = \frac{1}{2}\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)Q^2$$

$$= \frac{1}{2}\frac{Q^2}{C_1} + \frac{1}{2}\frac{Q^2}{C_2} + \frac{1}{2}\frac{Q^2}{C_3}$$

or $$U = U_1 + U_2 + U_3$$

(iii) (a) The capacitance of a capacitor is given by

$$C = \frac{\varepsilon_0 A}{d}$$

As d is doubled, therefore the capacitance will become half.

(b) The electric field is given by the expression $E = \dfrac{\sigma}{\varepsilon_0} = \dfrac{q}{\varepsilon_0 A}$. This remains same as there is no change in charge and area of the plates.

Q. 32. (a) Why do the free electrons', in a metal wire, flowing by themselves', not cause any current flow in the wire ? Define 'drift velocity' and obtain an expression for the current flowing in a wire, in terms of the drift velocity' of the free electrons.

(b) Use the above expression to show that the resistivity', of the material of a wire is inversely proportional to the relaxation time' for the free electrons in the metal.

Ans. (a) The free electrons, in a metal, (flowing by themselves), have random distribution of their velocities. Hence the net charge crossing any cross section, in a unit time, is zero.

The 'drift velocity 'equals the average (time dependent) velocity acquired by free electrons, under the action of an applied (external) electric field. We have, for an applied electric field

$$\vec{a} = \frac{F}{m} = -\frac{e\vec{E}}{m}$$

Therefore

$$\vec{v}_d = -\left(\frac{e\vec{E}}{m}\right)\tau$$

Where τ is the average relaxation time.

(*b*) Let n be the electrons per unit volume in the conductor. Here n is called the number density of electrons. Assume that all electrons move with the same drift velocity v_d. In a time interval dt, each electron moves a distance $v_d dt$. Now the volume of the cylinder covered by the electrons in time dt is

$$V = A\, v_d dt \quad .....(1)$$

and the number of electrons in this volume are $N = nV = nA\, v_d dt$ .....(2)

If e is the charge on the electron, then charge flowing through the conductor in small time dt is

$$dQ = e\,(nA\, v_d dt) \quad ......(3)$$

hence the current through the conductor is

$$I = \frac{dQ}{dt} = nAev_d$$

Because of the drift, we can write

$$\text{Or } I = enA\left(\frac{eE\tau}{m}\right) = \frac{ne^2AE\tau}{m}$$

But I = JA hence

$$JA = \frac{ne^2AE\tau}{m} \Rightarrow J = \frac{ne^2E\tau}{m}$$

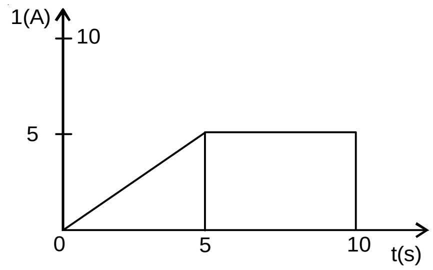
$$\text{But } J = \sigma E = \frac{E}{\rho}$$

$$\text{Hence } \frac{E}{\rho} = \frac{ne^2E\tau}{m} \Rightarrow \sigma = \frac{m}{ne^2\tau}$$

Or

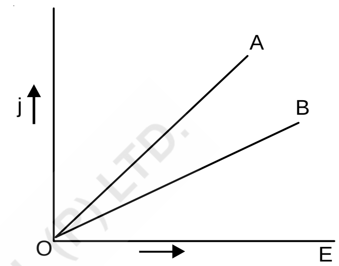
(*a*) Plot a graph showing the variation of current density (*i*) versus the electric field (E) for two conductors of different materials. What information from this plot regarding the properties of the conducting material, can be obtained which can be used to select suitable materials for use in making (*i*) standard resistance and (ii) connecting wires in electric circuits ?

(*b*) Figure shows a plot of current 'I' flowing through the cross-section of a wire versus the time 't'. Use the plot to find the charge flowing in 10s through the wire.



Ans. (*a*) We know that $J = \sigma E$

Therefore the graph between J and E will be a straight line passing through the origin. This is as shown



The slope of the graph = conductivity (σ)

Hence material with less slope (smaller conductivity) is used for making standard resistors and material with greater slope (higher conductivity) for making connecting wires.

(*b*) The area under the I-t curve gives the value of charge

$$Q = \frac{1}{2} \times 5 \times 5 + (10 - 5) \times 5$$

$$= 12.5 + 25 = 37.5 \text{ C}$$

Q. 33. (*a*) Define a wavefront. How is it different from a ray?

(*b*) Depict the shape of a wavefront in each of the following cases.

(*i*) Light diverging from a point source.

(*ii*) Light emerging out of a convex lens when a point source is placed at its focus.

(*iii*)Using Huygen's construction of secondary wavelets, draw a diagram showing the passage of a plane wavefront from a denser into a rarer medium.

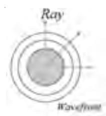
OR

(*a*) Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses.

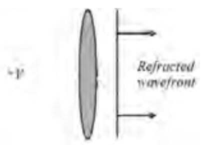
(*b*) A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is 3/4th of the angle of prism. Calculate the speed of light in the prism.

Ans. (*a*) A wave front is defined as the locus of all adjacent points at which the phase of vibration of a physical quantity associated with the wave is the same. It is in two dimension while a ray is in one dimension.

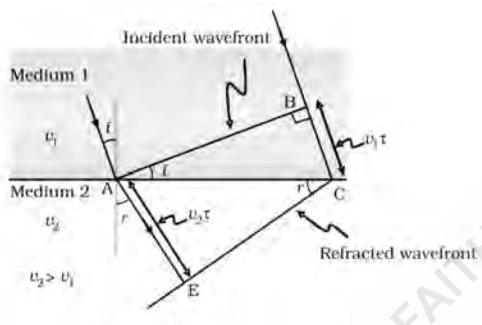
(*b*) (*i*)



(*ii*)

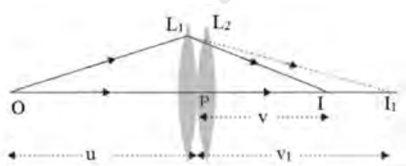


The diagram is as shown



OR

(*a*) Consider two lenses A and B of focal length f_1 and f_2 placed in contact with each other. Let the object be placed at a point O beyond the focus of the first lens L_1 as shown.



The first lens L_1 produces an image at I_1. Since image I_1 is real, it serves as a virtual object for the second lens L_2, producing the final image at I. Since the lenses are thin, we assume the optical centres of the lenses to be coincident. Let this central point be denoted by P.

For the image formed by the first lens L_1, we get

$$\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1} \quad ...(i)$$

For the image formed by the second lens L_2, we get

$$\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2} \quad ...(ii)$$

Adding equations (i) and (ii) we have

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

If the two lens-system is regarded as equivalent to a single lens of focal length f, we have

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

Therefore form equations (iii) and (iv) we get

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \text{ or } P = P_1 + P_2$$

(b) Given A = 60^0, i = ¾ × 60=45^0 c = 3×10^8 m s^{-1},
Now $?_m$ = 2i – A = 90 – 60 = 30^0
Using the formula

$$\mu = \frac{c}{v} = \frac{\sin\left[\frac{A + \delta_m}{2}\right]}{\sin\left(\frac{A}{2}\right)}$$ we have

$$\frac{c}{v} = \frac{\sin 45}{\sin 30} \text{ or}$$

$$v = 3 \times 10^8 \times \frac{\sin 30}{\sin 45} = 2.12 \times 10^8 \text{ ms}^{-1}$$

Holy Faith New Style Sample Paper—2

(Based on the Latest Design & Syllabus issued by C.B.S.E.)

CLASS – 12th

PHYSICS (Theory)

Time allowed : 3 hours **Maximum Marks : 70**

General Instructions : Same as in MTP – 1

SECTION – A

Q. 1. Each of the two-point charges is doubled and the distance between them is halved. Now the force of interaction between them becomes n times, where *n* is :

(*a*) 4 (*b*) 1 (*c*) 18 (*d*) 16.

Ans. (*d*) 16.

Q. 2. If a unit positive charge is taken from one point to another over an equipotential surface, then :

(*a*) work is done on the charge.
(*b*) work is done by the charge.
(*c*) work done is constant.
(*d*) no work is done.

Ans. (*d*) no work is done.

Q. 3. The temperature (T) dependence of resistivity of materials A and material B is represented by fig (*i*) and fig (*ii*) respectively. Material A and material B are :

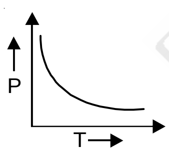


Fig. (*i*)

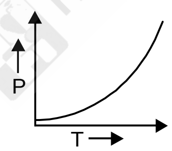


Fig. (*ii*)

(*a*) material A is copper and material B is germanium
(*b*) material A is germanium and material B is copper
(*c*) material A is nichrome and material B is germanium
(*d*) material A is copper and material B is nichrome

Ans. (*b*) material A is germanium and material B is copper

Q. 4. An electron is projected with uniform velocity along the axis of a current carrying long solenoid. Which of the following is true ?

(*a*) The electron will be accelerated along the axis.
(*b*) The electron path will be circular about the axis.
(*c*) The electron will experience a force at 45° to the axis and hence execute a helical path.
(*d*) The electron will continue to move with uniform velocity along the axis of the solenoid.

Ans. (*d*) The electron will continue to move with uniform velocity along the axis of the solenoid.

Q. 5. A moving coil galvanometer can be converted into an ammeter by :

(*a*) introducing a resistance of large value in series.
(*b*) introducing a resistance of small value in parallel.
(*c*) introducing a resistance of small value in series
(*d*) introducing a resistance of large value in parallel.

Ans. (*b*) introducing a resistance of small value in parallel.

Q. 6. If the magnetizing field on a ferro-magnetic material is increased, its permeability :

(*a*) decreases (*b*) increases
(*c*) remains unchanged
(*d*) first decreases and then increases

Ans. (*a*) decreases

Q. 7. An electrical element X when connected to an alternating voltage source has current through it leading the voltage by $\frac{\pi}{2}$ radian. Element X is :

(*a*) Capacitor (*b*) Resistor
(*c*) Inductor
(*d*) Series LR circuit.

Ans. (*a*) Capacitor.

Q. 8. During the propagation of electro-magnetic waves in a medium

(*a*) Electric energy density is double of the magnetic energy density.
(*b*) Electric energy density is half of the magnetic energy density.
(*c*) Electric energy density is equal to the magnetic energy density.
(*d*) Both electric and magnetic energy densities are zero.

Ans. (*c*) Electric energy density is equal to the magnetic energy density.

Q. 9. Which of the following statement is correct ?

(*a*) The induced EMF is not the direction opposing the change in magnetic flux so as to oppose the cause which produces it
(*b*) Relative motion between coil and magnet produces change in magnetic flux.
(*c*) Emf is induced only if the magnet is moved toward the coil
(*d*) Emf is induced only if the coil is moved toward the coil

Ans. (*b*) Relative motion between coil and magnet produces change in magnetic flux.

Q. 10. A convex lens of focal length 40 cm is in contact with a concave lens of focal length 25 cm. The power of the combination is :

(*a*) – 1.5 D (*b*) – 6.5 D
(*c*) + 6.5 D (*d*) + 6.67 D

Ans. (*a*) – 1.5 D.

Q. 11. The maximum kinetic energy of the photoelectrons depends only on :

(*a*) potential (*b*) frequency
(*c*) incident angle (*d*) intensity

Ans. (*b*) frequency.

Q. 12. The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. The radius of the n = 3 orbit is :

(*a*) 1.01×10^{-10} m (*b*) 1.59×10^{-10} m
(*c*) 2.12×10^{-10} m (*d*) 4.77×10^{-10} m

Ans. (*d*) 4.77×10^{-10} m

Questions number 13 to 16 are Assertion (A) and Reason (R) type questions.

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (*a*), (*b*), (*c*) and (*d*) as given below.

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

Q. 13. Assertion (A) : Silicon is preferred over germanium for making semiconductor devices.

Reason (R) : The energy gap in germanium is more than the energy gap in silicon.

Ans. (*c*) (A) is true but (R) is false

Q. 14. Assertion (A) : No interference pattern is detected when two coherent sources are infinitely close to each other.

Reason (R) : The fringe width is inversely proportional to the distance between the two sources.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

Q. 15. Assertion (A) : The photoelectrons produced by a monochromatic light beam incident on a metal surface have a spread in their kinetic energies.

Reason (R) : The work function of the metal is its characteristics property.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

Q. 16. Assertion : When a current flows in the coil of a transformer, then its core becomes hot.

Reason : The core of a transformer is made of iron.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

SECTION – B

Q. 17. An e.m. wave is travelling in a medium with a velocity = $v\hat{i}$. The electric field oscillations, of this e.m. wave, are along the y-axis.

(*a*) Identify the direction in which the magnetic field oscillations are taking place, of the e.m. wave.

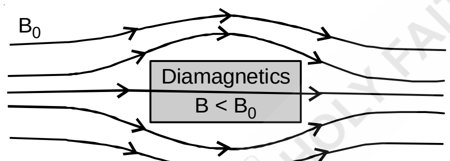
(*b*) How are the magnitudes of the electric and magnetic fields in the electromagnetic wave related to each other ?

Ans. (*a*) The magnetic field oscillations are taking place along the Z-axis.

(*b*) $c = \dfrac{E_0}{B_0}$.

Q. 18. The susceptibility of a magnetic material is –0.085. Identify the magnetic type of the material. A specimen of this material is kept in a non-uniform magnetic field. Draw the modified field pattern.

Ans. The material is a diamagnetic material as diamagnetic materials have negative susceptibility. The modified field pattern is as shown below.



Q. 19. In the Geiger-Marsden experiment, an α-particle of 5.12 MeV energy approaches a gold target (Z = 79), comes momentarily to rest and then reverses its direction. Find the distance of closest approach of a-particle to the target nucleus.

Ans. The equation of distance of closest approach is

$$r_0 = \frac{2kZe^2}{E_k} = \frac{1}{4\pi\varepsilon_0} \times \frac{2Ze^2}{E_K}$$

$$r_0 = 9 \times 10^9 \times \frac{2 \times 79 \times (1.6 \times 10^{-19})^2}{5.12 \times 1.6 \times 10^{-13}}$$

$$= 4.44 \times 10^{-14} \text{ m.}$$

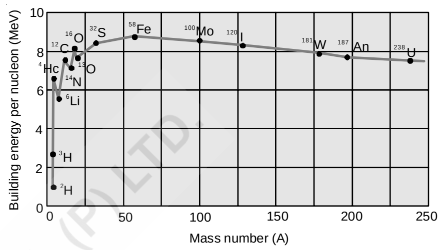
(*i*) It shows that the nuclear force is a saturated force.

(*ii*) It shows that for distances larger than 0.8 fm the force is attractive and is repulsive if the distance is less than this.

Or

Draw the plot of the binding energy per nucleon as a function of mass number for different nuclei. The nuclei lying at the middle flat portion of the curve are more stable. Explain.

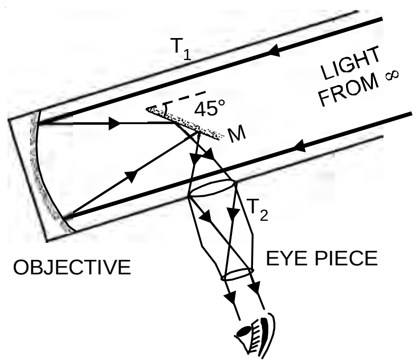
Ans. The plot is an shown below.



It is because their binding energy per nucleon is high and almost constant.

Q. 20. Draw a labelled ray diagram of a reflecting telescope. Mention its two advantages over the refracting telescope.

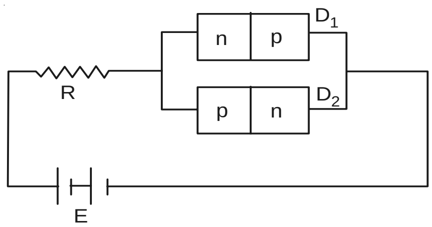
Ans. The ray diagram is as shown.



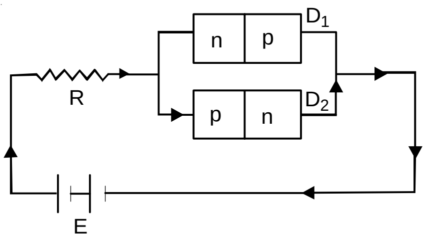
(*a*) Less chromatic aberration in a mirror.

(*b*) A mirror can be made which has a much larger size than a lens, thus high resolving power and light gathering power.

Q. 21. In the circuit diagram shown below two p-n junction diodes D_1 and D_2 are connected with a resistance R and a dc battery E as shown. Redraw the diagram and indicate the direction of flow of appreciable current in the circuit. Justify your answer.



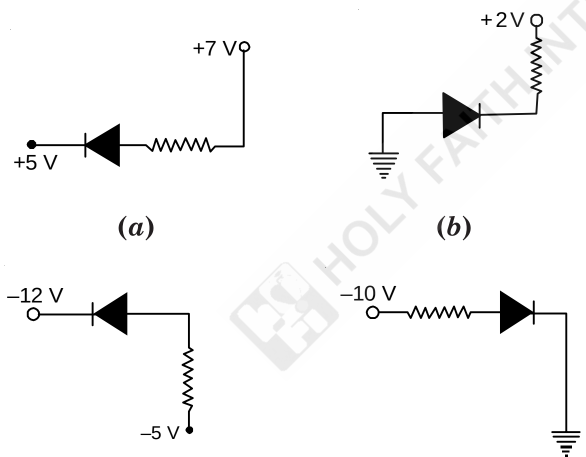
Ans. The redrawn diagram showing the flow of appreciable current is as shown below.



Here diode D_2 is forward biased hence it conducts. Therefore, an appreciable current will pass through it. However, diode D_1 is reverse biased, hence negligible current will flow through it.

OR

In the following diagrams, indicate which of the diodes are forward biased and which are reverse biased.

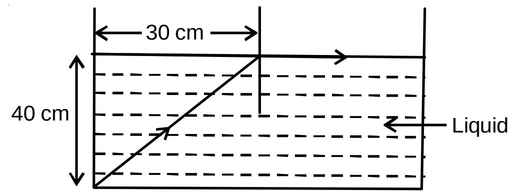


(*a*) (*b*) (*c*) (*d*)

Ans. (*a*) Forward biased. (*b*) Reverse biased
(*c*) Forward biased. (*d*) Reverse biased.

SECTION – C

Q. 22. (*i*) Define refracive index of a medium.
(*ii*) In the following ray diagram, calculate the speed of light in the liquid of unknown refractive index.

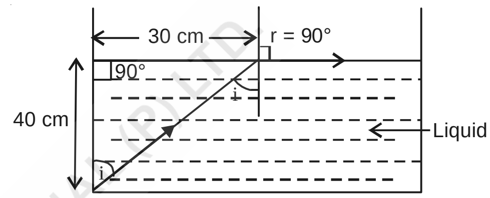


Ans. (*i*) It is defined as the ratio of speed of lightin vacuum to the speed of light in the given medium.

(*ii*) The speed of light can be found by using the formula

$$\frac{v}{c} = \frac{\sin i}{\sin r} \text{ or } v = \frac{\sin i}{\sin r} \times c$$

From the diagram we find that



$$\sin i = \frac{30}{\sqrt{(30)^2 + (40)^2}} = \frac{3}{5} \text{ and } r = 90°$$

Therefore we have

$$v = \frac{3/5}{1} \times 3 \times 10^8 = 1.8 \times 10^8 \text{ m s}^{-1}$$

Q. 23. A hollow conducting sphere of inner radius r_1 and outer radius r_2 has a charge Q on its surface. A point charge -*q* is also placed at the centre of the sphere. (*a*) What is the surface charge density on the (*i*) inner and (*ii*) outer surface of the sphere ?

Ans. The – q charge will induce a charge + q on the inner surface and – q on the outer surface of the sphere. Therefore total charge on the inner surface is + q

Now surface charge density on the inner surface is

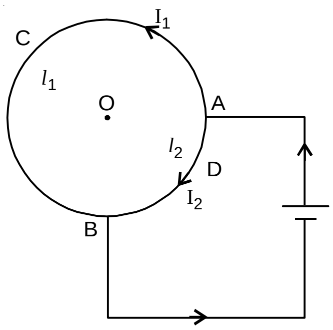
$$\sigma_i = \frac{\text{Total charge on inner surface}}{\text{Area of inner surface}} = \frac{+q}{4\pi r_1^2}$$

A charge – q is induced on the outer surface, therefore net charge on the outer surface is (Q – q)

Now surface charge density on the outer surface is

$$\sigma_0 = \frac{\text{Total charge on inner surface}}{\text{Area of inner surface}} = \frac{Q-q}{4\pi r_2^2}$$

Q. 24. The figure shows a circular loop connected to a battery. The arc ACB of length l_1 carries a current I_1 and arc ADB of length l_2 carries a current I_2. Show that the net magnetic field at the centre of the loop is zero.



Ans. Let resistance of the part ACB be R_1 and that of part ADB be R_2. Since these are connected in parallel, therefore we have

$I_1R_1 = I_2R_2$

Or $\frac{I_1\rho I_1}{A} = \frac{I_2\rho I_2}{A}$

Or $I_1 l_1 = I_2 l_2$

Now the magnetic field at the centre of an arc of length is $B = \frac{\mu_0 I}{2r}\frac{\theta}{2\pi}$

Hence $B_1 = \frac{\mu_0 I_1}{2r}\frac{I_1}{2\pi r} = \frac{\mu_0 I_1 I_1}{4\pi r^2}$

and $B_2 = \frac{\mu_0 I_2}{2r}\frac{I_2}{2\pi r} = \frac{\mu_0 I_2 I_2}{4\pi r^2}$

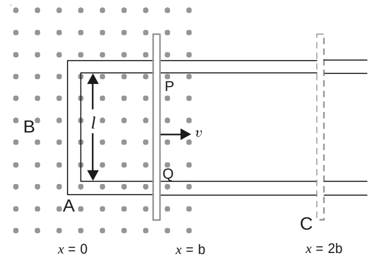
and $B_2 = \frac{\mu_0 I_2}{2r}\frac{I_0}{2\pi r} = \frac{\mu_0 I_2 I_2}{4\pi r^2}$

From the above expression we have $B_1 = B_2$

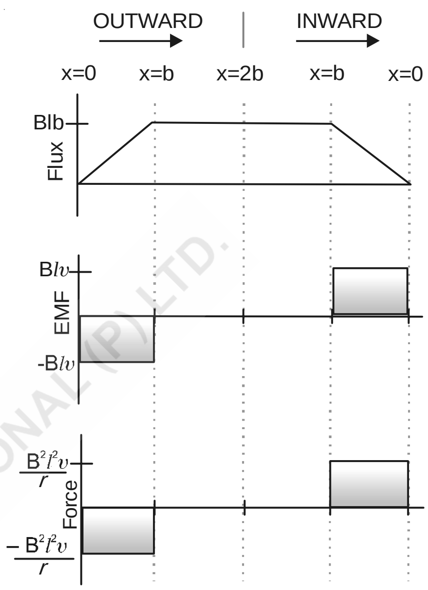
By right hand thumb rule the two fields are oppositely directed hence they will cancel out.

Thus, $B_1 + B_2 = 0$

Q. 25. Sketch the change in flux, emf and force when a conducting rod PQ of resistance R and length *l* moves freely to and fro between A and C with speed v on a rectangular conductor placed in uniform magnetic field as shown in the figure.



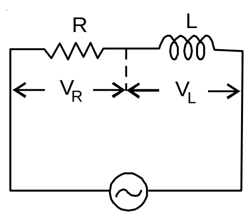
Ans. The sketch is as shown below.



Q. 26. (*a*) An ac circuit as shown in the figure has an inductor of inductance L and a resistor of resistance R connected in series. Using the phasor diagram, explain why the voltage in the circuit will lead the current in phase.

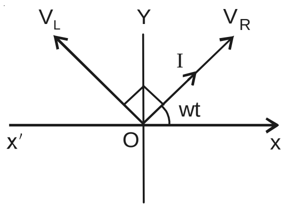
(*b*) The potential difference across the resistor is 160 V and that across the inductor is 120 V. Find the effective value of the applied voltage. If the effective current in the circuit be 1.0 A, calculate the total impedance of the circuit.

(c) What will be the potential difference in the circuit when direct current is passed through the circuit ?



$\varepsilon = \varepsilon_0 \sin \omega t$

Ans. (*a*) When ac passes through a resistor voltage and current are in phase. When ac flows through an inductor voltage leads current by a phase angle of $\pi/2$. The phasor diagram is as shown.



Or

Hence resultant voltage in the circuit will lead V_R and therefore the current in the circuit.

(*b*) Let V be the effective potential difference across L-R circuit, therefore

$$V = \sqrt{V_R^2 + V_L^2} = \sqrt{(160)^2 + (120)^2}$$

$= 200$ V

Therefore impedance of the circuit

$$Z = \frac{V}{I} = \frac{200}{I} = 200\Omega$$

For *dc* $V_L = 0$, therefore

Potential difference in the circuit V_R = potential difference across resistor = 160 V

OR

An ac circuit consists of a series combination of circuit elements X and Y. The current is ahead of the voltage in phase by $\pi/4$. If element X is a pure resistor of 100 Ω,

(*a*) name the circuit element Y.

(*b*) calculate the rms value of current, if rms value of voltage is 141 V.

(c) What will happen if the ac source is replaced by a dc source ?

Ans. Y is a capacitor.

Phase angle $\pi/4$, also $\cos\phi = \frac{R}{Z}$

$$\Rightarrow \quad Z = \frac{R}{\cos\phi} = \frac{R}{\cos(\pi/4)} = \frac{100}{1/\sqrt{2}}$$

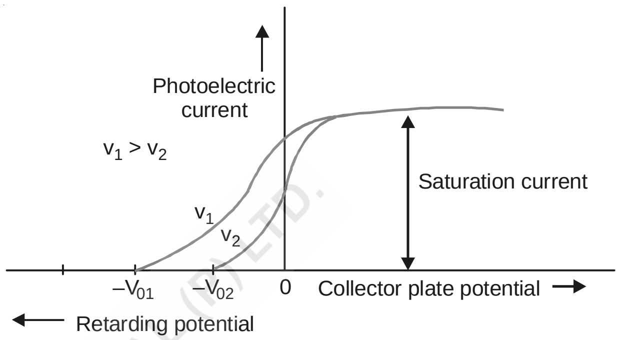
$$I_{rms} = \frac{V_{rms}}{Z} = \frac{141}{141.4} \cong 1A$$

The current becomes zero.

Q. 27. (*a*) Draw a graph showing the variation of photoelectric current with collector plate potential for two different frequencies ($v_1 > v_2$) of the incident radiation.

(*b*) Write Einstein's photoelectric equation. Explain two features of photoelectric effect which cannot be explained by wave theory of light.

Ans. (*a*) The graph is as shown.



(*b*) Einstein's photoelectric equation is

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

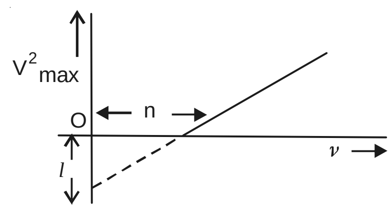
Two Factors:

(*i*) Maximum KE of emitted photoelectrons is independent of the intensity of incident radiation

(*ii*) There is a threshold frequency below which photo electrons are not emitted.

Or

Light of frequency v is incident on a photosensitive surface. A graph of the square of the maximum speed of the electrons (V^2_{max}) vs. v is obtained as shown in the figure. Using Einstein's photo-electric equation, obtain expressions for (*i*) Planck' s constant (*ii*) work function of the given photosensitive material in terms of parameters *l*, n and mass of the electron m.



Ans. Einstein's photoelectric equation

$$E_{max} = \frac{1}{2}mv^2_{max} = h(\nu - \nu_0)$$

Or $v^2_{max} = \left(\frac{2h}{m}\right)\nu - \frac{2\phi_0}{m}$

Thus the graph is a straight line.

Clearly

(i) slope of graph = $\frac{2h}{m} = \frac{1}{n} \Rightarrow h = \frac{ml}{2n}$

Intercept on the v^2_{max} axis is $\frac{2\phi_0}{m} = l$

$\Rightarrow \phi_0 = \frac{ml}{2}$

Q. 28. Find the frequency of light that ejects electrons from a metal surface, fully stopped by a retarding potential of 3.3 V. If photoelectric emission begins in this metal at a frequency of 8 × 10^14 Hz, calculate the work function (in eV) for this metal.

Ans. Work function is given by $w_0 = h\nu_0$

$$\omega_0 = \frac{6.63\times10^{-34}\times8\times10^{14}}{1.6\times10^{-19}} = \mathbf{3.315\ eV}$$

Now using the expression

$eV_0 = h\nu - w_0$

We have

$$\nu = \frac{eV_0+\omega_0}{h} = \frac{(3.3+3.315)\times1.6\times10^{-19}}{6.63\times10^{-34}}$$

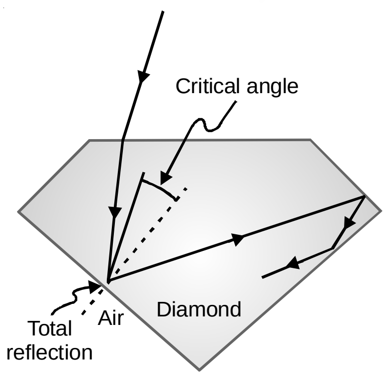
$\nu = 1.596 \times 10^{15}$ Hz

SECTION – D

Questions number 24 to 30 are case study based questions.

Read the following paragraphs and answer the questions.

Q. 29.



The total internal reflection of the light is used in polishing diamonds to create a sparking brilliance. By polishing the diamond with specific cuts, it is adjusted the most of the light rays approaching the surface are incident with an angle of incidence more than critical angle. Hence, they suffer multiple reflections and ultimately come out of diamond from the top. This gives the diamond a sparking brilliance.

(i) Light cannot easily escape a diamond without multiple internal reflections. This is because :

(a) Its critical angle with reference to air is too large

(b) Its critical angle with reference to air is too small

(c) The diamond is transparent

(d) Rays always enter at angle greater than critical angle.

Ans. (b) A diamond cannot easily allow light to escape, as its critical angle with respect to air is very small. This allows for multiple total internal reflections.

(ii) The critical angle for a diamond is 24.4°. Then its refractive index is :

(a) 2.42 (b) 0.413

(c) 1 (d) 1.413.

Ans. (a)

$$n = \frac{1}{\sin i_C} = \frac{1}{\sin 24.4°} = \frac{1}{0.413} = 2.42$$

(iii) The basic reason for the extraordinary sparkle of suitably cut diamond is that

(a) It has low refractive index

(b) It has high transparency

(c) It has high refractive index is very hard

(d) It is very hard.

Ans. (c)

(iv) A diamond is immersed in a liquid with a refractive index greater than water. Then the critical angle for total internal reflection will :

(a) will depend on the nature of the liquid

(b) decrease

(c) remains the same

(d) increase.

Ans. (d)

This is because the effective refractive index of diamond decreases.

Or

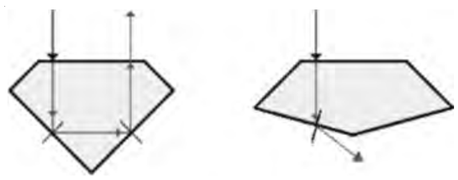
A diamond is immersed in a liquid with a refractive index greater than water. What happens to the critical angle for total internal reflection ?

Ans. (*d*)

$$n = \frac{1}{\sin i_C} \Rightarrow \sin i_C = \frac{1}{n}$$

Or

The following diagram shows same diamond cut in two different shapes.



The brilliance of diamond in the second dimond will be :

(*a*) less than the first (*b*) greater than first

(*c*) same as first

(*d*) will depend on the intensity of light.

Ans. (*a*)

Q. 30. Read the following paragraph and answer the questions

LED is a heavily doped P-N junction which under forward bias emits spontaneous radiation. When it is forward biased, due to recombination of holes and electrons at the junction, energy is released in the form of photons. In the case of Si and Ge diode, the energy released in recombination lies in the infrared region. LEDs that can emit red, yellow, orange, green and blue light are commercially available. The semi-conductor used for fabrication of visible LEDs must at least have a band gap of 1.8 eV. The compound semiconductor Gallium Arsenide –Phosphide is used for making LEDs of different colours.

(*i*) A light-emitting diode (LED) converts

(*a*) optical signal into thermal energy

(*b*) thermal energy into electrical signal

(*c*) electrical current into optical signal

(*d*) sound energy into optical signal.

Ans. (*c*)

It converts electrical energy into light energy.

(*ii*) The colour of the emitted light from the P-N junction made of GaAsP is :

(*a*) red or yellow (*b*) far infrared

(*c*) near infrared (*d*) ultraviolet.

Ans. (*a*)

(*iii*) Which of the following statements about LED is INCORRECT ?

(*a*) It needs small power for operation

(*b*) It emits light

(*c*) It uses materials like gallium and arsenide

(*d*) It uses materials like silicon and germanium.

Ans. (*d*)

(*iv*) The basic material for fabrication of an LED is :

(*a*) gallium arsenide

(*b*) gallium arsenide phosphide

(*c*) indium antimonide

(*d*) indium antimonide phosphide.

Ans. (*b*)

Or

The energy gap for an LED should be

(*a*) 1 eV (*b*) 0.7 eV

(*c*) 1.8 eV (*d*) 2 eV.

Ans. (*c*)

SECTION – E

Q. 31. (*i*) (A) Why does the electric field inside a dielectric slab decrease when kept in an external electric field ?

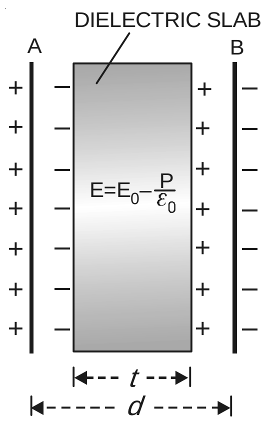
(B) Derive an expression for the capacitance of a parallel plate capacitor filled with a medium of dielectric constant K.

(*ii*) A charge q = 2 mC is placed at the centre of a sphere of radius 20 cm. What is the amount of work done in moving 4 mC from one point to another point on its surface ?

(*iii*) Write a relation for polarisation $\vec{P}$ of a dielectric in the presence of an external electric field.

Ans. (*i*) (A) A dielectric material gets polarized when it placed in an electric field. The field produced due to the polarization of material minimizes the effect of external field. Hence, the electric field inside a dielectric decreases when it is placed in an external electric field.

(B) Suppose that when the capacitor is connected to a battery, electric field of strength E_0 is produced between the two plates of the capacitor. Further, suppose that when dielectric slab of thickness t ($t < d$) is introduced between the two plates of the capacitor as shown in figure, the electric field reduces to E due to polarisation of the dielectric.



Therefore between the two plates of the capacitor; over a distance t, the strength of the electric field is E and over the remaining distance (d-t) the strength is E_0. If V is the potential between the plates of the capacitor, then

$$V = Et + E_0 (d - t) \quad ...(1)$$

Since $E = E_0/K$ where K is the dielectric constant, therefore the above equation becomes

$$V = \frac{E_0}{K}t + E_0 (d - t) = E_0\left(d - t + \frac{t}{K}\right) \quad ...(2)$$

The electric field between the plates of the capacitor is given by

$$E_0 = \sigma / e_0 = Q/ A\, e_0 \quad ...(3)$$

Hence the potential between the two plates becomes

$$V = E_0\left(d - t + \frac{t}{K}\right) = \frac{Q}{\varepsilon_0 A}\left(d - t + \frac{t}{K}\right) \quad ...(4)$$

Hence the capacitance of the parallel plate capacitor is given by

$$C = \frac{Q}{V} = \frac{Q}{\frac{Q}{\varepsilon_0 A}\left(d - t + \frac{t}{K}\right)} = \frac{\varepsilon_0 A}{d - t(1 - 1/K)}$$

When $t = d$ then we have

$$C = \frac{K\varepsilon_0 A}{d}$$

(*ii*) The surface of the sphere is an equipotential surface, therefore the work done will be zero.

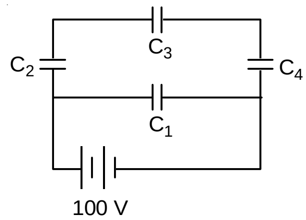
(*iii*) $\vec{P} = \chi_e \vec{E}$

Or

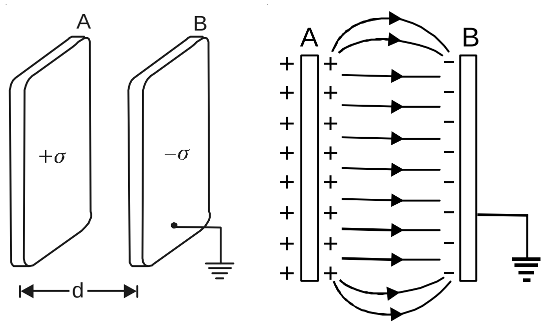
(*a*) Consider a system of two parallel metal plates of area 'A', each placed at a separation 'd' in air. Derive the expression for the capacitance of this parallel plate capacitor.

(*b*) If the two plates of the capacitor have + q and -q charges, respectively, find the force experienced by the negative plate due to the positive plate.

(*c*) A network of four capacitors each of capacitance 12 mF is connected to a battery as shown in the figure. Find the total charge stored in the network.



Ans. (*a*) Suppose Q is the charge on the capacitor, and is the uniform surface charge density on each plate as shown in figure. Therefore by Gauss's theorem the electric field between the plates of the capacitor (neglecting fringing of electric field at the edges) is given by



(*a*) (*b*)

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A} \qquad ...(1)$$

The field is uniform, and the distance between the plates is d, so the potential difference between the two plates is

$$V = Ed = \frac{1}{\varepsilon_0}\frac{Qd}{A} \qquad ...(2)$$

Therefore by the definition of capacitance we have

$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d} \qquad ...(3)$$

This gives the capacitance of a parallel plate capacitor with vacuum between plates.

(*b*) In a capacitor as the plates carry equal and opposite charges, there exists a force of attraction between the plates. To calculate this force we use the fact that the electric field is conservative and in a conservative field $F = -\frac{dU}{dx}$. In the case of a parallel plate capacitor

$$U = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}\frac{q^2 x}{\varepsilon_0 A} \text{ since } C = \frac{\varepsilon_0 A}{x}$$

Therefore $F = -\frac{d}{dx}\left(\frac{1}{2}\frac{Q^2}{\varepsilon_0 A}x\right) = -\frac{1}{2}\frac{Q^2}{\varepsilon_0 A}$

$= -\frac{1}{2}QE$ where $\frac{Q}{\varepsilon_0 A} = \frac{\sigma}{\varepsilon_0} = E$ the electric field between the plates of the capacitor. The negative sign shows the attractive nature of the force.

(c) Capacitors C_2, C_3 and C_4 are in series, hence net capacitance is

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{12} + \frac{1}{12} + \frac{1}{12} = \frac{1}{4}$$

Therefore $C_S = 4\ m$F

Now this is in parallel with the capacitor C_1, hence net capacitance

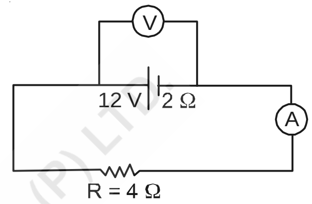
$C_P = C_S + C_1 = 4 + 12 = 16$ mF

Hence total charge stored in the network

$Q = CV = 16 \times 10^{-6} \times 100 = 16 \times 10^{-4}$ C

Q. 32. (*a*) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change ?

(*b*) 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 12 V having an internal resistance of 2 W. Calculate the voltmeter and ammeter readings.



Ans. (*a*) The heat produce across a resistor is given by $H = \frac{V^2}{R}t$

$H_1 = H$, $H_2 = 9H$, $V_1 = V$, $V_2 = ?$

$$\frac{H_2}{H_1} = \frac{V_2^2}{V_1^2} \text{ or } \frac{V_2}{V_1} = \sqrt{\frac{H_2}{H_1}} = \sqrt{\frac{9H}{H}} = 3$$

Therefore $V_2 = 3\ V_1$

(*b*) Given E = 12 V, r = 2 W, R = 4 W,

Now total resistance in the circuit,

$R_T = r + R = 2 + 4 = 6\Omega$

Hence current in the circuit and through the ammeter is

$$I = \frac{E}{r+R} = \frac{12}{6} = 2A$$

Now reading of voltmeter

$V = E - Ir = 12 - 2 \times 2 = 8$ V

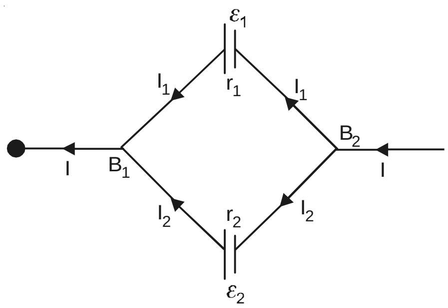
Or

Two cells of emfs e_1 and e_2 and internal resistances r_1 and r_2 respectively are connected in parallel. Obtain expressions for the equivalent.

(*i*) resistance and

(*ii*) emf of the combination

Ans. Consider a parallel combination of the cells (Fig.).



I_1 and I_2 are the currents leaving the positive electrodes of the cells. At point B_1, I_1 and I_2 flow in whereas current I flows out. Therefore, we have

$$I = I_1 + I_2 \qquad ....(1)$$

Let $V(B_1)$ and $V(B_2)$ be the potentials at B_1 and B_2, respectively.

Then, considering the first cell, the potential difference across its terminals is $V(B_1) - V(B_2)$. Hence, from eq $V = E - Ir$ we have

$$V = V(B_1) - V(B_2) = E_1 - I_1 r_1 \qquad ....(2)$$

Points B_1 and B_2 are connected exactly similarly to the second cell. Hence considering the second cell, we also have

$$V = V(B_1) - V(B_2) = E_2 - I_2 r_2 \qquad ....(3)$$

Combining equations 1, 2 and 3 we have

$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$$

$$= \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \qquad ....(4)$$

Solving for V we have

$$V = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} \frac{- I r_1 r_2}{r_1 + r_2} \qquad ....(5)$$

If we want to replace the combination by a single cell, between B_1 and B_2, of emf E_{eq} and internal resistance r_{eq} we would have

$$V = E_{eq} - I r_{eq} \qquad ....(6)$$

From 5 and 6 we have

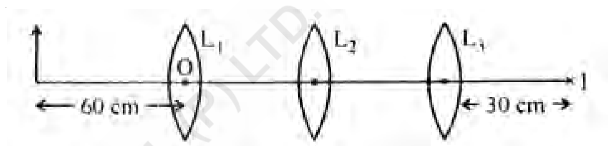
$$E_{eq} - I r_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} - I \frac{r_1 r_2}{r_1 + r_2}$$

Hence we have

$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} \text{ and } r_{eq} = \frac{r_1 r_2}{r_1 + r_2} \qquad ....(7)$$

Q. 33. (*a*) Explain with reason, how the power of a diverging lens changes when (*i*) it is kept in a medium of refractive index greater than that of the lens. (*ii*) Incident red light is replaced by violet light.

(*b*) Three lenses L_1, L_2, and L_3 each of focal length 30 cm are placed coaxially as shown in the figure. An object is held at 60 cm from the optic centre of L_1. The final image is formed at the focus of L_3. Calculate the separation between (*i*) L_1 and L_2 and (*ii*) L_2 and L_3



Or

(*a*) Deduce the expression, by drawing a suitable ray diagram, for the refractive index of a triangular glass prism in terms of the angle of minimum deviation (D) and the angle of prism (A).

Draw a plot showing the variation of the angle of deviation with the angle of incidence.

(*b*) Calculate the value of the angle of incidence when a ray of light incident on one face of an equilateral glass prism produces the emergent ray, which just grazes along the adjacent face. Refractive index of the prism is 2.

Ans. (*a*) (*i*) The power of a diverging lens is given by the expression $P = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$. If the medium is changed the power of the lens decreases as its focal length increases.

(*ii*) We know that $f \propto \lambda$, therefore a decrease in the wavelength from red to violet decreases the focal length and increases the power of the lens.

(*b*) Given $f_1 = f_2 = f_3 = 30$ cm

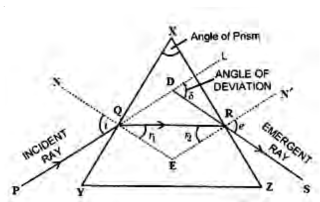
For lens L_1, $u_1 = 60$ cm $= 2f_1$, therefore the image will be formed at $2f$ on the other side of the lens L_1.

Since the final image for lens L_3 is formed at the focus, therefore the rays of light falling on lens L_3 should come from infinity. This is possible if the image of L_1 lies at the focus of L_2.

Thus distance $L_1L_2 = 60 + 30 = 90$ cm

Also distance L_2L_3 can have any value as the rays between L_2 and L_3 will be parallel.

Consider a cross section XYZ of a prism as shown in figure.



As seen from figure we have in triangle QDR that $\angle DQR = i - r_1$ and $\angle DRQ = e - r_2$, Therefore from triangle QDR we have

$\delta = \angle DQR + \angle DRQ = (i - r_1) + (e - r_2)$

or $\delta = (i + e) - (r_1 + r_2)$ ...(1)

Now from the quadrilateral XQER, we have

$A + E = 180^0$ ...(2)

In triangle QER we have

$r_1 + r_2 + E = 180^0$ ...(3)

From equations 2 and 3 we have

$A = r_1 + r_2$ ...(4)

Substituting in equation 1 we have

$\delta = i + e - A$ or $i + e = A + \delta$ ...(5)

In this position the ray of light passes symmetrically through the prism *i.e.,* the refracted ray QR is parallel to the base of the prism. In this position the angle of incidence is equal to the angle of emergence *i.e.* $i = e$. Also in this position the angle of refraction at the faces of the prism are equal *i.e.* $r_1 = r_2$.

Substituting these values in equations 4 and 5 we have

$A = r_1 + r_2 = r + r = 2r$

or $r = A / 2$ ...(6)

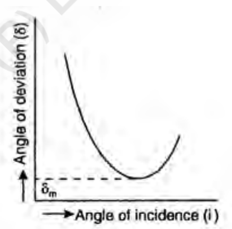
and $i + i = A + \delta_m$ or

$$2i = A + \delta_m \text{ or } i = \frac{A + \delta_m}{2} \quad ...(7)$$

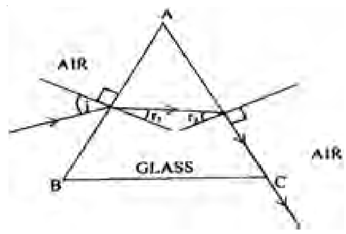
substituting for i and r in the expression for Snell's law we have

$$m = \frac{\sin i}{\sin r} = \frac{\sin\left[\dfrac{A + \delta_m}{2}\right]}{\sin\left(\dfrac{A}{2}\right)}$$

The graph is as shown



(*b*) The diagram is as shown.



$${}_a n_g = \frac{\sin i}{\sin r_1} \Rightarrow \sqrt{2} = \frac{\sin i}{\sin r_1} \text{ and}$$

$${}_g n_a = \frac{\sin r_2}{90°} \Rightarrow \frac{1}{\sqrt{2}} = \sin r_2$$

Therefore $r_2 = 45°$

Now $A = r_1 + r_2$, therefore

$r_1 = A - r_2 = 60 - 45 = 15°$

$$\sqrt{2} = \frac{\sin i}{\sin 15°} \Rightarrow \sin i = \sqrt{2} \times \sin 15°$$

$= 1.414 \times 0.258 = 0.365$

$i = 21.4°$

Holy Faith New Style Sample Paper—3

(Based on the Latest Design & Syllabus issued by C.B.S.E.)

CLASS – 12th

PHYSICS (Theory)

Time allowed : 3 hours **Maximum Marks : 70**

General Instructions : Same as in MTP – 1

SECTION – A

Q. 1. Two charged spheres are separated by 2 mm. Which of the following would yield the greatest attractive force ?

(*a*) $+ 2q$ and $– 2q$ (*b*) $+ 2q$ and $+ 2q$

(*c*) $– 2q$ and $– 2q$ (*d*) $– 1q$ and $– 4q$.

Ans. (*a*) $+ 2q$ and $– 2q$.

Q. 2. By increasing the temperature, the specific resistance of a conductor and semiconductor :

(*a*) increases for both

(*b*) decreases for both

(*c*) increases, decreases

(*d*) decreases for both

Ans. (*c*) increases, decreases.

Q. 3. Two wires A and B, of the same material having length in the ratio 1 : 2 and diameter in the ratio 2 : 3 are connected in series with a battery. The ratio of the potential differences (*VA / VB*) across the two wires respectively is :

(*a*) 1/3 (*b*) 3/4

(*c*) 4/5 (*d*) 9/8.

Ans. (*d*) 9/8.

Q. 4. A long straight wire in the horizontal plane carries a current of 15 A in north to south direction. The magnitude and direction of magnetic field at a point 2.5 m east of the wire respectively are :

(*a*) 1.2 T, vertically upward

(*b*) 1.2 T, vertically downward

(*c*) 0.6 T, vertically upward

(*d*) 0.6 T, vertically downward

Ans. (*a*) 1.2 T, vertically upward.

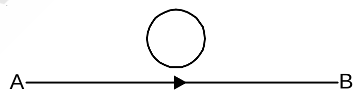
Q. 5. Lenz's law is the consequence of the law of conservation of:

(*a*) energy (*b*) charge

(*c*) mass (*d*) momentum

Ans. (*a*) energy.

Q. 6. The current flows from A to B is increasing as shown in the figure. The direction of the induced current in the loop is :



(*a*) clockwise (*b*) anticlockwise.

(*c*) straight line

(*d*) no induced e.m.f. produced.

Ans. (*a*) clockwise.

Q. 7. Which of the following statement is NOT true about the properties of electromagnetic waves ?

(*a*) These waves do not require any material medium for their propagation

(*b*) Both electric and magnetic field vectors attain the maxima and minima at the same time

(*c*) The energy in an electromagnetic wave is divided equally between electric and magnetic fields

(*d*) Both electric and magnetic field vectors are parallel to each other.

Ans. (*d*) Both electric and magnetic field vectors are parallel to each other.

Q. 8. Find the incorrect statement (s) about the photoelectric effect.

(*a*) There is no significant time delay between the absorption of a suitable radiation and the emission of electrons

(*b*) Einstein analysis gives a threshold frequency above which no electron can be emitted
(*c*) The maximum kinetic energy of the emitted photoelectrons is proportional to the frequency of incident radiation
(*d*) The maximum kinetic energy of electrons does not depend on the intensity of radiation.

Ans. (*b*) Einstein analysis gives a threshold frequency above which no electron can be emitted

Q. 9. The work function for a certain metal is 4.2 eV. Will this metal give photoelectric emission for incident radiation of wavelength 330 nm ?

(*a*) No (*b*) Yes
(*c*) Depends upon the metal
(*d*) Incomplete data.

Ans. (*a*) No.

Q. 10. A set of atoms in an excited state decay :

(*a*) in general, to any of the states with lower energy
(*b*) into a lower state only when excited by an external electric field
(*c*) all together simultaneously into a lower state
(*d*) to emit photons only when they collide.

Ans. (*a*) in general, to any of the states with lower energy.

Q. 11. The conductivity of a semiconductor increases with increase in temperature because :

(*a*) number density of free current carriers increases.
(*b*) relaxation time increases.
(*c*) both number of charge carriers and relaxation time increase.
(*d*) Number density of current carrier increases, relaxation time decreases but effect of decrease in relation time is much less that the increase in the number density of charge carriers.

Ans. (*d*) Number density of current carrier increases, relaxation time decreases but effect of decrease in relation time is much less that the increase in the number density of charge carriers.

Q. 12. Hole is :

(*a*) an anti-particle of electron
(*b*) a vacancy created when an electron leaves a covalent bond
(*c*) absence of free electrons
(*d*) an artificially created particle.

Ans. (*b*) a vacancy created when an electron leaves a covalent bond.

Questions number 13 to 16 are Assertion (A) and Reason (R) type questions

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (*a*), (*b*), (*c*) and (*d*) as given below.

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

Q. 13. Assertion (A) : A pure semiconductor has negative temperature coefficient of resistance.

Reason (R) : In a semiconductor on raising the temperature, more charge carriers are released, conductance increases and resistance decreases.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

Q. 14. Assertion (A) : The energy of a charged particle moving in a magnetic field does not change.

Reason (R) : Magnetic field does not do any work.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

Q. 15. Assertion (A) : In process of photoelectric emission, all emitted electrons do not have the same kinetic energy.

Reason (R) : If radiation falling on the photo-sensitive surface of metal consists of different wavelengths then energy acquired by electrons absorbing photons of different wavelengths shall be different.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

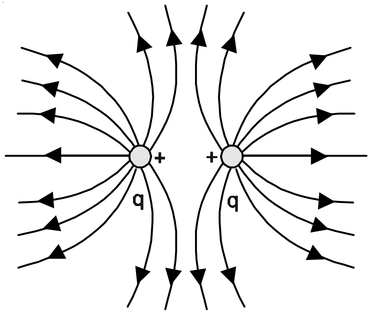
Q. 16. Assertion (A) : A pure semiconductor has negative temperature coefficient of resistance.
Reason (R) : In a semiconductor on raising the temperature, more charge carriers are released, conductance increases and resistance decreases.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

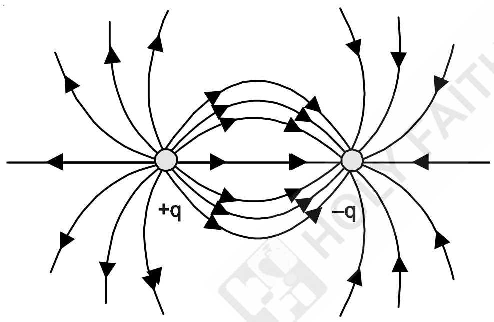
SECTION – B

Q. 17. Draw electric field lines due to (*i*) two similar charges, (*ii*) two opposite charges, separated by a small distance.

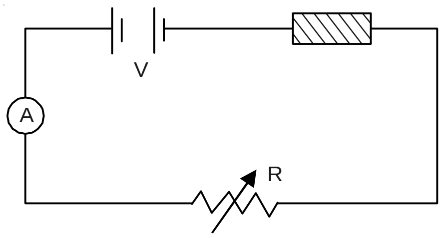
Ans. (*i*) The diagram is as shown.



(*ii*) The diagram is as shown.

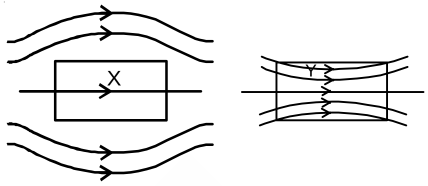


Q. 18. The diagram shows a piece of pure semiconductor, S in series with a variable resistor *R*, and a source of constant voltage *V*. Would you increase or decrease the value of *R* to keep the reading of ammeter (A) constant when semi conductor S is heated ? Give reason.



Ans. Here *R* is connected in series to the semiconductor. As the temperature of semiconductor S increases, its resistivity decreases. As a result, the circuit resistance decreases and current increases. To keep the reading of ammeter (A) constant, *i.e.* the same current, the value of *R* has to be increased.

Q. 19. A uniform magnetic field gets modified as shown below when two specimens X and Y are placed in it.



(*i*) Identify the two specimens X and Y.
(*ii*) State the reason for the behaviour of the field lines in X and Y.

OR

Increasing the current sensitivity may not necessarily increase the voltage sensitivity of a galvanometer. Justify.

Ans. (*i*) X is a diamagnetic substance and Y is a paramagnetic/ferromagnetic substance.

(*ii*) This is because the permeability of a diamagnetic substance is less than one and that of a paramagnetic/ferromagnetic substance is greater than one.

OR

Voltage and current sensitivities are related as $VS = \frac{CS}{R}$. An increase in current sensitivity may lead to an increase in the resistance of the coil. Thus the factor C.S/*R* may not be affected

Q. 20. A proton and an alpha particle having the same kinetic energy are in turn allowedto pass through a uniform magnetic field perpendicular to their direction of motion. Compare the radii of the paths of the proton and the alpha particle.

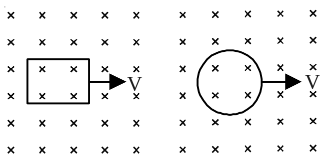
Ans. Given $E_\alpha = E_p, m_a = 4m_p$, $q_{\alpha=}\ 2q_P$, B is same for both. Now the radius of the path followed is given by the expression

$$r = \frac{mv}{Bq} = \frac{\sqrt{2mE}}{Bq}$$

Therefore

$$\frac{r_\alpha}{r_P} = \frac{\sqrt{m_\alpha}}{q_\alpha} \times \frac{q_P}{\sqrt{m_P}} = \sqrt{\frac{4m_P}{m_P}} \times \frac{q_P}{2q_P} = 1$$

Q. 21. A rectangular loop and circular loop are moving out of a uniform magnetic field region with a constant velocity *v* as shown in the figure. In which loop do you expect the induced emf to be constant during the passage out of the field region ? The field is normal to the loops.



Ans. It is expected that the induced emf will be constant in the rectangular coil. In case of the rectangular coil, when pulled out of the magnetic field, the rate of change of magnetic flux will be constant because rate of change of area is constant. This is not so in the case of the circular coil.

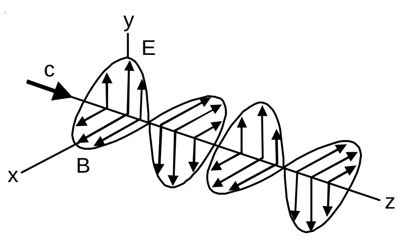
SECTION – C

Q. 22. Draw a sketch of a plane electromagnetic wave propagating along the *z*-direction. Depict clearly the directions of electric and magnetic fields varying sinusoidally with *z*.

OR

Identify the part of the electromagnetic spectrum used in (*i*) radar and (*ii*) eye surgery. Write their frequency range.

Ans. The sketch is as shown below.

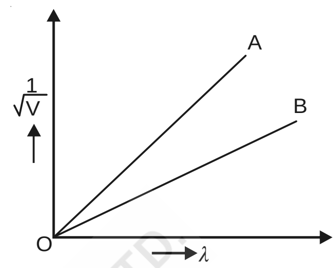


OR

Microwaves : Frequency range (10^{10} to 10^{12} Hz)

Ultraviolet rays : Frequency range (10^{15} to 10^{17} Hz)

Q. 23. The figure shows a plot of $\frac{1}{\sqrt{V}}$ (V is the accelerating potential) versus the de Broglie wavelength λ in case of two particles having the same charge q but different masses m_1 and m_2. Which line A or B represents the particle of greater mass ? Why?



Ans. We know that $\lambda = \frac{h}{\sqrt{2mqV}}$

Now slope of graph is

$$\frac{1}{\lambda\sqrt{V}} = \frac{\sqrt{2mqV}}{h} \Rightarrow \text{slope} \propto \sqrt{m}$$

More the mass more is the slope. Therefore, mass of A is greater than mass of B

Q. 24. Calculate the de Broglie wavelength associated with the electron revolving in the first excited state of hydrogen atom. The ground state energy of the hydrogen atom is 13.6 eV.

Ans. The de Broglie wavelength is given by $2\pi r_n = n\lambda$

In the first excited state, $n = 2$ and

$r_1 = 4 \times 0.53$ Å = 2.12 Å,

Therefore,

$\lambda_1 = (2 \times 3.14 \times 2.12)/2 = 6.66$ Å

Q. 25. (*a*) Differentiate between electrical resistance and resistivity of a conductor.

(*b*) Two metallic rods, each of length *L*, area of cross A_1 and A_2, having resistivitiesr ρ_1 and ρ_2 are connected in parallel across a d.c. battery. Obtain the expression for the effective resistivity of this combination.

Ans. (*a*) **Resistance :** It is the opposition offered to the flow of current by a resistor.

Resistivity: The resistance per unit length of the conductor.

(*b*) Let ρ be the effective resistivity. Let R_1, R_2 and R_P be the respective resistances. Since they are connected in parallel, we have

$$R_P = \frac{R_1 R_2}{R_1 + R_2}$$

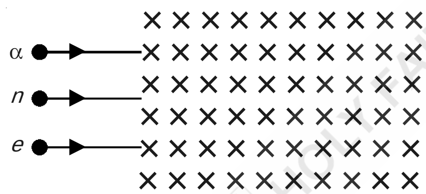
Where $R_1 = \frac{\rho_1 L}{A_1}, R_2 = \frac{\rho_2 L}{A_2}$ $R_P = \frac{\rho L}{A_1 + A_2}$,

Substituting in the equation for R_P and solving we have

$$\rho = \frac{\rho_1 p_2 (A_1 A_2)}{\rho_1 A_2 + \rho_2 A_1}$$

Q. 26. (*a*) Write the expression for the magnetic force acting on a charged particle moving with velocity *v* in the presence of magnetic field B.

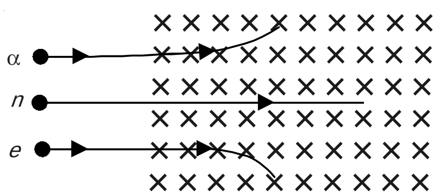
(*b*) A neutron, an electron and an alpha particle moving with equal velocities enter a uniform magnetic field going into the plane of the paper as shown.



Trace their paths in the field and justify your answer.

Ans. (*a*) $\vec{F} = q(\vec{v} \times \vec{B})$

(*b*) The paths are as shown.



The radius of the circular path travelled by each particle is given by the expression

$r = \frac{mv}{Bq}$ since B and v is same therefore $r \propto \frac{m}{q}$. Since neutron does not have a charge, therefore it passes straight without deflection. The ratio m/q for alpha particle is greater for an electron therefore its path will be less curved. Also by Fleming's left-hand rule, the alpha particle and the electron will experience a force in the direction as shown.

Q. 27. (*a*) In a single-slit diffraction pattern, how does the angular width of the central maximum vary, when

(*i*) aperture of slit is increased ?

(*ii*) distance between the slit and the screen is decreased ?

Justify your answer in each case.

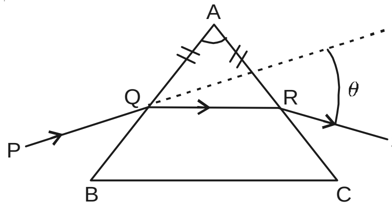
(*b*) How is the diffraction pattern different from the interference pattern obtained in Young's double-slit experiment ?

Ans. (*a*) The angular width of the central maxima in a single-slit diffraction pattern is given by $2\theta = \frac{2\lambda}{a}$ where λ is the wave length of light and 'a' the slit width.

(*i*) When the aperture of the slits increased the angular width decreases.

(*ii*) When the distance between the slit and the screen is decreased, the angular width will remain the same but the linear width will increase.

Q. 28. A ray PQ incident on the refracting face BA is refracted in the prism BAC as shown in the figure and emerges from the other refracting face AC as RS such that AQ = AR. If the angle of prism A = 60° and refractive index of material of prism is $\sqrt{3}$, calculate angle θ.



OR

Calculate the value of the angle of incidence when a ray of light incident on one face of an equilateral glass prism produces the emergent ray, which just grazes along the adjacent face. Refractive index of the prism is $\sqrt{2}$.

Ans. Here AQ = AR, therefore QR is parallel to BC, hence prism is in minimum deviation position

A = 60^0, ? = d_m = ?, $n = \sqrt{3}$

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

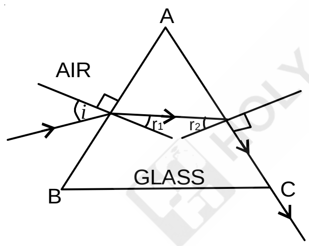
Or $$\sqrt{3} = \frac{\sin\left(\frac{60+\delta_m}{2}\right)}{\sin\left(\frac{60}{2}\right)} = \frac{\sin\left(\frac{60+\delta_m}{2}\right)}{\sin 30}$$

or $$\frac{\sqrt{3}}{2} = \sin\left(\frac{60+\delta_m}{2}\right)$$

Solving θ = 60^0.

OR

The diagram is as shown



$${}_a n_g = \frac{\sin i}{\sin r_1} \Rightarrow \sqrt{2} = \frac{\sin i}{\sin r_1}$$

and $${}_g n_a = \frac{\sin r_2}{\sin 90^0} \Rightarrow \frac{1}{\sqrt{2}} = \sin r_2$$

Therefore $r_2 = 45°$

Now $A = r_1 + r_2$, therefore

$r_1 = A - r_2 = 60° - 45° = 15°$

$$\sqrt{2} = \frac{\sin i}{\sin 15°} \Rightarrow \sin i = \sqrt{2} \times \sin 15°$$

$= 1.414 \times 0.258 = 0.365$

$i = 21.40°$

SECTION – D

Questions number 29 to 30 are case study based questions

Q. 29. Rhea was watching her favourite TV programme Monk. Suddenly the picture started shaking on the TV screen. She asked her elder brother to check the dish antenna. Her brother found nothing wrong with the antenna. A little later, Rhea again noticed the same problem on the TV screen. At the same time, she heard the sound of a low flying aircraft passing over their house. She asked her brother again. Her brother being a Physics student explained the cause of shaking the picture on the TV screen when aircraft passes overhead.

(*i*) Why does the picture started shaking when a low flying aircraft passes overhead ?

(*a*) Due to Interference
(*b*) Due to reflection
(*c*) Due to refraction
(*d*) Due to polarisation

Ans. (*a*) Due to Interference.

(*ii*) The main principle used in interference is :

(*a*) Heisenberg's Uncertainty principle
(*b*) Superposition principle
(*c*) Quantum Mechanics
(*d*) Fermi Principle.

Ans. (*b*) Superposition Princple.

Interference is based on superposition principle

(*iii*) When two waves of same amplitude add constructively, the intensity becomes :

(*a*) double (*b*) half
(*c*) four times (*d*) one-fourth.

Ans. (*c*) four times.

(*iv*) The shape of the fringes observed in interference is :

(*a*) straight (*b*) circular
(*c*) hyperbolic (*d*) elliptical.

Ans. (*c*) The fringes observed in an interference pattern are hyperbolic in shape. When the distance between the slits and the screen is large, they appear almost straight.

Or

Which of the following incident light wavefronts is most suitable for observing a single slit diffraction pattern?

(*a*) Either a cylinderical wavefront or a spherical wavefront

(*b*) Cylinderical wavefront only

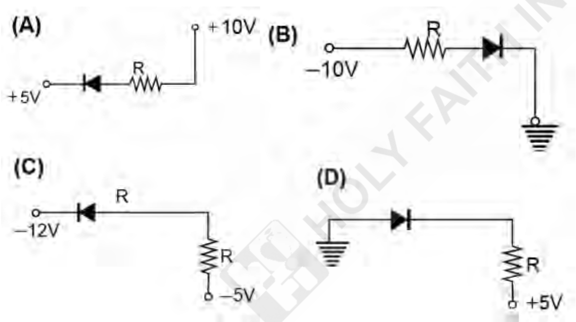
(*c*) Plane wavefront only

(*d*) Spherical wavefront.

Ans. (*c*) Plane wavefront.

Q. 30. When the diode is forward biased, It is found that beyond forward voltage $V = V_K$ called knee voltage, the conductivity is very high. At this value of biasing for p-n junction, the potential barrier is overcome and the current increases rapidly with increase in forward voltage. When the diode is reverse biased, the reverse bias voltage produces a very small current about a few micro ampere, which almost remains constant with bias. This small current is reverse saturation current.

(*i*) In which of the following figure, the p-n diode is forward biased ?



(*a*) (*a*), (*b*) and (*d*) (*b*) (*c*) and (*a*)

(*c*) (*b*) and (*d*) (*d*) (*c*) only.

Ans. (*b*)

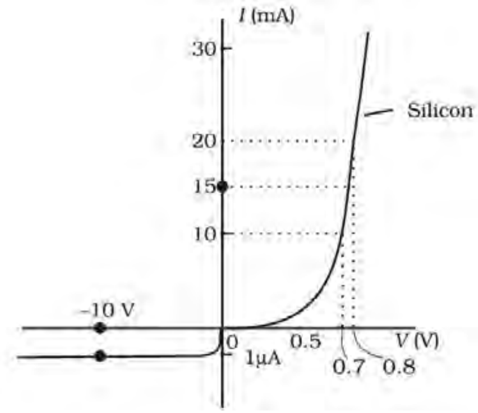
(*ii*) Based on the V-I characteristics of the diode, we can classify diode as

(*a*) bi-directional device (*b*) ohmic device

(*c*) non-ohmic device (*d*) passive element.

Ans. (*c*)

(*iii*) The V-I characteristic of a diode is as shown in the figure. The ratio of forward to reverse bias resistance is :



(*a*) 100 (*b*) 10^6

(*c*) 10 (*d*) 10^{-6}.

Ans. (*d*)

Forward bias resistance

$$R_P = \frac{\Delta V}{\Delta I} = \frac{0.8-0.7}{(20-10)\times 10^{-3}} \times 10\ \Omega$$

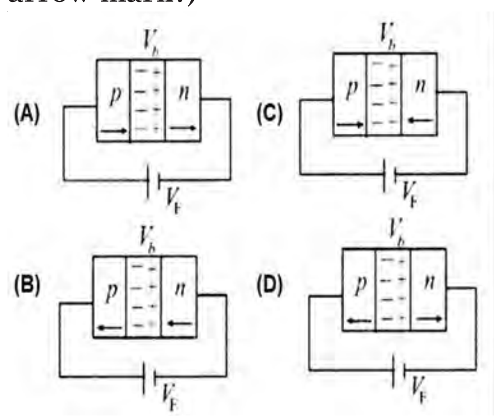
Reverse biased resistence

$$R_R = \frac{\Delta V}{\Delta I} = \frac{10}{1\times 10^{-6}} \times 10^7\ \Omega$$

Ratio of forward to reverse resistance is

$$\frac{R_P}{R_R} = \frac{10}{10^7} = 10^{-6}.$$

(*iv*) In the case of forward biasing of a p-n junction diode, which one of the following figures correctly depicts the direction of conventional current (indicated by an arrow mark?)

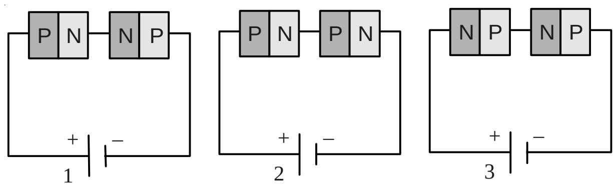


Ans. (*b*) R = 15 Ω, L = 3.5 H, C = 30 μF.

OR

Two identical pn junctions can be connected in series by three different methods as shown in the figure. If the potential difference in the junctions is

the same, then the correct connections will be :



(*a*) in the circuits (1) and (2)
(*b*) in the circuits (2) and (3)
(*c*) in the circuits (1) and (3)
(*d*) only in the circuit (1).

Ans. (*b*)

SECTION – E

Q. 31. Using Gauss' law, obtain expressions for the electric field (*i*) inside, and (*ii*) outside a positively charged spherical shell.

(*b*) Show graphically variation of the electric field as a function of the distance *r* from the centre of the sphere.

(*c*) A square plane sheet of side 10 cm is inclined at an angle of 30° with the direction of a uniform electric field of 200 N C^{-1}. Calculate the electric flux passing through the sheet.

OR

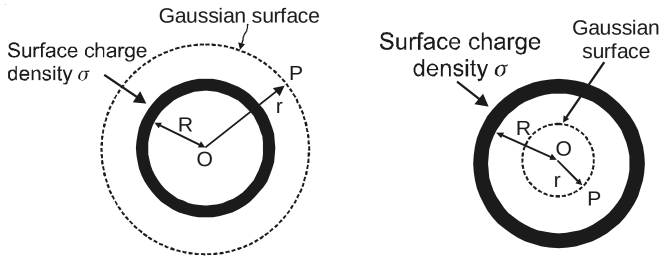
(*i*) Obtain an expression for the potential energy of an electric dipole placed in a uniform electric field.

(*ii*) Three capacitors of capacitance C_1, C_2 and C_3 are connected in series to a source of V volt. Show that the total energy stored in the combination, of capacitors is equal to sum of the energy stored in individual capacitors.

(*iii*) A capacitor of capacitance C is connected across a battery. After charging, the battery is disconnected and the separation between the plates is doubled. How will (*i*) the capacitance of the capacitor, and (*ii*) the electric field between the plates be affected ? Justify your answer.

Ans. At a Point outside the spherical shell

In order to find the electric field at a point P outside the shell let us consider a Gaussian surface in the form of a sphere of radius *r* (*r* >> R) .



(*a*) (*b*)

By symmetry we find that the electric field acts radically outwards and has a normal component at all points on the Gaussian sphere. Therefore by definition of electric flux we have

= E × A where A is the surface area of the Gaussian sphere therefore

$= E \times 4r^2$ ...(1)

But by Gauss's law

$$\phi = \frac{Q}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0} = \frac{\sigma \times 4\pi R^2}{\varepsilon_0} \quad ...(2)$$

from equation 1 and 2 it follows that

$$E = 4\pi r^2 = \frac{Q}{\varepsilon_0} \text{ or } E \times 4\pi r^2 = \frac{\sigma \times 4\pi R^2}{\varepsilon_0} \quad ...(3)$$

$$\text{or } E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \text{ and } E = \frac{\sigma R^2}{\varepsilon_0 r^2} \quad ...(4)$$

It follows from equation 4 that the electric field due to a spherical shell outside it is same as that due to a point charge. Therefore for points lying outside the spherical shell the shell behaves as if the entire charge is concentrated at the centre.

CASE 2 : At a point on the spherical shell

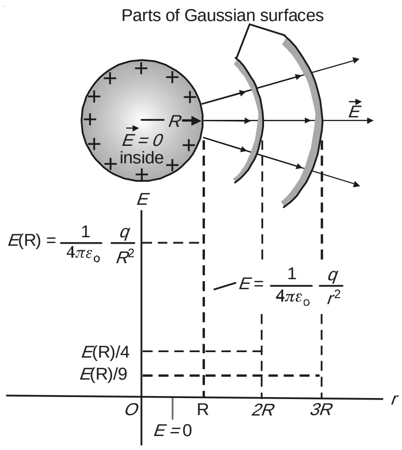
In this case the Gaussian surface will have the same radius as that of the shell. Therefore R can replace *r* in equation 4.

$$\text{Hence } E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2} \text{ and } E = \frac{\sigma}{\varepsilon_0}$$

CASE 3: At the point inside the spherical shell.

In this case the Gaussian surface drawn inside the shell does not enclose any charge hence

$$E \times 4\pi r^2 = \frac{0}{\varepsilon_0} \quad \text{or} \quad \mathbf{E = 0}$$



(*c*) Given

r = 10 cm = 0.1m

Electric field 'E' = 200 N C^{-1}

The angle between the sheet and electric field 30^o

The angle between the electric field and normal to the plane sheet $\theta = 90 - 30 = 60^o$

Electric flux $\phi = EA \cos\theta$

$\phi = 200 \times (0.1)^2 \times \cos 60^o = 1 \text{ N m}^2 \text{ C}^{-1}$

OR

(*i*) The torque acting on the dipole in a uniform electric field tends to align it in the direction of the electric field. If the dipole is moved against this torque, work will have to be done. This work is stored in the dipole as its potential energy. If is the angle between the dipole moment and the electric field, then the torque acting on the dipole is given by

$$\tau = pE \sin\theta \quad ...(1)$$

Suppose the dipole is rotated through an infinitesimally small angle $d\theta$ against the torque then the small work done is

$$dW = \tau\, d\theta = pE \sin\theta\, d\theta \quad ...(2)$$

The net work done in rotating the dipole from its initial position θ_1 to its final position θ_2 is given by

$$W = \int_{\theta_1}^{\theta_2} pE \sin\theta\, d\theta = pE \left| -\cos\theta \right|_{\theta_1}^{\theta_2}$$

or $\quad W = pE(\cos\theta_1 - \cos\theta_2) \quad ...(3)$

This work done is stored in the dipole in the form of its potential energy. Hence

$U = pE(\cos\theta_1 - \cos\theta_2) \quad ...(4)$

(*ii*) Suppose three capacitors of capacitances C_1, C_2 and C_3 are connected in series, then

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Since in series the charge on each capacitor is same therefore the energy stored in the parallel combination is

$$U = \frac{1}{2}\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)Q^2 = \frac{1}{2}\frac{\theta_2}{C_1} + \frac{1}{2}\frac{\theta_2}{C_2} + \frac{1}{2}\frac{\theta_2}{C_3}$$

or $U = U_1 + U_2 + U_3$

(*iii*) (*a*) The capacitance of a capacitor is given by $C = \frac{\varepsilon_0 A}{d}$

As d is doubled, therefore the capacitance will become half.

(*b*) The electric field is given by the expression $E = \frac{\sigma}{\varepsilon_0} = \frac{q}{\varepsilon_0 A}$. This remains same as there is no change in charge and area of the plates.

Q. 32. **(*a*) Define a wavefront. How is it different from a ray ?**

(*b*) Depict the shape of a wavefront in each of the following cases.

(*i*) Light diverging from a point source.

(*ii*) Light emerging out of a convex lens when a point source is placed at its focus.

(*iii*) Using Huygen's construction of secondary wavelets, draw a diagram showing the passage of a plane wavefront from a denser into a rarer medium.

OR

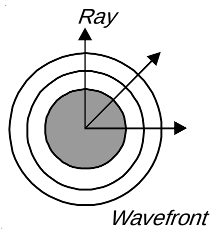
(*a*) Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses.

(*b*) A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of

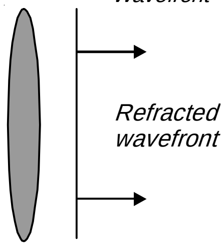
incidence is 3/4th of the angle of prism. Calculate the speed of light in the prism.

Ans. (*a*) A wave front is defined as the locus of all adjacent points at which the phase of vibration of a physical quantity associated with the wave is the same. It is in two dimesion while a ray is in one dimension.

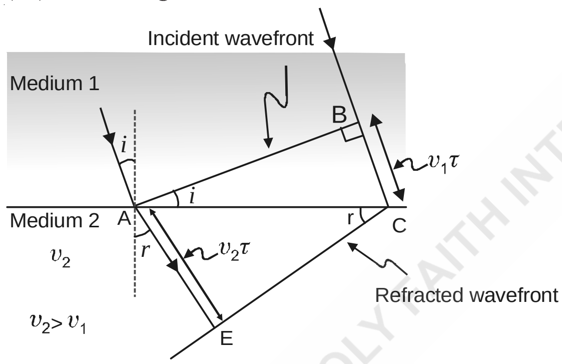
(*b*) (*i*)



(*ii*) F

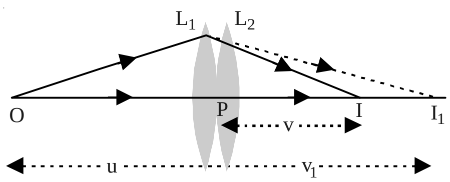


(*iii*) This diagram is as shown



OR

(*a*) Consider two lenses A and B of focal length f_1 and f_2 placed in contact with each other. Let the object be placed at a point O beyond the focus of the first lens L_1 as shown.



The first lens L_1 produces an image at I_1. Since image I_1 is real, it serves as a virtual object for the second lens L_2, producing the final image at I. Since the lenses are thin, we assume the optical centres of the lenses to be coincident. Let this central point be denoted by P.

For the image formed by the first lens L_1, we get

$$\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1} \qquad ...(i)$$

For the image formed by the second lens L_2, we get

$$\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2} \qquad ...(ii)$$

Adding equations (*i*) and (*ii*) we have

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \qquad ...(iii)$$

If the two lens-system is regarded as equivalent to a single lens of focal length *f*, we have

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_2} \qquad ...(iv)$$

Therefore from equations (*iii*) and (*iv*) we get

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \text{ or } P = P_1 + P_2$$

(*b*) Given $A = 60^0$, $i = \frac{3}{4} \times 60 = 45^\circ$ $c = 3 \times 10^8$ m s^{-1}, Now ${}_{m} = 2i - A = 90 - 60 = 30^\circ$

Using the formula

$$\mu = \frac{c}{v} = \frac{\sin\left[\frac{A + \delta_m}{2}\right]}{\sin\left(\frac{A}{2}\right)} \text{ we have}$$

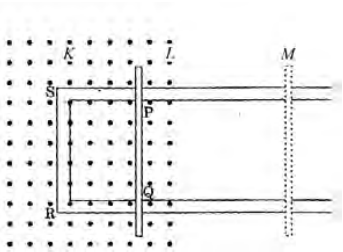
$$\frac{c}{v} = \frac{\sin 45}{\sin 30} \text{ or}$$

$$v = 3 \times 10^8 \times \frac{\sin 30}{\sin 45} = 2.12 \times 10^8 \text{ m s}^{-1}$$

Q. 33. State Faraday's law of electromagnetic induction.

Figure shows a rectangular conductor PQRS in which the conductor PQ is free to move in a uniform magnetic field B perpendicular to the plane of the paper. The field extends from x = 0 to x = b and is zero for x > b. Assume that only the arm PQ possesses resistance r. When the arm

PQ is pulled outward from x = 0 to x = 2b and is then moved backward to x = 0 with constant speed v, obtain the expressions for the flux and the induced emf. Sketch the variations of these quantities with distance 0 ? x ? 2b.



OR

Draw a schematic diagram of a step-up transformer. Explain its working principle. Deduce the expression for the secondary to primary voltage in terms of the number of turns in the two coils. In an ideal transformer, how is this ratio related to the currents in the two coils?

How is the transformer used in large scale transmission and distribution of electrical energy over long distances?

Ans. Faraday's law of electromagnetic induction states that

The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

Let us first consider the forward motion from x = 0 to x = 2b

The flux ϕ_B linked with the cirtuit SPQR is

ϕ_B = Blx $\quad 0 \le x \le b$

= Blb $\quad b \le x < 2b$

The induced emf is,

$$\varepsilon = -\frac{d\phi_B}{dt} = -Blv$$

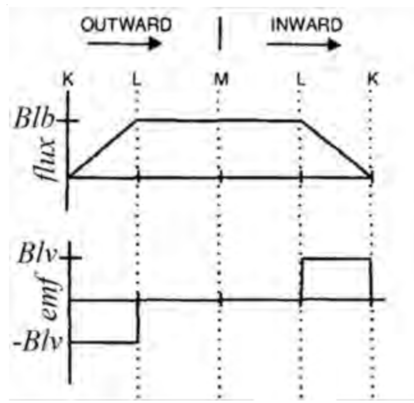
$0 \le x \le b = 0$

$b \le x < 2b$

When the induced emf is non zero the current I is (in magnitude)

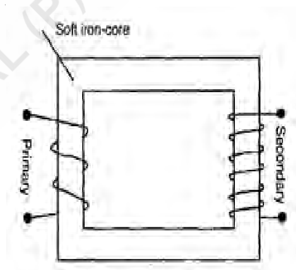
I= ε/r = B l v/ r

The variation of flux and emf with distance is as shown below.



OR

The schematic diagram is as shown



Principle: It works on the principle of mutual inductance i.e., whenever the magnetic flux linked with a coil changes an induced emf is produced in the neighbouring coil.

Expression: The ac source causes an alternating current in the primary, which sets up an alternating flux in the core; this induces an emf in each winding of the secondary, in accordance with Faraday's law. The induced emf in the secondary gives rise to an alternating current in the secondary, and this delivers energy to the device to which the secondary is connected.

At any time the magnetic flux ? is same in each turn of the primary and secondary windings. Let N_p be the number of turns in primary and N_s be the number of turns in the secondary. When the magnetic flux changes, because of the changing currents in the two coils, the resulting induced emf's across the primary and the secondary are

$$\varepsilon_p = -N_p \frac{d\phi}{dt} \text{ and } \varepsilon_s = -N_s \frac{d\phi}{dt} \qquad \text{— (1)}$$

The ratio of the primary emf ?$_P$ to the secondary emf ?$_S$ is equal at any instant to the ratio of the primary to secondary turns;

$$\frac{\varepsilon_p}{\varepsilon_s} = \frac{N_p}{N_s} \qquad \text{— (2)}$$

But ?$_s$ = V_s and ?$_p$ = V_p

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

Therefore we have

If the transformer is ideal then

output power = input power or $I_P V_P = I_S V_S$

Hence $\frac{V_p}{V_s} = \frac{I_s}{I_p}$

Hence $\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{I_s}{I_p}$

The large scale transmission and distribution of electrical energy over long distances is done with the use of transformers. The voltage output of the generator is stepped-up. It is then transmitted over long distances to an area substation near the consumers. There the voltage is stepped down. It is further stepped down at distributing sub-stations and utility poles before a power supply of 240 V reaches our homes.

Holy Faith New Style Sample Paper—4

(Based on the Latest Design & Syllabus issued by C.B.S.E.)

CLASS – 12th

PHYSICS (Theory)

Time allowed : 3 hours **Maximum Marks : 70**

General Instructions : Same as in MTP – 1

SECTION – A

Q. 1. If a charge is moved against a coulomb force of an electric field, then the :

(*a*) the intensity of the electric field increases
(*b*) the intensity of the electric field decreases
(*c*) Work is done by the electric field
(*d*) Work is done by the external source.

Ans. (*d*) Work is done by the external source.

Q. 2. The capacity of a parallel plate capacitor is C_0. If a dielectric of relative permittivity ε_r and thickness equal to one-fourth the plate separation is placed between the plates, then its capacity becomes *C*. The value of C/C_o will be :

(*a*) $\frac{5\varepsilon_r}{4\varepsilon_r+1}$ (*b*) $\frac{4\varepsilon_r}{4\varepsilon_r+1}$

(*c*) $\frac{3\varepsilon_r}{2\varepsilon_r+1}$ (*d*) $\frac{2\varepsilon_r}{\varepsilon_r+1}$.

Ans. (*b*) $\frac{4\varepsilon_r}{4\varepsilon_r+1}$.

Q. 3. Infinity resistance in a resistance box has :

(*a*) a resistance of $10^5\ \Omega$
(*b*) a resistance of $10^7\ \Omega$
(*c*) a resistance of infinite ohm
(*d*) a gap only.

Ans. (*d*) a gap only.

Q. 4. A long straight wire in the horizontal plane carries a current of 15 A in the north-to-south direction. The magnitude and direction of the magnetic field at a point 2.5 m east of the wire respectively are :

(*a*) 1.2 T, vertically upward
(*b*) 1.2 T, vertically downward
(*c*) 0.6 T, vertically upward
(*d*) 0.6 T, vertically downward

Ans. (*a*) 1.2 T, vertically upward

Q. 5. An electron is projected with velocity *v* along the axis of a current carrying long solenoid. Which one of the following statements is true ?

(*a*) The path of the electron will be circular about the axis
(*b*) The electron will be accelerated along the axis
(*c*) The path of the electron will be helical
(*d*) The electron will continue to move with the same velocity *v* along the axis of the solenoid.

Ans. (*d*) The electron will continue to move with the same velocity *v* along the axis of the solenoid.

Q. 6. The work done in turning a magnet of magnetic moment *M* by an angle of 90° from the meridian, is *n* times the corresponding work done to turn it through an angle of 60. The value of *n* is given by

(*a*) 2 (*b*) 1
(*c*) 1/2 (*d*) 1/4

Ans. (*a*) 2.

Q. 7. Lenz's law is the consequence of the law of conservation of :

(*a*) energy (*b*) charge
(*c*) mass (*d*) momentum.

Ans. (*a*) energy.

Q. 8. If $\vec{E}$ and $\vec{B}$ represent electric and magnetic field vectors of the electromagnetic wave, the direction of propagation of electromagnetic wave is along :

(*a*) $\vec{E}$ (*b*) $\vec{B}$

(*c*) $\vec{B} \times \vec{E}$ (*d*) $\vec{E} \times \vec{B}$.

Ans. (*d*) $\vec{E} \times \vec{B}$.

Q. 9. The magnetic flux linked with a coil is given by $\phi = 5t^2 + 3t + 16$, where ϕ is in weber and t in seconds. The induced emf in the coil at $t = 5$ s will be :

(*a*) 53 V (*b*) 43 V

(*c*) 10 V (*d*) 6 V.

Ans. (*a*) 53 V.

Q. 10. The time required for the light to pass through a glass slab ($\mu = 1.5$) of thickness 4 mm is ($c = 3 \times 10^8$ m s^{-1}, speed of light in free space)

(*a*) 2×10^{-5} s (*b*) 2×10^{11} s

(*c*) 2×10^{-11} s (*d*) 10^{-11} s.

Ans. (*c*) 2×10^{-11} s.

Q. 11. The photoelectric cut-off voltage in a certain experiment is 1.5 V. What is the maximum kinetic energy of photo electrons emitted ?

(*a*) 2.4×10^{-10} J (*b*) 4.2×10^{-10} J

(*c*) 2.4×10^{-19} J (*d*) 4.2×10^{-19} J.

Ans. (*c*) 2.4×10^{-19} J.

Q. 12. The Bohr model for the spectra of an H-atom :

(*a*) will not be applicable to hydrogen in the molecular form

(*b*) will be applicable as it is for a He-atom

(*c*) is valid only at room temperature

(*d*) predicts continuous as well as discrete spectral lines.

Ans. (*a*) will not be applicable to hydrogen in the molecular form.

Questions number 13 to 16 are Assertion (A) and Reason (R) type questions

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (*a*), (*b*), (*c*) and (*d*) as given below.

(*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

(*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A)

(*c*) (A) is true but (R) is false

(*d*) (A) is false and (R) is also false.

Q. 13. Assertion (A) : At a fixed temperature, silicon will have minimum conductivity, when it has smaller acceptor doping.

Reason (R) : The conductivity of an intrinsic semiconductor is slightly higher than that of a lightly doped p-type.

Ans. (*c*) (A) is true but (R) is false.

Q. 14. Assertion (A) : White light falls on a double slit, with one slit covered by a green filter. The bright fringes observed are of green colour.

Reason (R) : The fringes observed are coloured.

Ans. (*c*) (A) is true but (R) is false.

Q. 15. Assertion (A) : Stopping potential is a measure of the maximum kinetic energy of photoelectrons.

Reason (R) : $W = eV_o = KE_{max}$

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A).

Q. 16. Assertion (A) : Sparks sometimes occur when an electric iron is switched off.

Reason (R) : Sparks are caused by the substantial self-induced emf in the circuit when the electric iron is turned off.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A).

SECTION – B

Q. 17. (*a*) Identify the part of the electromagnetic spectrum used in (*i*) radar and (*ii*) eye surgery. Write their frequency range.

Ans. (*i*) Microwaves :

Frequency range (10^{10} to 10^{12} Hz)

(*ii*) Ultraviolet rays:

Frequency range (10^{15} to 10^{17} Hz).

Q. 18. (*a*) Define the term magnetic susceptibility and write its relation in terms of relative magnetic permeability.

(*b*) Two magnetic materials A and B have relative magnetic permeabilities of 0.96 and 500. Identify the magnetic materials *A* and B.

Ans. (*a*) It refers to the ease with which a substance can be magnetized. It is defined as the ratio of intensity of magnetisation to the magnetising field. The required relation is $\mu_r = 1 + \chi_m$.

(*b*) A : Paramagnetic, B: Ferromagnetic

Q. 19. Write the short comings of Rutherford atomic model. Explain how these were overcome by the postulates of Bohr's atomic model.

OR

Calculate the orbital period of the electron in the first excited state of hydrogen atom.

Ans. (*a*) Rutherford's model cannot explain the stability of the nucleus.

(*b*) The spectra of the atom is continuous.But in fact an atom has line spectra.Thus Rutherford's model fails to explain the line spectra of the atom. According to Bohr, as long as electron revolves in its stationary orbit, it does not radiate energy. According to Bohr, energy is emitted by an electron as it moves from a higher to a lower energy level.

OR

First excited state $n = 2$, T = ?

$$T = \frac{2\pi r}{v} = \frac{n^2\ h^2}{4\ \pi^2 m\ e^4\ k^2} \text{ where } k = \frac{1}{4\pi\varepsilon_0}$$

Substituting the values, we have

$$T = \frac{(2)^3(6.6\times10^{-34})^3}{4\times(3.14)^2\times9.1\times10^{-31}\times(1.6\times10^{-19})^4\times(9\times10^9)^2}$$

$T = 1.22 \times 10^{-15}$ s

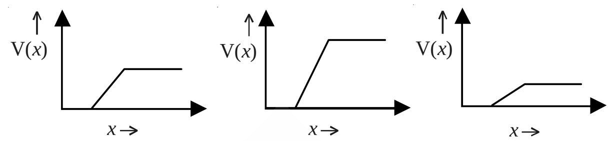
Q. 20. A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens ? Justify your answer.

Ans. It will behave as a concave lens. This is because the focal length of the lens will become negative in accordance with the formula

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$ here n will be negative.

Q. 21. The graph of the potential barrier versus the width of the depletion region for an unbiased diode is shown in graph A. In comparison to A, graphs B and C are obtained after biasing the diode in different ways . Identify the type of biasing in B and C and justify your answer.

'A' 'B' 'C'



OR

Explain the two processes involved in the formation of a pn junction.

Ans. In B, reverse biasing, because the potential barrier increases.

In C, forward biasing as the potential barrier decrease.

OR

The two processes are

(*i*) Diffusion

(*ii*) Drift

Diffusion : The holes diffuse from the p-side to the n-side and electrons diffuse from the n-side to the p-side.

Drift : The motion of the charge carriers on the application of an electric field, which results in the drifting of holes along the direction of electric field and the electrons opposite to the direction of electric field.

SECTION – C

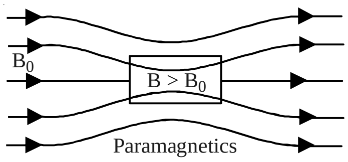
Q. 22. An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why not ?

Ans. Electric field is a continuous field and it exists at all points around a charge distribution. Hence an electrostatic field line is a continuous curve and cannot have sudden breaks.

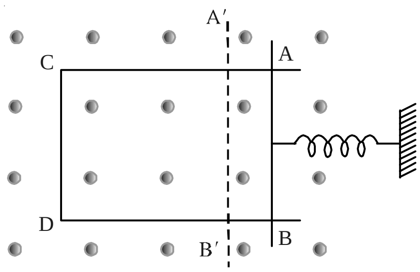
Q. 23. The susceptibility of a magnetic material is 0.9853. Identify the type of the magnetic material. Draw the modification of field

pattern on keeping a piece of this material in a uniform magnetic field.

Ans. The susceptibility has a small positive value. Therefore, it is a paramagnetic substance. The pattern is as shown.

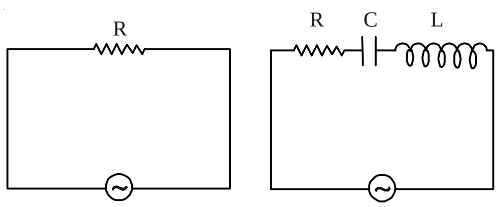


Q. 24. A rectangular frame of wire is placed in a uniform magnetic field directed outwards,normal to the paper. AB is connected to a spring which is stretched to A′B′ and then released at time *t* 0. Explain qualitatively how induced emf in the coil would vary with time. (Neglect damping of oscillations of spring)



Ans. As the spring is released AB is pulled out of the field. This increases the area of the loop inside the magnetic field. This increases flux and hence an induced emf is produced. The portion AB does not stop at AB but moves outwards. Now the spring will push AB inwards. This will decrease the area of the loop thereby decreasing the induced emf. This continues and hence the emf increases and decreases periodically.

Q. 25. Study the circuits (*a*) and (*b*) shown in figure and answer the following questions.



(*a*) **(*b*)**

(*a*) Under which conditions would the rms currents in the two circuits be the same ?

(*b*) Can the rms current in circuit (*b*) be larger than that in (*a*) ?

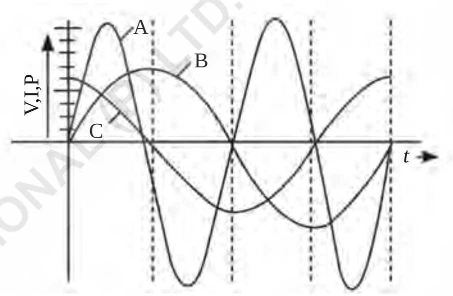
OR

A device 'X' is connected to an AC source. The variation of voltage, current and power in one complete cycle is shown in figure.

(*a*) Which curve shows power consumption over a full cycle ?

(*b*) What is the average power consumption over a cycle ?

(*c*) Identify the device 'X'.



Ans. (*a*) This will happen when the impedance of both the circuits is same, *i.e.* *R*. This is possible when circuit (*b*) is in resonance.

(*b*) No, because in circuit (*b*)

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{V_{rms}}{\sqrt{R^2 + (X_L - X_C)^2}}$$

Z cannot be less than R.

OR

(*a*) A

(*b*) Zero

(c) Capacitor.

Q. 26. For the light of wavelength 400 nm incident on the cathode of a photocell, the stopping potential is 6 V. If the wavelength of incident light is increased to 600 nm, calculate the new stopping potential. (Take *h* = 4.14 × 10^{-15} eV. s)

Ans. Given λ_1 = 400 nm , V_{o1} = 6 V,

λ_2 = 600 nm, V_{o2} = ?

We know that

$$eV_o = \frac{hc}{\lambda} - \phi_0$$

Or $\quad eV_{o1} = \dfrac{hc}{\lambda_1} - \phi_o$ ...(*i*)

$eV_{o2} = \dfrac{hc}{\lambda_2} - \phi_o$ ...(*ii*)

Subtracting (*ii*) from (*i*) we have

$$e(V_{o1} - V_{o2}) = hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$\Rightarrow e(V_{o1} - V_{o2}) = \frac{hc}{e}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$(V_{o1} - V_{o2}) = 4.14 \times 10^{-15} \times 3 \times 10^{8}$

$$\left(\frac{1}{400\times10^{-9}} - \frac{1}{600\times10^{-9}}\right)$$

Or $6 - V_{02} = 1.03$

$V_{o2} = 6 - 1.03 = 4.97$ V.

Q. 27. A compound microscope consists of an objective lens of focal length 2 cm and an eye piece of focal length 6.25 cm separated by a distance of 15 cm. How far from the objective should an object be placed in order to obtain the final image at the least distance of distinct vision (25 cm) ? Calculate the magnifying power of the microscope.

Ans. Given $f_0 = 2.0$ cm, $f = 6.25$ cm, L = 15 cm, $u_o = ?$, $v_e = -25$ cm, $u_e = ?$

Using the formula $\dfrac{1}{f} = \dfrac{1}{v} - \dfrac{1}{u}$ or $\dfrac{1}{u} = \dfrac{1}{v} - \dfrac{1}{f}$ we

have $\dfrac{1}{u_e} = \dfrac{1}{25} - \dfrac{1}{6.25} = \dfrac{1}{5}$ or $u_e = -5$ cm

Hence $v_0 = L - u_e = 15 - 5 = 10$ cm

Now applying lens formula for objective lens

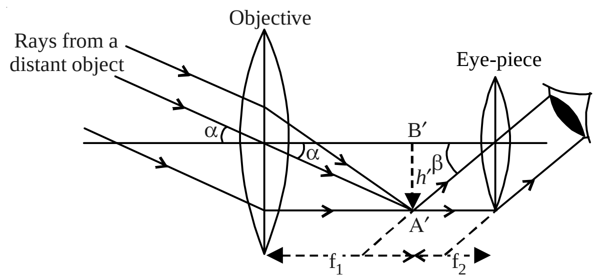
we have $\dfrac{1}{f} = \dfrac{1}{v} - \dfrac{1}{u}$ or $\dfrac{1}{u_0} = \dfrac{1}{v_0} - \dfrac{1}{f_0}$

Or $\dfrac{1}{u_0} = \dfrac{1}{10} - \dfrac{1}{2} = \dfrac{1-5}{10} = \dfrac{4}{10}$ or $u_0 = -2.5$ cm

Now $M = \dfrac{v_0}{u_0}\left(1 + \dfrac{D}{f_0}\right) = -\dfrac{10}{-2.5}\left(1 + \dfrac{25}{6.25}\right) = 20$

Q. 28. Draw a ray diagram of an astronomical refracting telescope in normal adjustment. Obtain an expression for its magnifying power. How can we increase the magnifying power of the telescope?

Ans. The ray diagram is as shown.



The object subtends an angle α at the objective and would subtend essentially the same angle at the unaided eye. Also, since the observers' eye is placed just to the right of the focal point F_2, the angle subtended at the eye by the final image is very nearly equal to the angle β. Therefore,

$M = \dfrac{\beta}{\alpha} = \dfrac{\tan\alpha}{\tan\beta}$ ...(1)

From right triangles ABC and ABC′ as shown in figure, we have

$\tan\alpha = \dfrac{AB}{CB} = \dfrac{h'}{f_0}$ and $\tan\beta = \dfrac{AB}{C'A} = \dfrac{-h'}{f_e}$

substituting the above two equations in

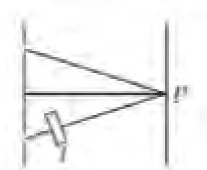
equation 1, we have $M = \dfrac{\beta}{\alpha} = \dfrac{-h'}{f_e} \times \dfrac{f_0}{-h'} = \dfrac{f_0}{f_e}$

The magnifying power can be increased by taking an objective of higher focal length and an eyepiece of lower focal length

SECTION – D

Questions number 29 to 30 are case study based questions

Q. 29. If double slit apparatus is immersed in a liquid of refractive index, *n* the wavelength of light reduces to λ' and fringe width reduces to $\beta' = \beta/n$ The given figure shows a double-slit experiment in which coherent monochromatic light of wavelength λ, from a distant source is incident upon the two slits, each of width w(w >> λ) and the interference pattern is viewed on a distant screen. A thin piece of glass of thickness and refractive index n is placed between one of the silts and the screen, perpendicular to the light path.



(*i*) In Young's double slit interference pattern, the fringe width

(*a*) can be changed only by changing the wavelength of incident light

(*b*) can be changed only by changing the separation between the two slits

(c) can be changed either by changing the wavelength or by changing the separation between two sources.

(*d*) is a universal constant and hence cannot be changed.

Ans. (*c*) In Young's double slit experiment the fringe width is $\beta = D\lambda/d$ where D is the distance of the slits from the screen, d is the separation of the slits and λ, the wavelength. Therefore, the fringe width β can be changed either by changing the separation between the sources or the distance of the screen from the source.

Or

In Young's double slit experiment, a third slit is made in between the double slits then

(*a*) fringes of unequal width are formed

(*b*) contrast between bright and dark fringes is reduced

(*c*) intensity of fringes totally disappears

(*d*) only bright light is observed on the screen.

Ans. (*b*) Contrast between the bright and dark fringes will be reduced. This is because light now passes through three slits instead of two, which reduces the contrast.

(*ii*) If the width w of one of the slits is increased to 2w, the amplitude light, due to the slit will become :

(*a*) 1.5 a (*b*) a/2

(c) 2a (*d*) no change.

Ans. (*c*) As the width of one of the slits is increased to 2w, the amplitude due to slit becomes 2a.

(*iii*) The fringe width observed in Young's double slit experiment is β. If the frequency of the source is doubled, the fringe width will become :

(*a*) 2β (*b*) β

(*c*) $\beta/2$ (*d*) None of these.

Ans. (*c*) $\beta = \dfrac{D\lambda}{d} \Rightarrow \beta \propto \lambda \propto \dfrac{1}{\nu}$

(*iv*) In Young's double-slit experiment, using sodium light λ = 5898 Å, 85 fringes are seen. If another colour (λ = 5461 Å) is used then find the number of fringes.

(*a*) 62 (*b*) 91

(*c*) 99 (*d*) 85.

Ans. (*b*)

Q. 30. Semiconductors may exist as elemental semiconductors and also compound semiconductors. Si and Ge are elemental semiconductor and CdS, GaAs, CdSe, anthracene, polypyrrole etc. are the compound semiconductors. Each electron in an atom has different energy level and such different energy levels continuing forms the band of energy called as energy bands. Those energy bands, which have energy levels of valence electrons, is called as valence band and the energy band which is present above the valence band is called as conduction band. Based on energy bands materials are also defined as metals, semiconductors and insulators. In case of metals, conduction band and valence band overlaps with each other due to which electrons are easily available for conduction. In semiconductors, there is a small energy gap between conduction band and valence band and if we give some external energy then electron from valence band goes to conduction band due to which conduction will be possible. These semiconductors are classified as intrinsic semiconductors and extrinsic semiconductors also. Intrinsic semiconductors are those semiconductors, which exist, in pure form. The semiconductors doped with some impurity in order to increase its conductivity are called as extrinsic semiconductors. Two types of dopants are used they are trivalent impurity and pentavalent impurity also. The extrinsic semiconductors doped with pentavalent impurity like Arsenic, Antimony, Phosphorus etc are called as n - type semiconductors. In n type semiconductors, electrons are the majority charge carriers and holes are the minority charge carriers. When trivalent impurity is like Indium, Boron, Aluminium etc. are added to extrinsic semiconductors then p type semiconductors will be formed. In p type semiconductors holes are majority charge carriers and electrons are the minority charge carriers.

(*i*) In case of p-type semiconductors _______

(*a*) $n_h << n_e$ (*b*) $n_h = n_e$

(*c*) $n_h >> n_e$ (*d*) $n_h = n_e = 0$

Ans. (*c*)

There are more holes than electrons in a p-type semiconductor.

(*ii*) At T = 0 K an intrinsic semiconductor behaves like

(*a*) conductor (*b*) metal

(*c*) non metal (*d*) insulator.

Ans. (*d*)

It does not conduct.

(*iii*) If the energy band gap E_g > 3 eV then such materials are called as :

(*a*) conductors (*b*) semiconductors

(*c*) insulators (*d*) superconductors.

Ans. (*c*)

OR

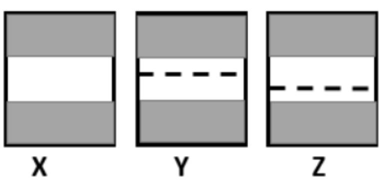
The forbidden gap (approximately) in the energy bands of germanium at room temperature is :

(*a*) 1.1 eV (*b*) 0.1 eV

(*c*) 0.67 eV (*d*) 6.7 eV.

Ans. (*c*)

(*iv*) The energy band diagrams for semiconductor samples of silicon are as shown. We can assert that :



(*a*) Sample X is undoped while samples Y and Z are doped with third group and fifth group impurities respectively

(*b*) Sample X is undoped while samples Y and Z have been doped with fifth group impurities.

(*c*) Sample X has been doped with equal amounts of third group and fifth group impurities.

(*d*) Sample X is undoped while samples Y and Z are doped with fifth group and third group impurities respectively.

Ans. (*d*)

SECTION – E

Q. 31. (*a*) Distinguish with the help of a suitable diagram, the difference in the behaviour of a conductor and a dielectric placed in an external electric field. How does polarized dielectric modify the original external field' ?

(*b*) A capacitor of capacitance C is charged fully by connecting it to a battery of emf E. It is then disconnected from the battery. If the separation between the plates of the capacitor is now doubled, how will the following change' ?

(*i*) charge stored by the capacitor.

(*ii*) field strength between the plates.

(*iii*) energy stored by the capacitor.

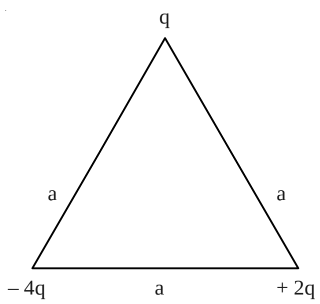
Justify your answer in each case.

OR

(*a*) Explain why, for any charge configuration the equipotential surface through a point is normal to the electric field at that point.

Draw a sketch of equipotential surfaces due to a single charge (-q), depicting the electric field lines due to the charge.

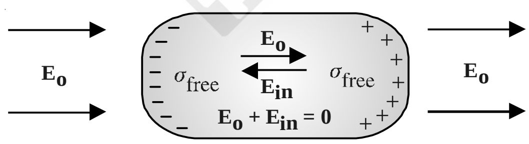
(*b*) Obtain an expression for the work done to dissociate the system of three charges placed at the vertices of an equilateral triangle of side 'a as shown below.



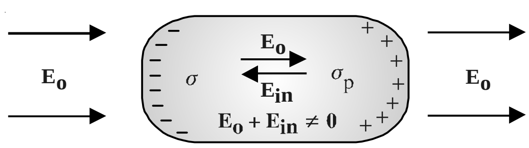
Ans. (*a*) When a conductor is placed in an external electric field. The free charge carriers move and charge distribution in the conductor adjusts itself in such a way that the electric field due to induced charges opposes the external field within the conductor. This happens until, in the static situation, the two fields cancel each other and the net electro static field in the conductor is zero.

In a dielectric, this free movement of charges is not possible. It turns out that the external field induces dipole moment by stretching or re-orienting molecules of the dielectric. The collective effect of all the molecular dipole moments is net charges on the surface of the dielectric which produce a field that opposes the external field. Unlike in a conductor, however, the opposing field so induced does not exactly cancel the external field. It only reduces it. The extent of the effect depends on the nature of the dielectric.

This is diagrammatically shown as under.



Conductor



Dielectric

(*b*) (*i*) Charge does not depend upon the distance between plates, therefore there is no change in it.

(*ii*) Now $C = \dfrac{\varepsilon_0 A}{d}$ as d is doubled capacitance becomes half.

Thus potential V = Q/C becomes double.

Now $E = 2V_0/2d = V_0/d$ remains same.

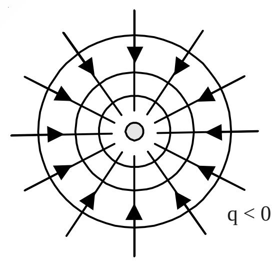
(*iii*) Now $U = \dfrac{1}{2}CV^2$ as C becomes half and V is doubled, U becomes 2 times.

OR

(*a*) We know that work done in moving a charge over an equipotential surface is zero. Therefore $W = \int \vec{E}.\vec{dl} = 0$ or $\vec{E} \perp \vec{dl}$

Now dl represents an equipotential surface therefore electric field is perpendicular to the equipotential surface.

The diagram is as shown.



Let $q_1 = q$, $q_2 = -4q$ and $q_3 = +2q$, then

(*b*) $$U_i = \frac{1}{4\pi\varepsilon_o}\left(\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right)$$

$$U_i = \frac{1}{4\pi\varepsilon_0}\left(\frac{q\times -4q}{a} + \frac{q\times +2q}{a} + \frac{-4q\times +2q}{a}\right)$$

$$= \frac{1}{4\pi\varepsilon_0 a}\left(-4q^2 + 2q^2 - 8q^2\right) = -\frac{1}{4\pi\varepsilon_0}\frac{10q^2}{a}$$

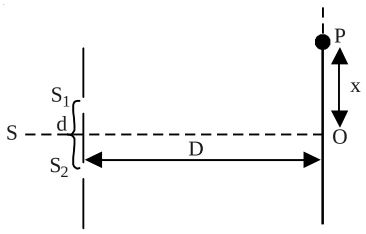
$U_r = 0$

Therefore $W = U_f - U_i$

$$= 0 - \left(-\frac{1}{4\pi\varepsilon_0}\frac{10q^2}{a}\right) = -\frac{1}{4\pi\varepsilon_0}\frac{10q^2}{a}.$$

Q. 32. (***a***) **Can the interference pattern be produced by two independent monochromatic sources of light ? Explain.**

(*b*) The intensity at the central maximum (O) in a Young's double slit experimental set-up shown in the figure is I_0. If the distance OP equals one-third of the fringe width of the pattern, show that the intensity at point P, would equal $I_0/4$



(*c*) In Young's double slit experiment, the slits are separated by 0.5 mm and screen is placed 1.0 m away from the slit. It is found that the 5th bright fringe is at a distance of 4.13 mm from the 2nd dark fringe. Find the wavelength of light used.

OR

(*a*) Derive the relation a sin θ = λ for the first minimum of the diffraction pattern produced due to a single slit of width 'a' using light of wavelength λ.

(*b*) State with reason, how the linear width of central maximum will be affected if (*i*) monochromatic yellow light is replaced with red light, and (*ii*) distance between the slit and the screen is increased.

(*c*) Using the monochromatic light of same wavelength in the experimental set-up of the diffraction pattern as well as in the interference pattern where the slit separation is 1 mm, 10 interference fringes are found to be within the central maximum of the diffraction pattern. Determine the width of the single slit, if the screen is kept at the same distance from the slit in the two cases.

Ans. (*a*) No, a sustained interference will not be obtained. This is because light waves emitted from a source undergoes abrupt phase changes in times of the order of 10^{-8} s. so light from two independent sources will not have a fixed phase relation and will be incoherent.

(*b*) Given $x = \beta/3$, path difference $\lambda/3$

Phase difference $2\pi/3$

Using the expression $I = I_0 \cos^2 \frac{\phi}{2}$ we have

$$I = I_0 \cos^2 \left(\frac{2\pi}{3\times 2}\right) = I_0 \cos^2 \left(\frac{\pi}{3}\right) = \frac{I_0}{4}$$

(*c*) Given $d = 0.5$ mm, D = 1.0 m

$x = y_{5B} - y_{2D} = 4.13 \times 10^{-3}$

Now

$$x = \frac{5\lambda D}{d} - \frac{3\lambda D}{2d} = \frac{7\lambda D}{2d} \Rightarrow \lambda = \frac{2xd}{7D}$$

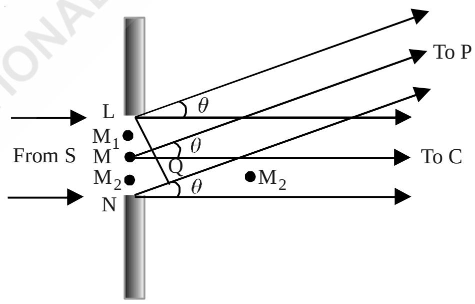
$$\lambda = \frac{2\times 4.13\times 10^{-3}\times 0.5\times 10^{-3}}{7\times 1}$$

$= 0.59 \times 10^{-6}$ m

$\lambda = 590$ nm

OR

(*a*) Consider the diagram shown.



From the diagram the path difference between the waves from L to N = $a \sin\theta$

When first minima is obtained at P then the path difference is λ.

This has been obtained by imagining that the slit is dividied into two halves. Wavelets from the first half interefere with a corresponding wavelength from the second half. As they have a path difference λ/2, therefore they interfere destructively to give rise to a minima.

Hence condition for first minima

$\lambda = a \sin\theta$

(*b*) $\beta_{cm} = \frac{2\lambda D}{d}$

(*i*) Increases

(*ii*) Increases.

(*c*) Given $10\frac{\lambda D}{d} = 2\frac{\lambda D}{a} \Rightarrow a = \frac{d}{5} = 0.2\text{mm}$.

Q. 33. State the working of a.c. generator with the help of a labelled diagram.

The coil of an a.c. genertor having N turns, each of area A. is rotated with a constant angular velocity (*i*). Deduce the expression for the alternating e.m.f. generated in the coil.

What is the source of energy generation in this device?

OR

(a) Show that in an a.c. circuit containing a pure inductor, the voltage is ahead of current by $\pi/2$ in phase.

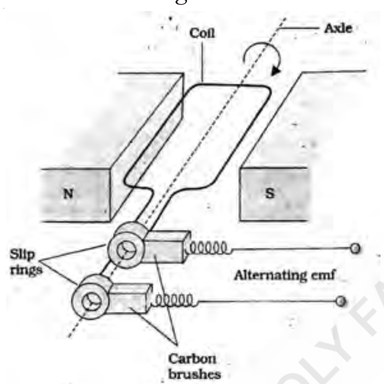
(b) A horizontal straight wire of length L extending from east to west is falling with speed v at right angles to the horizontal component of Earth's magnetic field B.

(*i*) Write the expression for the instantaneous value of the e.m.f. induced in the wire.

(*ii*) What is the direction of the e.m.f. ?

(*iii*) Which end of the wire is at the higher potential ?

Ans. (*i*) The labelled diagram is as shown



Working : When a coil (armature) rotates inside a uniform magnetic field, magnetic fjux linked with the coil changes w.r.t. time. This produces an e.m.f according to Faraday's Law. For first half of the rotation to Faraday's Law. For first half of the rotation the current will be from one end (first ring) to the other end (second ring). For Second half of the rotation it is in oppsite sense.

(b) Consider an armature of the ac generator having n turns and placed in a uniform magnetic field B.

Suppose at any instant t the normal to the plane of the coil makes an angle θ with the direction of the magnetic field. If ω is the uniform angular velocity with which, the coil rotates then $\theta = \omega t$.The flux through the loop equals its area A multiplied by $B_1 = B \cos\theta$, the components of magnetic field B perpendicular to the area, hence

$\phi = n B A \cos\phi = n B A \cos\omega t$ ... (1)

Where is the number of turns in the armature. By Faraday's flux rule,

$$\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt} n \text{ B A} \cos\omega t$$

$$= -n \text{ B A} \frac{d}{d\phi} \cos\omega t = -n \text{ B A} (-\omega \sin\omega t) \quad \text{... (2)}$$

Or $\varepsilon = n$ B A $\sin\omega t$

The induced emf is maximum when = $\sin\omega t$ = maximum = 1, therefore the maximum induced emf is given by $\varepsilon_0 = n$ B A ω Sin ωt ...(3)

Or $\varepsilon = \varepsilon_0 \sin\omega t$

The source of energy generation in the coil is mechanical energy.

OR

(a) Consider an ac circuit consisting of a pure inductor connected to the terminals of an ac source. Let the instantaneous value of the ac source be

$$V = V_m \sin\omega t \quad \text{... (1)}$$

Let v_L be the instantaneous voltage drop across the inductor, then Kirchoff's loop rule when applied to the circuit gives $\rho + V_L = 0$

$$\text{Or } v - L\frac{di}{dt} = 0 \quad \text{... (2) Since}$$

$$V_L = -L\frac{di}{dt}$$

$I_L = I_m \sin(\omega t - \pi/2)$

Using equations 1 and 2 we have

$$L\frac{di}{dt} = V_m \sin\omega t \;. \quad \text{...(3)}$$

$$\text{Or } di = \frac{V_m}{L}\sin\omega t \quad \text{....(4)}$$

Integrating the above equation we have

$$\int di = \int\frac{V_m}{L}\sin\omega t\, dt \quad \text{...(5)}$$

$$\text{or } i_L = -\frac{V_m}{\omega L}\cos\omega t = -I_m\cos\omega t \quad \text{...(6)}$$

where $\frac{V_m}{\omega L} = I_m$, $\omega L = X_L$ has the dimensions of resistance and is called the inductive reactance of the circuit.

Now $\cos\omega t = -\sin(\omega t - \pi/2)$ in equation 6 we have

...(7)

Comparing equation 1 with equation 7 clearly shows that the current is lags voltage by radian or 90^0.

(b) (*i*) ε = BLv (*ii*) west to east (*iii*)East.

Holy Faith New Style Sample Paper—5

(Based on the Latest Design & Syllabus issued by C.B.S.E.)

CLASS – 12th

PHYSICS (Theory)

Time allowed : 3 hours **Maximum Marks : 70**

General Instructions : Same as in MTP – 1

SECTION – A

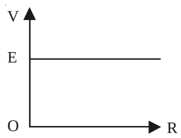
Q. 1. A charge particle is placed between the plates of a charged parallel plate capacitor. It experiences a force F. If one of the plates is removed, the force on the charge particle becomes :

(*a*) F (*b*) 2F (*c*) F/2 (*d*) Zero.

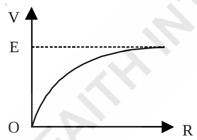
Ans. (*c*) F/2.

Q. 2. A cell of emf (E) and internal resistance r is connected across a variable external resistance R. The graph of terminal potential difference V as a function of R is :

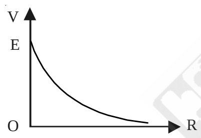
(*a*)



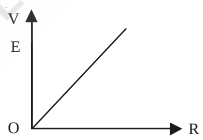
(*b*)



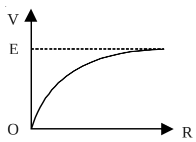
(*c*)



(*d*)



Ans. (*b*)



Q. 3. The potential difference applied across a given conductor is doubled. The mobility of the electrons in the conductor :

(*a*) is doubled

(*b*) is halved

(*c*) remains unchanged

(*d*) becomes four times.

Ans. (*b*) is halved.

Q. 4. A circular loop of radius r, carrying a current I lies in y-z plane with its centre at the origin. The net magnetic flux through the loop is

(*a*) directly proportional to r

(*b*) zero

(*c*) inversely proportional to r

(*d*) directly proportional to I.

Ans. (*b*) zero.

Q. 5. A capacitor and an inductor are connected in two different ac circuits with a bulb glowing in each circuit. The bulb glows more brightly when:

(*a*) the number of turns in the inductor is increased

(*b*) the separation between the plates of the capacitor is increased

(*c*) an iron rod is introduced into the inductor

(*d*) a dielectric is introduced into the gap between the plates of the capacitor.

Ans. (*d*) a dielectric is introduced into the gap between the plates of the capacitor.

Q. 6. A pure inductor of 318 mH and a pure resistor of 75 Ω are connected in series to an ac source of 50 Hz. The voltage across 75 Ω resistor is found to be 150 V. The source voltage is :

(*a*) 150 V (*b*) 175 V

(*c*) 220 V (*d*) 250 V.

Ans. (*d*) 250 V.

Q. 7. Rank the following radiations according to their associated energies, greatest first.

I. Yellow light from a sodium lamp.

II. γ - rays emitted by a radioactive nucleus.

III. Radio waves emitted by the antenna.
IV. Microwaves beam emitted by radar.
(*a*) II, I, IV, III (*b*) I, II, III, IV
(*c*) III, IV, I, II (*d*) I, II, IV, III.

Ans. (*a*) II, I, IV, III.

Q. 8. The maximum kinetic energy of the photoelectrons depends only on :
(*a*) potential (*b*) frequency
(*c*) incident angle (*d*) pressure.

Ans. (*b*) frequency.

Q. 9. A particle is dropped from a height H. The de-Broglie wavelength of the particle as a function of height is proportional to :
(*a*) H (*b*) $H^{1/2}$
(*c*) H^0 (*d*) $H^{-1/2}$.

Ans. (*d*) $H^{-1/2}$.

Q. 10. As one consider orbits with higher values of n in a hydrogen atom, the electric potential energy of the atom :
(*a*) decreases (*b*) increases
(*c*) remains the same (*d*) does not increase

Ans. (*b*) increases.

Q. 11. For the depletion region of a diode which one is incorrect ?
(a) there are no mobile charges
(*b*) equal number of holes and electrons exist, making the region neutral.
(*c*) recombination of holes and electrons has taken place.
(*d*) immobile charged ions exist.

Ans. (*a*) there are no mobile charges.

Q. 12. In an n-type silicon, which of the following Assertions true :
(*a*) Electrons are majority carriers and trivalent atoms are the dopants.
(*b*) Electrons are minority carriers and pentavalent atoms are the dopants.
(*c*) Holes are minority carriers and pentavalent atoms are the dopants.
(*d*) Holes are majority carriers and trivalent atoms are the dopants.

Ans. (*c*) Holes are minority carriers and pentavalent atoms are the dopants.

Questions number 13 to 16 are Assertion (A) and Reason (R) type questions.
Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (*a*), (*b*), (*c*) and (*d*) as given below.

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

Q. 13. Assertion (A) : Ohm's Law is not valid, if current depends on voltage non-linearly.
Reason (R) : Ohm's Law is a fundamental Law of nature.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

Q. 14. Assertion (A) : When a charged particle moves with velocity $\vec{V}$ in a magnetic field $\vec{B}$, the force on the particle does no work.
Reason (R) : The magnetic force is perpendicular to the velocity of the particle.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A).

Q. 15. Assertion (A) : Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion.
Reason (R) : For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei it decreases with increasing Z.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

Q. 16. Assertion : Electron has higher mobility than hole in a semiconductor.
Reason : The mass of electron is less than the mass of the hole.

Ans. (*a*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

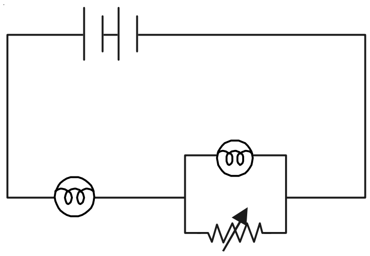
SECTION – B

Q. 17. (*a*) Electric field inside a conductor is zero. Explain.
(*b*) The electric field due to a point charge at any point near it is given as $E = \underset{q \to 0}{Lt} \frac{E}{q}$. What is the physical significance of this limit ?

Ans. (*a*) By Gauss's Theorem $\oint \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$. Since there is no charge inside a conductor, therefore in accordance with the above equation the electric field inside the conductor is zero.

(*b*) It indicates that the test charge should be infinite simally small so that it maynot disturb the electric field of source charge.

Q. 18. The circuit shown in the diagram contains a battery 'B', a rheostat 'Rh' and identical lamps P and Q. What will happen to the brightness of the lamps if the resistance through the rheostat is increased ? Give reason.



Ans. The sum of the potential drops across lamps P and Q is constant (equal to the battery voltage). As the resistance through the rheostat is increased, the resistance of the parallel combination and hence the total resistance increase. This decreases the current in the whole circuit. This will decrease the brightness of lamp P. However, the brightness of lamp Q increases because its resistance does not change, while the potential difference across it increases due to the decrease in potential difference across P.

Q. 19. A coil of 'N' turns and radius 'R' carries a current 'I'. It is unwound and rewound to make a square coil of side 'a' having same number of turns (N). Keeping the current 'I' same, and the ratio of the magnetic moments of the square coil and the circular coil.

Ans. The magnetic moment of a current loop is given by the relation M = nIA

For the circular loop $M_C = NI\pi R^2$ ...(1)

Now when the coil is unwound and rewound to make a square coil, then

$2\pi R = 4a$ or $a = \pi /2$

Hence magnetic moment of the square coil is

$M_S = NI\ a^2 = NI\ (\pi R/2)^2 = NI\ \pi^2\ R/4$ ...(2)

From 1 and 2 we have

$$\frac{M_S}{M_C} = \frac{NI\pi^2R^2/4}{NI\pi R^2} = \frac{\pi}{4}$$

Q. 20. Two wires of equal length are bent in the form of two loops. One of the loops is square shaped and the other is circular. These are suspended in a uniform magnetic field and the same current is passed through them. Which loop will experience a greater torque? Give reasons.

OR

A straight wire of length *L* carrying a current *I*, stays suspended horizontally in mid-air in a region where there is a uniform magnetic field *B*. The linear mass density of the wire is *l*. Obtain the magnitude and direction of the magnetic field.

Ans. Torque experienced by a current-carrying loop placed in a uniform magnetic field is given by the expression BInA. In other words, torque is directly proportional to the area of the loop. Since a circular wire has more area than a square wire for the same dimension, therefore the circular wire experiences more torque than the square wire.

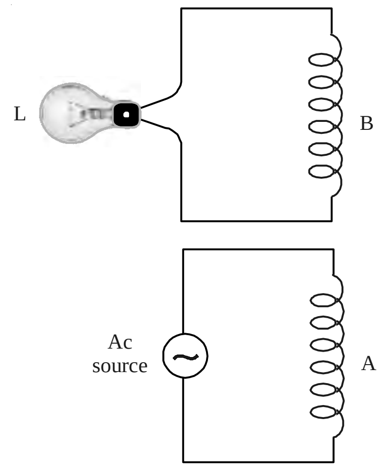
OR

The magnetic force acting on the straight wire balances the weight of the wire. Therefore, in equilibrium we have

$Mg = BIL$, here $M = L\ \lambda$, therefore we have

$L\ \lambda\ g = BIL$ or $B = \lambda/I\ g$

Q. 21. In the given diagram coil Bis connected to a low voltage bulb L and placed parallel to another coil A as shown. Explain the following observations (*i*) Bulb lights, and (*ii*) Bulb gets dimmer if coil B is moved upwards.



Ans. (*i*) When ac is applied across coil A an induced emf is produced in coil B due to mutual induction between the two coils. This makes the lamp light up.

(*ii*) When coil B is moved upwards the mutual induction and have induced emf in coil B dereases. This makes the lamp dimmer.

SECTION – C

Q. 22. (*a*) (*i*) Arrange the following electro magnetic radiations in the ascending order of their frequencies: X-rays, microwaves, gamma rays, radio waves

(*ii*) Write one uses of any two of these radiations.

OR

(*b*) Name the electromagnetic waves which are produced by the following:

(*i*) Radioactive decays of the nucleus

(*ii*) Welding arcs

(*iii*) Hot bodies

Write one use of each of these waves.

Ans. (*i*) Radio waves < Microwaves < X-rays < gamma rays

(*ii*) **Microwaves :** communication

X-rays : Medical diagnoses

OR

(*i*) Gamma rays

(*ii*) UV rays

(*iii*) Infrared rays

Gamma rays: These are used in medicine to destroy cancer cells.

UV rays: UV lamps are used to kill germs in water purifiers.

Infrared rays: These are used in remote switches of household electronic systems.

Q. 23. A proton and an electron have same kinetic energy. Which one has greater de-Broglie wavelength and why?

Ans. The de-Broglie wavelength is given by the expression $\lambda = \frac{h}{\sqrt{2mE}}$; since E is same, therefore $\lambda \propto \frac{1}{\sqrt{m}}$. An electron has less mass than a proton; therefore it has a greater de-Broglie wavelength than a proton.

Q. 24. The work function, for a given photosensitive surface, equals 2.5 eV. When light of frequency falls on this surface, the emitted photoelectrons are completely stopped by applying a retarding potential of 4.1 V. What is the value of ?

Ans. Given ω_0 = 2.5 eV, V_0 = 4.1 V, ?

Using the relation

$eV_0 = hv - \omega_0$

we have

$$v = \frac{eV_0 + \omega_0}{h} = \frac{(4.1+2.5)\times 1.6\times 10^{-19}}{6.6\times 10^{-34}}$$

$= 3.88 \times 10^{14}$ Hz

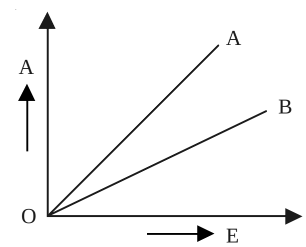
Q. 25. Plot a graph showing the variation of current density (J) versus the electric field (E) for two conductors of different materials. What information from this plot regarding the properties of the conducting material, can be obtained which can be used to select suitable materials for use in making (*i*) standard resistance and (*ii*) connecting wires in electric circuits?

Electrondrift speed is estimated to be of the order of mm s^{-1}. Yet large current of the order of few amperes can be set up in the wire. Explain briefly.

Ans. We know that J = σ E

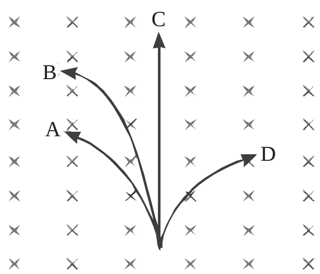
Therefore, the graph between *J* and *E* will be a straight line passing through the origin.

This is as shown.



The slope of the graph conductivity (σ). Hencematerial with less slope (smaller conductivity) is used for making standard resistors and material with greater slope (higher conductivity) for making connecting wires. Large current can be set up in the wire because the electron number density is enormous, 10^{29} m^{-3}

Q. 26. A neutron, a proton, an electron and ana -particle enter a region of constant magnetic field with equal velocities. The magnetic field is along the inward normal to the plane of the paper. The tracks of the particles are labelled in figure. Relate the tracks to the four particles. Justify your answer.



Ans. (*i*) For a neutron, q = 0, soF = qv B sin θ = 0. That is, a neutron goes undeflected through the magnetic field. Therefore, the track C corresponds to neutron.

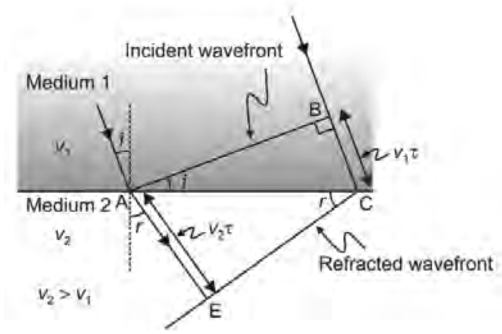
(*ii*) According to Fleming's left-hand rule, a negatively charged particle such asan electron will be deflected towards right. Therefore, the track D corresponds toan electron.

(*iii*) According to Fleming's left-handrule, a positively charged particlesuch as an α-particle or a proton will be deflected towards left. Its radii ofcurvature is given by the expression $r = \frac{mv}{Bq}$. Now for a proton and analpha particle, we have. Thus, the track B corresponds to an-α particle, and track A to a proton.

Q. 27. Define the term, "refractive index" of a medium. Verify Snell's law of refraction when a plane wavefront is propagating from a denser to a rarer medium.

Ans. The refractive index of medium 2, w.r.t. medium 1 equals the ratio of the sine of angle of incidence (in medium 1) to the sine of angle of refraction (in medium 2).

The diagram is as shown.



From diagram

$$\sin i = \frac{BC}{AC} = \frac{v_1\tau}{AC}$$

and $$\sin r = \frac{AE}{AC} = \frac{v_2\tau}{AC}$$

Therefore $$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = n_{12}$$

Q. 28. Yellow light (6000 Å) illuminates a single-slit of width 1 × 10^{-4} m. Calculate

(*a*) the distance between the two dark lines on either side of the central maximum, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit;

(*b*) the angular spread of the first diffraction minimum.

OR

A prism is made of glass of unknown refractive index. A parallel beam of light is incident on a face of the prism. By rotating the prism, the angle of minimum deviation is measured to be 40°. What is the refractive index of the material of the prism ? If the prism is placed in water (refractive index 1.33), predict the new angle of minimum deviation of a parallel beam of light. The refracting angle of the prism is 60°.

Ans. Given 6000 Å, d =10^{-4} m, 2β = ?, D= 2.5 m, θ = ?

(*a*) Using the expression

$$\beta = \frac{2D\lambda}{d} = \frac{2\times2.5\times6000\times10^{-10}}{1\times10^{-4}} = 3\times10^{-2} \text{ m}$$

(*b*) $\theta = \frac{\lambda}{d} = \frac{6000\times10^{-10}}{1\times10^{-4}} = 6\times10^{-3}$ rad

OR

Given that $\delta_m = 40°$, ${}_a\mu_g = ?$, ${}_a\mu_w = 1.33$, $A = 60°$

Using the relation

$${}_a\mu_g = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}} - \frac{\sin\left(\frac{60+40}{2}\right)}{\sin\frac{60}{2}} = \frac{\sin 50°}{\sin 30°} = \frac{0.7660}{0.5000}$$

= 1.53

Now when the prism is placed in water we have

$${}_w\mu_g = \frac{{}_a\mu_g}{{}_a\mu_w} - \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

$$\frac{1.53}{1.33} = \frac{\sin\left(\frac{60°+\delta_m}{2}\right)}{\sin\frac{60°}{2}} = \frac{\sin\left(\frac{60°+\delta_m}{2}\right)}{0.5}$$

Solving for δ_m we have $\delta_m = 10°$.

SECTION – D

Questions number 29 to 30 are case study based questions.

Q. 29. The British physicist Thomas Young explained the interference of light using the principle of superposition of waves. He observed the interference pattern on the screen, in his experimental set-up, known now as Young's double slit experiment. The two slits S_1 and S_2 were illuminated by light from a slit S. The interference pattern consists of dark and bright bands of light. Such bands are called fringes. The distance between two consecutive bright and dark fringes is called fringe' width.

(*i*) If the screen is moved closer to the plane of slits S_1 and S_2, then the fringe width:

(*a*) will decrease, but the intensity of bright fringe remains the same.

(*b*) will increase, but the intensity of bright fringe decreases.

(*c*) will decrease, but the intensity of bright fringe increases.

(*d*) and the intensity both remain the same.

Ans. (*c*) will decrease, but the intensity of bright fringe increases.

This is because $\beta = \frac{D\lambda}{d}$. As D decreases

β decreases. Also $1 \propto \frac{1}{D^2}$

(*ii*) What will happen to the pattern on the screen, when the two slits S_1 and S_2 are replaced by two independent but identical sources?

(*a*) The intensity of pattern will increase

(*b*) The intensity of pattern will decrease

(*c*) The number of fringes will become double

(*d*) No pattern will be observed on the screen.

Ans. (*d*) No pattern will be observed on the screen. There will be general illumination on the screen

(*iii*) Two sources of light are said to be coherent, when both emit light waves of

(*a*) same amplitude and have a varying phase difference

(*b*) same wavelength and a constant phase difference

(*c*) different wavelengths and same intensity

(*d*) different wavelengths and a constant phase difference.

Ans. (*b*) same wavelength and a constant phase difference.

Sources should can't same wavelengths having zero or constant phase difference.

(*iv*) The fringe width in a Young's double slit experiment is β ?'. If the whole set-up is immersed in a liquid of refractive index 'μ', then the new fringe width will be:

(*a*) β (*b*) $\beta\mu$

(*c*) $\frac{\beta}{\mu}$ (*d*) $\frac{\beta}{\mu^2}$.

Ans. (*c*) Fringe width will decrease and become $\frac{1}{\mu}$ of the original fringe width.

OR

The total path difference between two waves meeting at points P_1 and P_2 on the screen are $\left(\frac{3\lambda}{2}\right)$ and 2λ respectively.

Then :

(*a*) bright fringes are formed at both points.

(*b*) dark fringes are formed at both points.

(*c*) a bright fringe is formed at P_1 and a dark fringe is formed at P_2.

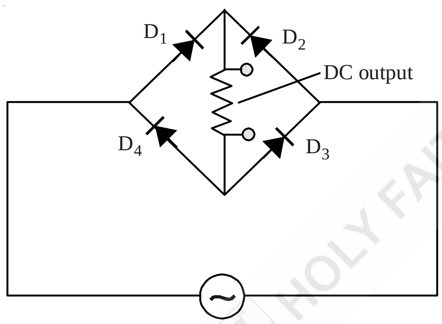
(*d*) a bright fringe is formed at P_2 and a dark fringe is formed at P_1.

Ans. (*d*) For bright fringes, path difference = even multiple of λ

For dark fringes, path difference odd multiple of λ.

Q. 30. A rectifier is an arrangement which converts AC into pulsating DC. It is of the following types:

(*i*) Half-wave rectifier, (*ii*) Full-wave rectifier and (*iii*) Bridge rectifier. A bridge rectifier comprises 4 diodes. An AC supply of + 10, –10 V, 50 Hz frequency and a resistance of 10 W are applied across it. A CRO (cathode ray oscilloscope) is used to note the AC input and DC output. The efficiency of this circuit is measured to be 81.2%.



The form factor is worked out as

$$\text{form factor} = \frac{\text{rms value of output}}{\text{average value of output}}$$

The peak factor is worked out as $\frac{\pi}{2\sqrt{2}} = 1.1$

$$\text{Peak factor} = \frac{\text{peak value of output}}{\text{rms value of output}} = \frac{V_o}{V_0/2}$$

$$= 2$$

Using the above information and concepts of semiconductor devices, answer the following questions:

(*i*) A bridge rectifier consists of :

(*a*) 1 diode (*b*) 2 diodes

(c) 3 diodes (*d*) 4 diodes.

Ans. (*d*) 4 diodes.

(*ii*) The efficiency of a rectifier is given by :

(*a*) DC output current/AC input current

(*b*) AC output current/DC input current

(*c*) DC output power/AC input power

(*d*) AC input power/DC input power.

Ans. (*c*) DC output power/AC input power.

(*iii*) A large form factor means :

(*a*) that power loss is small

(*b*) that power loss is large

(*c*) that waveforms of input and output are same

(*d*) high waveform distortion.

Ans. (*d*) high waveform distortion.

(*iv*) A diode rectifier without a filter circuit gives :

(*a*) pure DC output

(*b*) ripples in the output

(*c*) full sine wave output

(*d*) none of these.

Ans. (*b*) ripples in the output.

OR

(*iv*) The efficiency of a bridge rectifier is :

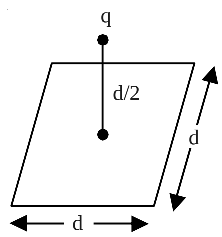
(*a*) 40.1% (*b*) 80.2%

(*c*) 100% (*d*) none of the above.

Ans. (*b*) 80.2%.

SECTION – E

Q. 31. (*a*) Define electric flux. Is it a scalar or a vector quantity ?



A point charge *q* is at a distance of *d*/2 directly above the centre of a square of side *d*, as shown in the figure. Use Gauss' law to obtain the expression for the electric flux through the square.

(*b*) If the point charge is now moved to a distance '*d*' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected.

OR

(*a*) Use Gauss' law to derive the expression for the electric field (E) due to a straight uniformly charged infinite line of charge density λ C m^{-1}.

(*b*) Draw a graph to show the variation of E with perpendicular distance *r* from the line of charge.

(*c*) Find the work done in bringing a charge *q* from perpendicular distance r_1 to r_2 ($r_2 > r_1$).

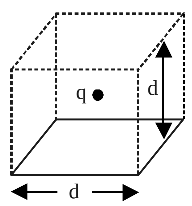
Ans. (*a*) Electric flux through a given surface is defined as the dot product of electric field and area vector over that surface.

It is a scalar quantity

Constructing a cube of side "*d*" so that charge „*q*" gets placed within of this cube (Gaussian surface)

According to Gauss's law the Electric flux

$$\phi = \frac{q}{\varepsilon_0}$$



This is the total flux through all the six faces of the cube.

Hence electric flux through the square

$$\phi = \frac{1}{6}\frac{q}{\varepsilon_0}$$

(*b*) If the charge is moved to a distance d and the side of the square is doubled the cube will be constructed to have a side 2d but the total charge enclosed in it will remain the same. Hence the total flux through the cube and therefore the flux through the square will remain the same as before.

OR

(*a*) To calculate the electric field, imagine a cylindrical Gaussian surface, since the field is everywhere radial, flux through two ends of the cylindrical Gaussian surface is zero.

At cylindrical part of the surface electric field E is normal to the surface at every point and its magnitude is constant.

Therefore flux through the Gaussian surface.

= Flux through the curved cylindrical part of the surface.

$= E \times 2\pi rL$ ...(*i*)

Applying Gauss's Law

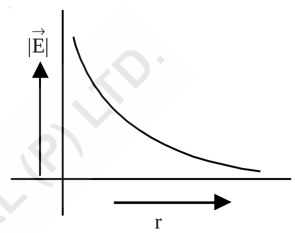
The flux is given by

$$\phi = \frac{q}{\varepsilon_0} = \frac{\lambda L}{\varepsilon_0} \quad ...(ii)$$

From eqn (*i*) and (*ii*) we have

$$E \times 2\pi rL = \frac{\lambda L}{\varepsilon_0} \Rightarrow E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

(*b*) The required graph is



(*c*) Work done in moving the charge "q". Through a small displacement 'dr'

$$dW = \vec{F}.d\vec{r} = q\vec{F}.dr$$

$dW = qEdr \cos 0 = qEdr$

Hence work done in moving the charge from r_1 to r_2($r_2 > r_1$)

$$W = \int_{r_1}^{r_2} \frac{\lambda q dr}{2\pi\varepsilon_0 r} = \frac{\lambda q}{2\pi\varepsilon_0}[\text{In } r_2 - \text{In } r_1]$$

$$W = \frac{\lambda q}{2\pi\varepsilon_0}\left[\text{In}\frac{r_2}{r_1}\right]$$

Q. 32. (*a*) **Draw a ray diagram to show image formation when the concave mirror produces a real, inverted and magnified image of the object.**

(*b*) **Obtain the mirror formula and write the expression for the linear magnification.**

(*c*) **Explain two advantages of a reflecting telescope over a refracting telescope.**

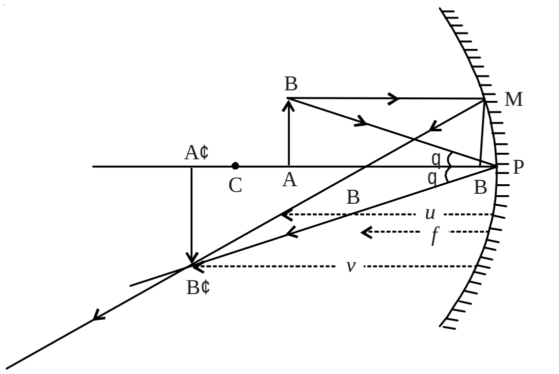
OR

(*a*) **Define a wavefront. Using Huygens' Principle, verify the laws of reflection at a plane surface.**

(*b*) In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band? Explain.

(*c*) 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 obstacle. Explain why.

Ans. (*a*) The ray diagram is as shown



(*b*) In the above figure

Δ BAP and ΔB 'A' P are similar

$$\Rightarrow \frac{BA}{B'A'} = \frac{PA}{PA'} \quad ...(i)$$

similarly, Δ MNF and ΔB 'A' F are similar

$$\Rightarrow \frac{MN}{B'A'} = \frac{NF}{FA'} \quad ...(ii)$$

As MN = BA

NF ≈ PF

FA' = PA' – PF

∴ equation (*ii*) takes the following form

$$\frac{BA}{B'A'} = \frac{PF}{PA' - PF} \quad ...(iii)$$

Using equation (*i*) and (*iii*)

$$\frac{PA}{PA'} = \frac{PF}{PA' - PF}$$

For the given figure, as per the sign convention,

PA = – u

PA' = – *v*

PF = – f

$$\Rightarrow \frac{-u}{-v} = \frac{-f}{-v-(-f)}$$

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

uv – uf = vf

Dividing each term by uvf, we get

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

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

Linear magnification $= -{}^{v}\!/_{u}$, (alternatively $m = \frac{h_1}{h_0}$)

(c) Advantages of reflecting telescope over refracting telescope

(*i*) Mechanical support is easier

(*ii*) Magnifying power is large

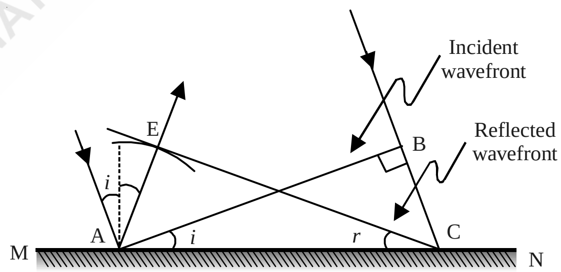
(*iii*) Resolving power is large

(*iv*) Spherical aberration is reduced

(*v*) Free from chromatic aberration

OR

(*a*) The wave front is the locii of all points that are in the same phase



Let speed of the wave in the medium be „*v*'

Let the time taken by the wave front, to advance from point B to point C is 'τ'

Hence BC = *v* τ

Let CE represent the reflected wave front

Distance AE = *v* τ = BC

Δ AEC and Δ are congruent

∴ ∠BAC = ∠ ECA

⇒ $\angle i = \angle r$

(*b*) Size of central maxima reduces to half,

(Size of central maxima = 2λD/*a*)

Intensity increases.

This is because the amount of light, entering the slit, has increased and the area, over which it falls, decreases.

(*c*) This is because of diffraction of light. Light gets diffracted by the tiny circular obstacle and reaches the centre of the shadow of the obstacle.

Q. 33. (*a*) Using postulates of Bohr's theory of hydrogen atom, show that

(*i*) the radii of orbits increases as n^2, and

(*ii*) the total energy of the electron increases as $1/n^2$, where n is the principal quantum number of the atom.

(*b*) Calculate the wavelength of H_2 line in Balmer series of hydrogen atom, given Rydberg constant R = 1.097 × 10^7 m^{-1}.

Or

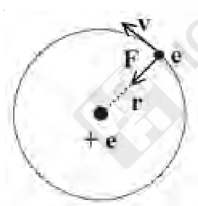
(*a*) Consider the D-T reaction (deuterium tritium fusion) given by the equation:

$${}_1^2H + {}_1^3H + {}_2^4H + n$$

Calculate the energy released in MeV in this reaction from the data: m(n) = 1.008665 u m(^{2}H) = 2.014102 u, m (^{3}H) = 3.016049 u, m (^{4}He) = 4.002603 u

(*b*) Explain, giving necessary reactions, how energy is released during (*i*) fission and (*ii*) fusion.

Ans. (*a*) (*i*) Let us consider a mechanical model of the hydrogen atom as shown in the figure.



This atom consists of a single electron with mass m and charge – *e* revolving around a single proton of charge + *e*. As the electron revolves around the nucleus the electrostatic force of attraction between the electron and the proton provides the necessary centripetal force. Therefore we have

$$k\frac{e^2}{r_n^2} = \frac{mv^2}{r_n} \quad ...(1) \text{ or}$$

$$k\frac{e^2}{r_n} = mv^2 \quad ...(2)$$

By Bohr's quantization condition we have

$$m v r = \frac{nh}{2\pi}$$

$$\text{or } v = \frac{nh}{2\pi m r_n} \quad ...(3)$$

substituting equation 3 in equation 2 we have

$$k\frac{e^2}{r_n} = m\left(\frac{nh}{2\pi m r_n}\right)^2 \quad ...(4)$$

Solving for *r* we have $r_n = \frac{n^2 h^2}{4\pi^2 m e^2 k}$ ...(5)

This gives the radius of the nth orbit of the hydrogen atom which shows that $r \alpha n^2$

(*ii*) The total energy possessed by an electron in the nth orbit of the hydrogen atom is given by

E = T + U ...(1)

i.e., the sum of its kinetic and electrostatic potential energies.

An electron of mass m moving around the nucleus with an orbital velocity v has a kinetic energy given by

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}\frac{k e^2}{r} \quad ...(2)$$

Now the potential energy of the electron at a distance *r* from the nucleus is given by

PE = potential due to the nucleus at a distance r × charge on the electron = V × – e ...(3)

Now the potential at a distance *r* from the nucleus having a charge e is given by

$$V = k\frac{e}{r} \quad ...(4)$$

substituting in equation 2 we have

$$P.E = V \times -e = -k\frac{e^2}{r} \quad ...(5)$$

Substituting equations 2 and 5 in equation 1 we have

$$E = K.E. + P.E. = \frac{1}{2}\frac{ke^2}{r} - \frac{ke^2}{r} = -\frac{1}{2}\frac{ke^2}{r} \quad ...(6)$$

But the radius of the nth orbit is given by

$$r_n = \frac{n^2h^2}{4\pi^2 me^2 k} \quad ...(7)$$

substituting in equation 6 we have

$$E = -\frac{2\pi^2 me^4k^2}{n^2h^2} \quad ...(7)$$

This gives the expression for the energy possessed by the electron in the nth orbit of the hydrogen atom which shows that

(*b*) For H_2 line in Balmer series $n_1 = 2$ and $n_2 = 3$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left[\frac{1}{4} - \frac{1}{9}\right] = 1.097 \times 10^7 \times \frac{5}{36}$$

Or $\lambda = 656.3$ nm

OR

(*a*) The net reaction is ${}^2_1H + {}^3_1H + {}^4_2H + n + Q$

Now energy released in the reaction

$$Q = \left[m_N\left({}^2_1H\right) + m_N\left({}^3_1H\right) - m_N\left({}^4_2He\right) - m_n\right]c^2$$

Adding and subtracting 2 m_e, we get

$$Q = \left[\left(m_N\left({}^2_1H\right) + m_e\right) + \left(m_N\left({}^3_1He + m_e\right)\right)\right]$$

$$-\left[m_N\left({}^4_2He\right) + 2m_e - m_n\right]c^2$$

$$Q = \left[m\left({}^2_1H\right) + m\left({}^3_1H\right) - m\left({}^4_2He\right) - m_n\right]c^2$$

= [2.014102 + 3.016049 - 4.002603 -1.008665] × 931.5 MeV

= 0.018883 × 931 MeV = 17.58 MeV.

(*b*) **Nuclear Fission :** It is a process in which a heavy nucleus splits up into two lighter nuclei of nearly equal masses. It is found that the sum of the masses of the products nuclei and particles is less than the sum of the masses of the reactants *i.e.*, there is some mass defect. This mass defect appears as energy. One such fission reaction is given below:

$${}^{235}_{92}U + {}^1_0 n \rightarrow {}^{236}_{92}U^* \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^1_0n + \text{energy}$$

The Q value of the above reaction is about 200 MeV. The sum of the masses of Ba, Kr and 3 neutrons is less than the sum of the masses of U and one neutron.

Nuclear Fusion : It is the process in which two lighter nuclei combine together to form a heavy nucleus. For fusion very high temperature of I is required. One such fusion reaction is given below:

$${}^2_1H + {}^2_1H \longrightarrow {}^4_2He + 24\text{ MeV}$$

The Q value of this nuclear reaction is 24 MeV. It is the energy equivalent of the mass defect in the above reaction. The energy released per fusion is much less than in fusion but the energy released per unit mass is much greater than that released in fission.

Holy Faith New Style Sample Paper—6

(Based on the Latest Design & Syllabus issued by C.B.S.E.)

CLASS – 12th

PHYSICS (Theory)

Time allowed : 3 hours **Maximum Marks : 70**

General Instructions : Same as in MTP – 1

SECTION – A

Q.1. An electric dipole placed in a non-uniform electric field will experience :

(*a*) only a force

(*b*) only a torque

(*c*) both force and torque

(*d*) neither force nor torque.

Ans. (*c*) both force and torque.

Q. 2. Two wires A and B, of the same material having length in the ratio 1 : 2 and diameter in the ratio 2 : 3 are connected in series with a battery. The ratio of the potential differences (V_A / V_B) across the two wires respectively is :

(*a*) $\frac{1}{3}$ (*b*) $\frac{3}{4}$

(*c*) $\frac{4}{5}$ (*d*) $\frac{9}{8}$

Ans. (*d*) $\frac{9}{8}$.

Q. 3. A battery of 15 V and negligible internal resistance is connected across a 50 Ω resistor. The amount of energy dissipated as heat in the resistor in one minute is :

(*a*) 122 J (*b*) 270 J

(*c*) 420 J (*d*) 720 J

Ans. (*b*) 270 J.

Q. 4. Two electrons of charge 'e' each move in the same circular path of radius 'r' with a constant speed '*v*' each. The magnetic moment associated with the motion of these electrons is :

(*a*) *evr* (*b*) *evr*/2

(*c*) *ev* (*d*) $\frac{4\pi^2 r^3 e}{v}$.

Ans. (*b*) *evr*/2.

Q. 5. A metal plate is getting heated. Which one of following statements is *incorrect* ?

(*a*) It is placed in a space varying magnetic field that does not vary with time.

(*b*) A direct current is passing through the plate.

(*c*) An alternating current is passing through the plate.

(*d*) It is placed in a time varying magnetic field.

Ans. (*a*) It is placed in a space varying magnetic field that does not vary with time.

Q. 6. The emf induced in a 10 H inductor in which current changes from 11 A to 2 A in 9×10^{-1} s is :

(*a*) 10^4 V (*b*) 10^3 V

(*c*) 10^2 V (*d*) 10 V

Ans. (*c*) 10^2 V.

Q. 7. The frequencies of X-rays, γ-rays and ultraviolet rays are respectively a, b and c. Then :

(*a*) $a < b, b < c$ (*b*) $a > b, b > c$

(*c*) $a > b, b > a$ (*d*) $a < b, b > c$

Ans: (*d*) $a < b, b > c$

Q. 8. The de Broglie wavelength of a photon is twice the de Broglie wavelength of an electron. The speed of the electron is $v_e = \frac{c}{100}$ then :

(*a*) $\frac{E_e}{E_p} = 10^{-4}$ (*b*) $\frac{E_e}{E_p} = 10^{-2}$

(c) $\frac{p_e}{m_e c} = 10^{-2}$ (d) $\frac{p_e}{m_e c} = 10^{-4}$.

Ans. (*b, c*).

Q. 9. The de-Broglie wavelength of a proton (charge = 1.6×10^{-19} C, m = 1.6×10^{-27} kg) accelerated through a potential difference of 1*k*V is :

(*a*) 600 A^0 (*b*) 0.9×10^{-12} m

(*c*) 7 A^0 (*d*) 0.9 nm

Ans. (*b*) 0.9×10^{-12} m

Q. 10. Paschen series of atomic spectrum of hydrogen gas lies in :

(*a*) Infrared region

(*b*) Ultraviolet region

(*c*) Visible region

(*d*) Partly in ultraviolet and partly in visible region

Ans. (*a*) Infrared region.

Q. 11. In an *p*-type silicon, which of the following Assertions true:

(*a*) Electrons are majority carriers and trivalent atoms are the dopants.

(*b*) Electrons are minority carriers and pentavalent atoms are the dopants.

(*c*) Holes are minority carriers and pentavalent atoms are the dopants.

(*d*) Holes are majority carriers and trivalent atoms are the dopants.

Ans. (*d*) Holes are majority carriers and trivalent atoms are the dopants.

Q. 12. In an unbiased *p-n* junction, holes diffuse from the *p*-region to n-region because :

(*a*) free electrons in the n-region attract them.

(*b*) they move across the junction by the potential difference.

(*c*) hole concentration in *p*-region is more as compared to *n*-region.

(*d*) All the above.

Ans. (*c*) hole concentration in *p*-region is more as compared to *n*-region.

Question number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (*a*), (*b*), (*c*) and (*d*) as given below.

(*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

(*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A)

(*c*) (A) is true but (R) is false

(*d*) (A) is false and (R) is also false.

Q. 13. Assertion (A) : The temperature coefficient of resistance is positive for metals and negative for semi-conductors.

Reason (R) : The charge carriers in metals are negatively charged whereas in semiconductors they are positively charged.

Ans. (*c*) (A) is true but (R) is false.

Q. 14. Assertion: When a bar of copper, is placed, in an external magnetic field, the field lines get concentrated inside the bar.

Reason: Copper is a paramagnetic substance.

Ans. (*d*) (A) is false and (R) is also false.

Q. 15. Assertion : Neutrons penetrate matter more readily as compared to protons.

Reason : Neutrons have no charge while a proton has a charge.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

Q. 16. Assertion : A *p*-type semiconductor is a positive type crystal.

Reason : A *p*- type semiconductor is an uncharged crystal.

Ans. (*d*) (A) is false and (R) is also false.

SECTION – B

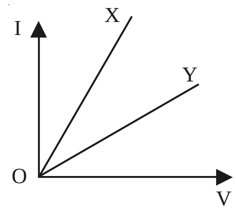
Q. 17. Define electric line of force and give its two important properties.

Ans. It is a line straight or curved, a tangent to which at any point gives the direction of the electric field at that point.

(*a*) No two-field lines can cross, because at the point of intersection two tangents can be drawn giving two directions of electric field, which is not possible.

(*b*) The field lines are always perpendicular to the surface of a charged conductor.

Q. 18. The voltage-current variation of two metallic wires X and Y at constant temperature is shown below. Assuming that the wires have the same length and the same diameter, explain which of the two wires will have larger resistivity.



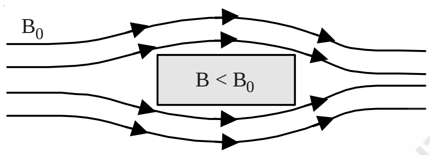
Ans. From the graph, we find that the slope of graph X > slope of graph Y. Thus, conductance of X is more than that of Y. In other words, resistance of Y is more than that of X. Hence for the same *L* and *A*, wire Y will have larger resistivity.

Q. 19. Two identical specimens of magnetic materials nickel and antimony are kept in a non-uniform magnetic field. Draw the modification in the field lines in each case. Justify your answer.

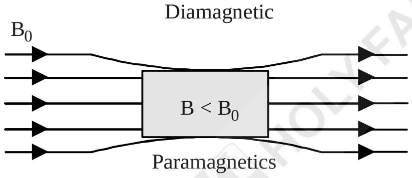
OR

The susceptibility of a magnetic material is 2.6 10^{-5}. Identify the type of magnetic material and state its two properties.

Ans. Nickel is ferromagnetic, antimony is diamagnetic. Therefore, they will show the behaviour as shown in the following figures.



Diamagnetic



Paramagnetics

OR

Diamagnetic :

(*i*) Very small and negative susceptibility

(*ii*) Permeability is less than one.

Q. 20. A short bar magnet placed with its axis at 30° with a uniform external magnetic field of 0.25 T experiences a torque of magnitude equal to 4.5 $\times 10^{-2}$ J. What is the magnitude of magnetic moment of the magnet ?

Ans. Given θ = 30°, B = 0.25 T, τ = 4.5 × 10^{-2} J, M ?

Using the expression τ = MB sin we have

$$M = \frac{\tau}{B\sin\theta} = \frac{4.5\times10^{-2}}{0.25\times\sin30^\circ} = 0.36\ JT^{-1}$$

Q. 21. Explain the principle on which the metal detector is used at airports for security reasons.

Ans. The metal detectors used in airport security checkpoints operate by detecting eddy currents induced in metallic objects. The detector generates an alternating magnetic field. This induces eddy currents in the conduction object carried through the detector. The eddy currents in turn produce an alternating magnetic field. This field induces a current in the detectors receiver coil.

SECTION – C

Q. 22. What does an electromagnetic wave consist of ? On what factors does its velocity in vacuum depend ?

OR

The charge on a parallel plate capacitor varies as q = q_0 cos 2πvt. The plates are very large and close together (area A, separation d). Neglecting the edge effects, and the displacement current through the capacitor.

Ans. An electromagnetic wave consists of electric and magnetic fields varying both in space and time. The two fields are perpendicular to each other and to the direction of propagation of the wave. The velocity of electromagnetic wave in vacuum depends upon the values of its absolute permittivity and permeability.

OR

The displacement current is equal to the conventional current; therefore we have

$$i_C = i_D = \frac{dq}{dt} = \frac{d}{dt}(q_0\cos\pi v t) = -2\pi q_0 v = \sin 2\pi v t.$$

Q. 23. The de-Broglie wavelength associated with an electron accelerated through a potential difference V is 1 V. What will be its wavelength when accelerating potential is increased to 4 V ?

Ans. The de-Broglie wavelength is inversely proportional to the square root of potential, therefore $\frac{\lambda_2}{\lambda_1} = \frac{\sqrt{V}}{\sqrt{4V}} = \frac{1}{2}$. Thus, wavelength will become half of its previous value.

Q. 24. Find the frequency of light, which ejects electrons from a metal surface, fully stopped by a retarding potential of 3.3 V. If photoelectric emission begins in this metal at a frequency of 8×10^{14} Hz, calculate the work function (in eV) for this metal.

Ans. Work function is given by $w_0 = hn_0$

$$\omega_0 = \frac{6.63\times10^{-34}\times8\times10^{14}}{1.6\times10^{-19}} = = 3.315\,e\text{V}$$

Now using the expression

$eV_0 = h\nu\ \omega_0$

We have

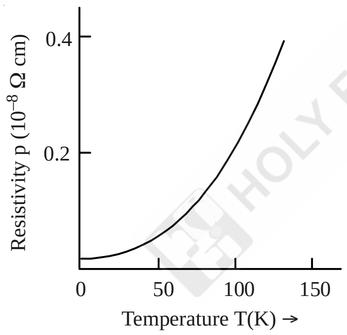
$$\nu = \frac{eV_0+\omega_0}{h} = \frac{(3.3+3.315)\times1.6\times10^{-19}}{6.63\times10^{-14}}$$

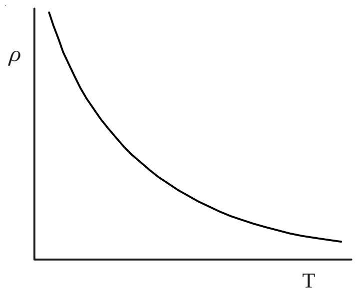
$\nu = 1.596 \times 10^{15}$ Hz

Q. 25. Draw a plot showing the variation of resistivity of a (*i*) conductor and (*ii*) semiconductor, with the increase in temperature.

How does one explain this behaviour in terms of number density of charge carriers and the relaxation time ?

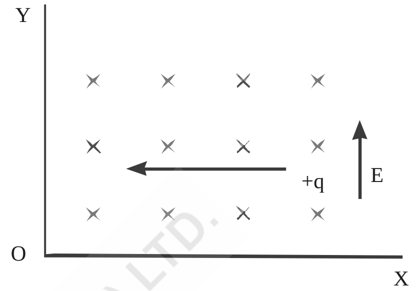
Ans. The plots are as shown.





With rise in temperature the average relaxation time for a conductor decreases and resistivity increases, while for a semiconductor the number density of charge carriers increases, hence the resistivity decreases.

Q. 26. A point charge *q* is moving with a speed *v* perpendicular to a magnetic field *B* as shown in the figure. Explain what should be the magnitude and direction of the applied electric field so that net force acting on the charge is zero.



Ans. By Fleming's left-hand rule, the magnetic force $F_m = qvB$ acts in the downward direction. An electric field E applied in the upward or positive Y-direction will exert an upward force $F_e = qE$. The two forces act opposite to each other. The net force on the charge q will be zero if $F_e = F_m$ or $qE = qvB$ or $E = vB$.

Q. 27. (*a*) Why are coherent sources necessary to produce a sustained interference pattern ?

(*b*) In Young's double-slit experiment using monochromatic light of wavelength screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is λ/3.

Ans. (*a*) Interference will be sustained if there is a constant phase difference between the two interfering waves. This is possible if the two waves are coherent.

(*b*) Intensity at any point on the screen

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

Let I_0 be the intensity of either source, then $I_1 = I = I_0$

When path difference, $\Delta x, = \lambda$, $\phi - 2\pi$

Therefore,

$$I = 4I_0\cos^2\frac{\phi}{2} = 4I_0\ \cos^2\pi = 4I_0 = K$$

When the path difference, $\Delta x = l/3$, $\phi = 2p/3$

Therefore,

$$I = 4I_0 \cos^2\frac{\phi}{2} = 4I_0\cos^2\frac{2\pi}{3} = 4I_0 \times \frac{1}{4} = I_0$$

$$= \frac{K}{4}$$

Q. 28. Laser light of wavelength 630 nm incident on a pair of slits produces an interference pattern in which the bright fringes are separated by 7.2 mm. Calculate the wavelength of another source of laser light which produces interference fringes separated by 8.1 mm using same pair of slits.

OR

Calculate the value of the angle of incidence when a ray of light incident on one face of an equilateral glass prism produces the emergent ray, which just grazes along the adjacent face. Refractive index of the prism is $\sqrt{2}$.

Ans. Given λ = 630 nm, β_1 = 7.2 mm, β_2 = 8.1 mm, λ_2= ?

We know that $\beta = \frac{D\lambda}{d}$ for same value of D and d we have

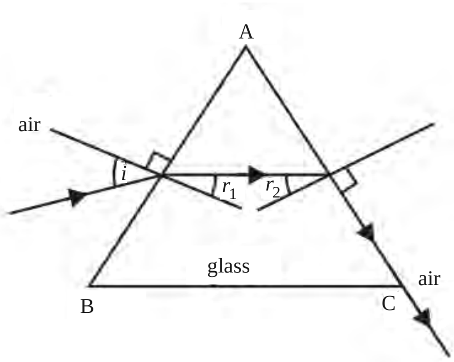
$\beta \propto \lambda$

Therefore

$$\frac{\beta_2}{\lambda_2} = \frac{\beta_1}{\lambda_1} \Rightarrow \lambda_2 = \frac{\beta_2}{\beta_1}\times\lambda_1 = \frac{8.1}{7.2}\times 630 =$$

708.75 nm

OR



$${}_an_g = \frac{\sin i}{\sin r_1} \Rightarrow \sqrt{2} = \frac{\sin i}{\sin r_1}$$

and $${}_gn_a = \frac{\sin r_2}{\sin 90°} \Rightarrow \frac{1}{\sqrt{2}} = \sin r_2$$

Therefore $r_2 = 45°$

Now $A = r_1 + r_2$, therefore

$r_1 = A - r_2 = 60° - 45° = 15°$

$$\sqrt{2} = \frac{\sin i}{\sin 15''} \Rightarrow \sin i = \sqrt{2} \times \sin 15''$$

$= 1.414 \times 0.258 = 0.365.$

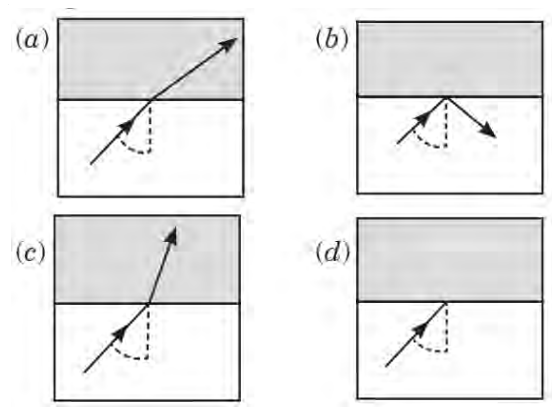
$i = 21.40°$

SECTION – D

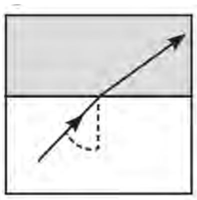
Questions number 29 to 30 are case study-based questions

Q. 29. A ray of light travels from a denser to a rarer medium. After refraction, it bends away from the normal. When we keep increasing the angle of incidence, the angle of refraction also increases till the refracted ray grazes along the interface of two media. The angle of incidence for which it happens is called the critical angle. If the angle of incidence is increased further, the ray will not emerge and it will be reflected back in the denser medium. This phenomenon is called total internal reflection of light.

(*i*) A ray of light travels from a medium into water at an angle of incidence of 18°. The refractive index of the medium is more than that of water and the critical angle for the interface between the two media is 20°. Which one of the following figures best represents the correct path of the ray of light ?



Ans. (*a*)



(*ii*) A point source of light is placed at the bottom of a tank filled with water of refractive index, to a depth *d*. The area of the surface of water through which light from the source can emerge is :

(*a*) $\frac{\pi d^2}{2(\mu^2-1)}$ (*b*) $\frac{\pi d^2}{(\mu^2-1)}$

(c) $\frac{\pi d^2}{\sqrt{2}\sqrt{(\mu^2-1)}}$ (*d*) $\frac{2\pi d^2}{(\mu^2-1)}$.

Ans. (*b*) $\frac{\pi d^2}{(\mu^2-1)}$.

(*iii*) For which of the following media, with respect to air, is the value of critical angle maximum ?

(*a*) Crown glass (*b*) Flint glass

(*c*) Water (*d*) Diamond

Ans. (c) Water.

(*iv*) The critical angle for a pair of two media A and B of refractive indices 2.0 and 1.0 respectively is :

(*a*) 0 (*b*) 30

(*c*) 45 (*d*) 60

Ans. (*b*) 30.

OR

(*iv*) The critical angle of a pair of medium and air is 30^0. The speed of light in the medium is :

(*a*) 1×10^8 ms^{-1} (*b*) 1.5×10^8 ms^{-1}

(*c*) 2.2×10^8 ms^{-1} (*d*) 2.8×10^8 ms^{-1}

Ans. (*b*) 1.5×10^8 ms^{-1}.

Q. 30. When p side of p-n junction is connected to positive terminal of battery and n side of p-n junction is connected to negative terminal of battery then the p-n junction is said to be in forward bias mode or forward biased. When p side of p-n junction is connected to negative terminal of battery and n side of p-n junction is connected to positive terminal of battery then the p-n junction is said to be reverse biased. The diode used to rectify an ac voltage is called as rectifier. Zener diode is also a p-n junction diode which works in reverse bias condition and used as voltage regulator. Also, p-n junction diodes are used in solar cells which is used to convert light energy into electrical energy. Light emitting diodes are also p-n junction diodes, which are used to produce light.

(*i*) Zener diode and photodiode work in the :

(*a*) forward bias mode

(*b*) reverse bias mode

(*c*) both (*a*) and (*b*)

(*d*) none.

Ans. (*b*) reverse bias mode.

(*ii*) The semiconductors, which are used to make visible LEDs, must have a band gap of :

(*a*) 3 eV (*b*) 0 eV

(*c*) 1.8 eV (*d*) 5 eV.

Ans. (*c*) 1.8 eV.

(*iii*) The rectifier in which the rectified output is only for half of the input AC wave is :

(*a*) Full wave rectifier

(*b*) Half wave rectifier

(*c*) Transformer

(*d*) Bridge rectifier.

Ans. (*b*) Half wave rectifier.

(*iv*) Which of the following is a characteristic of a reverse-biased p-n junction ?

(*a*) Very narrow depletion region

(*b*) Large current flow

(*c*) Almost no current

(*d*) Very low resistance

Ans. (*c*) Almost no current.

OR

In forward biased pn junction, if the forward biased in increased, then

(*a*) Circuit resistance increase

(*b*) Current through pn junction increases

(*c*) Current through pn junction decreases

(*d*) None of the above.

Ans. (*b*) Current through pn junction increases.

SECTION – E

Q. 31. Two-point charges q and -q are located at points (0, 0, – a) and (0, 0, a) respectively.

(*a*) Find the electrostatic potential at (0, 0, *z*) and (*x*, *y*, 0)

(*b*) How much work is done in moving a small test charge from the point (5, 0, 0) to (– 7, 0, 0) along the *x*-axis ?

(c) How would your answer change if the path of the test charge between the same points is not along the x-axis but along any other random path ?

(*d*) If the above point charges are now placed in the same positions in a uniform external electric field, what would be the potential energy of the charge system in its orientation of unstable equilibrium ? Justify your answer in each case.

OR

A capacitor of capacitance C_1 is charged to a potential V_1 while another capacitor of capacitance C_2 is charged to a potential difference V_2. The capacitors are now disconnected from their respective charging batteries and connected in parallel to each other.

(*a*) Find the total energy stored in the two capacitors before they are connected.

(*b*) Find the total energy stored in the parallel combination of the two capacitors.

(*c*) Explain the reason for the difference of energy in parallel combination in comparison to the total energy before they are connected.

Ans. The given system is an electric dipole

Given dipole length 2a, therefore dipole moment is $p = q\ 2a$

(*a*) For given dipole, point (0, 0, *z*) lies on the axial line at a distance *z* from the midpoint of dipole.

Hence $V = k\dfrac{p}{(z^2 - a^2)}$

The point (*x*, *y*, 0) lies at the equatorial line of dipole and hence electric potential at this point is zero.

when $r/a >> 1$ or $r >> a$ for a dipole we have

$$V \propto \frac{1}{r^2}$$

(*b*) As the motion of test charge from the point (5, 0, 0) to (– 7, 0, 0) is along x-axis and electric potential is only along *z*-axis, hence work done = 0.

(*c*) The answer does not change because the electric field is a conservative field and the work done simply depends on the position of initial and final points only.

(*d*) PE = pE

OR

When two capacitors having different capacitance's C_1 and C_2 and different potentials V_1 and V_2 are joined with the help of a wire, charge flows from a conductor at high potential to the conductor at low potential till they attain a common potential. (V).

(*a*) Energy stored when the capacitors are not connected

$$U_1 = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2 \qquad .....(1)$$

(*b*) When the capacitors are connected in parallel then the net capacitance of the combination is $C = C_1 + C_2$, therefore the common potential is

$$V = \frac{\text{total charge}}{\text{total capacitance}} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} \qquad ...(2)$$

Hence energy stored in the parallel combination

$$U_2 = \frac{1}{2}(C_1 + C_2)V^2U_2$$

$$= \frac{1}{2}(C_1 + C_2)\left[\frac{C_1V_2 + C_2V_2}{C_1 + C_2}\right]^2 \qquad ...(3)$$

Subtracting equation 3 from equation 1 we have

$U_1 - U_2$

$$= \frac{1}{2}(C_1V_1^2 + C_2V_2^2) - \frac{1}{2}\left(\frac{(C_1V_1 + C_2V_2)^2}{C_1 + V_2}\right) \text{ or}$$

$$= \frac{1}{2(C_1 + C_2)}\left[(C_1 + C_2) - (C_1V_1 + C_2V_2)^2\right]$$

and finally,

$$U_1 - U_2 = \frac{C_1C_2}{2(C_1 + C_2)}(V_1 - V_2)^2 \qquad ...(4)$$

Clearly $U_1 - U_2 > 0$, thus there is always a loss of energy when two capacitors are connected in parallel. This is because when connection is made energy is lost in terms of sparking and heat produced during connection.

Q. 32. **(*a*) Draw a labelled ray diagram of compound microscope, when final image forms at the least distance of distinct vision.**

(*b*) Why is its objective of short focal length and of short aperture, compared to its eyepiece ? Explain.

(*c*) The focal length of the objective is 4 cm while that of eyepiece is 10 cm. The object is placed at a distance of 6 cm from the objective lens.

(*i*) Calculate the magnifying power of the compound microscope, if its final image is formed at the near point.

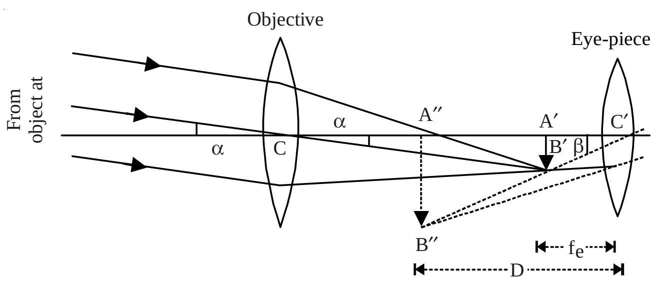
(*ii*) Also calculate length of the compound microscope.

OR

(*a*) With the help of a labelled ray diagram, explain the construction and working of a Cassegrainian reflecting telescope.

(*b*) An amateur astronomer wishes to estimate roughly the size of the Sun using his crude telescope consisting of an objective lens of focal length 200 cm and an eyepiece of focal length 10 cm. By adjusting the distance of the eyepiece from the objective, he obtains an image of the Sun on a screen 40 cm behind the eyepiece. The diameter of the Sun's image is measured to be 6·0 cm. Estimate the Sun's size, given that the average Earth-Sun distance is $1{\cdot}5 \times 10^{11}$ m.

Ans. (*a*) The diagram is as shown.



(*b*) The magnifying power of compound microscope

$$m = m_0 \times m_e = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

To have high magnifying power and high resolution, the focal length of the objective and itsaperture should be short.

Focal length of eyepiece is comparatively greater than the objective so that image formed by objective lens may form within the focal length of eyepiece and the final magnified image may be formed.

Aperture in short for higher resolution.

(*c*) Given $u_o = -6$ cm

For objective lens we have

$$\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$$

$$\text{Or } \frac{1}{v_0} = \frac{1}{f_0} + \frac{1}{u_0} = \frac{1}{4} + \frac{1}{-6} = \frac{1}{12}$$

$v_0 = 12$ cm

Since for eye piece $v_e = D = -25$ cm

$$\frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{10}$$

$u_e = -7.14$ cm

(*i*) For magnifying power of compound microscope we have

$$m = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right) = \frac{12}{6}\left(1 + \frac{25}{10}\right) = 7$$

(*ii*) Length of the compound microscope

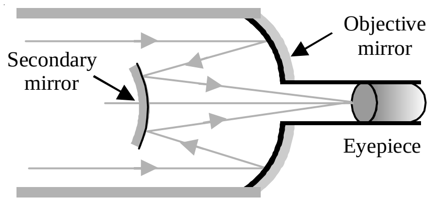
$L = v_o + u_e = 12 + 7.14 = 19.14$ cm

OR

(*a*) It consists of a large concave (primary) parabolic mirror having a hole in its centre. There is a small convex (secondary) mirror near the focus of concave mirror. Eye piece is placed near the hole of the concave mirror.

The parallel rays from distance object are reflected by the large concave mirror. These rays fall on the convex mirror which reflects these rays outside the hole. The final magnified image in formed at infinity.

The diagram is as shown.



(*b*) For the eye piece

$$\frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{40} - \frac{1}{10} = \frac{3}{40}$$

u_e = 40/3 cm

Magnification produced by the eye piece is

$$m_e = \frac{v_e}{u_e} = \frac{40}{40/3} = 3$$

Diameter of the image formed by the objective is

D = 6/3 = 2 cm

If D is the diameter of the Sun then the angle subtended y it on the objective will be

$$\alpha = \frac{D}{1.5 \times 10^{11}} \text{ rad}$$

Now

Angle subtended by the image at the objective = angle subtended by the sun

$$\alpha = \frac{\text{size of image}}{f_0} = \frac{2}{200} = \frac{1}{100} \text{ rad}$$

Therefore

$$\frac{D}{1.5 \times 10^{11}} = \frac{1}{100}$$

D = 1.5×10^9 m

Q 33. (*a*) Write the expression for the force $\vec{F}$, acting on a charged particle of charge 'q', moving with a velocity in the presence of both electric field $\vec{E}$ and magnetic field $\vec{B}$. Obtain the condition under which the particle moves undeflected through the fields.

(*b*) A rectangular loop of size $l \times b$ carrying a steady current I is placed in a uniform magnetic field $\vec{B}$. Prove that the torque acting on the loop is given by $\vec{\tau} = \vec{m} \times \vec{B}$, where $\vec{m}$ is the magnetic moment of the loop.

OR

(*a*) Explain, giving reasons, the basic difference in converting a galvanometer into (*i*) a voltmeter and (*ii*) an ammeter.

(*b*) Two long straight parallel conductors carrying steady currents I_1 and I_2 are separated by a distance 'd'. Explain briefly, with the help of a suitable diagram, how the magnetic field due to one conductor acts on the other. Hence deduce the expression for the force acting between the two conductors. Mention the nature of this force.

Ans. (*a*) The required expression is

$$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$$

The particle will move undeflected if the force acting on it due to the electric field balances the force acting on it due to the magnetic field. Thus

qE = Bqv or v = E/B

(*b*) Figure shows a rectangular loop of wire with length '*l*' and breadth 'b'. A line perpendicular to the plane of the loop (*i.e.*, a normal to the plane) makes an angle ϕ with the direction of the magnetic field B, and the loop carries a current I as shown. Let the forces acting on the various sides of the loop be

$$\vec{F_1}, \vec{F_2}, \vec{F_3} \text{ and } \vec{F4}$$

as shown. It follows from the expression for the force experienced by a conductor in a magnetic field that force on arm AB is ...(1)

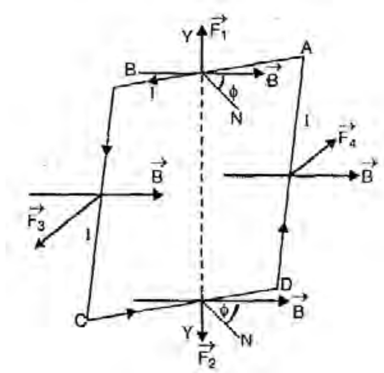
$F_1 = F_2$ = IbB sin (90 – θ) = Ib cos θ

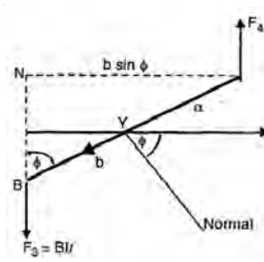
Since these two forces are equal and opposite and have the same line of action therefore they cancel out each other's effect and their resultant effect on the coil is zero.

Both forces F_3 and F_4 make an angle of 90^0 with the direction of the magnetic field. Therefore in magnitude these forces are given by

$$F_3 = F_4 = IlB \sin 90^0 \qquad ...(2)$$

The lines of action of both these forces are perpendicular to the plane of the paper.





The total force on the loop is zero, because the forces on opposite sides cancel out in pairs. The net force on a current loop in a uniform magnetic field is zero. However the net torque is not generally zero. The two forces F_1 and F_2 lie along the same line and so give rise to zero net torque. 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. The arm of the couple (perpendicular distance between the lines of action of the two forces) from the figure is given by

Arm of couple $= b \sin\phi$ ...(3)

Therefore by the definition of torque we have

Torque = either force × arm of couple ...(4)

Using equations 2, 3 and 4 we have

$$\text{Torque} = I B l \times b \sin\phi$$

But $l \times b = A$, area of the coil , therefore

$$\tau = IBA \sin\phi$$

But IA = m, magnetic dipole moment , therefore we have

$\tau = mB \sin\phi$

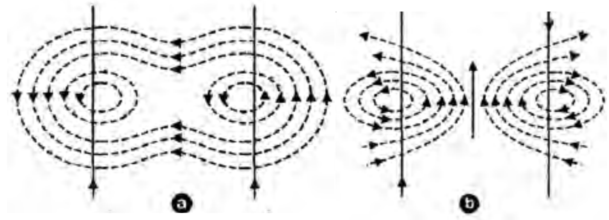
Hence $\vec{\tau} = \vec{m} \times \vec{B}$

OR

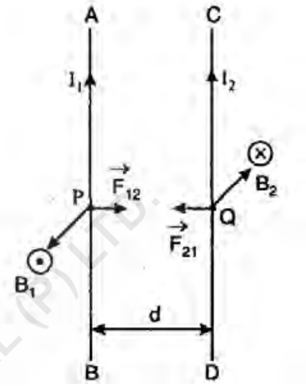
(*i*) A voltmeter is always connected in parallel with the section of the circuit whose potential difference has to be measured. Further it must draw a small current, otherwise the voltage measurement will disturb the original setup by an amount which is very large. Thus a large resistance is connected to the galvanometer in series so as to minimise this effect.

(*ii*) An ammeter measures current and is to be connected in series in a circuit. A galvanometer has a large resistance, therefore a shunt is connected to it in order to decrease its resistance such that the current in the circuit is not altered.

The pattern of magnetic field around them is as shown ahead.



Consider two straight, parallel, long current carrying conductors AB and CD carrying currents I_1 and I_2 ,respectively. Let 'd' be the distance between the two as shown.



Now magnetic field B_2 developed at a point Q on conductor CD due to current I_1 flowing in conductor AB is ...(1)

$$B = \frac{\mu_0 I_1}{2\pi d}$$

By right hand rule magnetic field B_2 acts normal to the plane of the paper and directed inward. Thus, conductor CD carrying current I_2 is in a magnetic field which is perpendicular to its length.

Therefore, force experienced by conductor CD due to magnetic field B_2 is

$F_2 = B_2 I_2 L,$ ...(2)

where L is the length of the second conductor. Substituting for B_2 in equation 2 we have

$$\frac{F_{21}}{L} = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$

or force per unit length is

$$\frac{F_{21}}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

In accordance with Fleming's left hand rule this force is directed towards the conductor AB. Similarly, the force on conductor AB due to current in CD can be found which is

$\frac{F_{12}}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$ and is directed towards CD.

Holy Faith New Style Sample Paper—7

(Based on the Latest Design `& Syllabus issued by C.B.S.E.)

CLASS – 12th (CBSE)

PHYSICS (Theory)

Time allowed : 3 hours **Maximum Marks : 70**

General Instructions : Same as in MTP – 1

SECTION – A

Q. 1. Let F_1 be the magnitude of the force between two small spheres, charged to a constant potential in free space and F_2 be the magnitude of the force between them in a medium of dielectric constant k. Then (F_1/F_2) is :

(*a*) $\frac{1}{k}$ (*b*) k (*c*) k^2 (*d*) $\frac{1}{k^2}$.

Ans. (*b*) k.

Q. 2. Two students A and B calculate the charge flowing through a circuit. A concludes that 300 C of charge flows in 1 minute. B concludes that $3{\cdot}125 \times 10^{19}$ electrons flow in 1 second. If the current measured in the circuit is 5 A, then the correct calculation is done by :

(*a*) A (*b*) B

(*c*) both A and B (*d*) neither A nor B.

Ans. (*c*) both A and B.

Q. 3. The resistances of two wires having same length and same area of cross-section are 2 Ω and 8 Ω respectively. If the resistivity of 2 Ω wire is $2{\cdot}65 \times 10^{-8}$ Ω-m then the resistivity of 8 Ω wire is :

(*a*) material A is copper and material B is germanium

(*a*) $10{\cdot}60 \times 10^{-8}$ Ω-m (*b*) $8{\cdot}32 \times 10^{-8}$ Ω-m

(*c*) $7{\cdot}61 \times 10^{-8}$ Ω-m (*d*) $5{\cdot}45 \times 10^{-8}$ Ω-m.

Ans. (*a*) $10{\cdot}60 \times 10^{-8}$ Ω-m.

Q. 4. An electron with velocity $\vec{v} = (v_x \hat{i} + v_y \hat{j})$ moves through a magnetic field $\vec{B} = (B_x \hat{i} - B_y \hat{j})$. The force $\vec{F}$ on the electron is : (e is the magnitude of its charge)

(*a*) $-e(v_x B_y - v_y B_x)\hat{k}$ (*b*) $e(v_x B_y - v_y B_x)\hat{k}$

(*c*) $-e(v_x B_y + v_y B_x)\hat{k}$ (*d*) $e(v_x B_y + v_y B_x)\hat{k}$.

Ans. (*d*) $e(v_x B_y + v_y B_x)\hat{k}$.

Q. 5. A pure inductor of 318 mH and a pure resistor of 75 Ω are connected in series to an ac source of 50 Hz. The voltage across 75 Ω resistor is found to be 150 V. The source voltage is :

(*a*) 150 V (*b*) 175 V

(*c*) 220 V (*d*) 250 V.

Ans. (*d*) 250 V.

Q. 6. Lenz's law is the consequence of the law of conservation of :

(a) energy (b) charge

(*c*) mass (*d*) momentum.

Ans. (*a*) energy.

Q. 7. An electromagnetic wave is propagating along Y-axis. Then :

(*a*) Oscillating electric field is along X-axis and oscillating magnetic field is along Y-axis

(*b*) Oscillating electric field is along Z-axis and oscillating magnetic field is along X-axis

(*c*) Both oscillating electric and magnetic fields are along Y-axis, but phase difference between them is 90º

(*d*) Both oscillating electric and magnetic fields are mutually perpendicular in arbitrary directions.

Ans. (*b*) Oscillating electric field is along Z-axis and oscillating magnetic field is along X-axis.

Q. 8. Photons absorbed in a matter are converted to heat. A source emitting n photon/sec of frequency n is used to convert 1 kg of ice at 0°C to water at 0° C. Then, for time T for the conversion which statement is incorrect

(*a*) decreases with increasing *n* with *n* fixed

(*b*) decreases with *n* fixed, *n* increasing

(*c*) remains constant with *n* and *n* changing such that *n* = constant

(*d*) increases when the product *n n* increases.

Ans. (*d*) increases when the product *n n* increases.

Q. 9. The photoelectric cut-off voltage in a certain experiment is 1.5 V. What is the maximum kinetic energy of photo-electrons emitted ?

(*a*) 2.4×10^{-10} J (*b*) 4.2×10^{-10} J

(*c*) 2.4×10^{-19} J (*d*) 4.2×10^{-19} J.

Ans. (*c*) 2.4×10^{-19} J.

Q. 10. Taking the Bohr radius as a_0 = 53 pm, the radius of Li^{++} ion in its ground state, on the basis of Bohr's model, will be about :

(*a*) 53 pm (*b*) 27 pm

(*c*) 18 pm (*d*) 13 pm.

Ans. (*c*) 18 pm.

Q. 11. In a *p-n* junction diode, change in temperature due to heating :

(*a*) Affects only reverse resistance

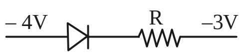
(*b*) Affects only forward resistance

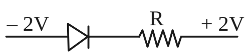
(*c*) Does not affect resistance of *p-n* junction

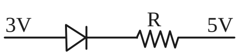
(*d*) affects the overall V – I characteristics of *p-n* junction.

Ans. (*d*) affects the overall V – I characteristics of *p-n* junction.

Q. 12. Which one of the following represents forward bias diode ?

(*a*) 

(*b*) 

(*c*) 

(*d*) 

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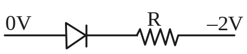
Ans. (*d*) 

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Questions number 13 to 16 are Assertion (A) and Reason (R) type questions.

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (*a*), (*b*), (*c*) and (*d*) as given below.

(*a*) Both (A) and (R) are true and (R) is the correct explanation of (A)

(*b*) Both (A) and (R) are true and (R) is not the correct explanation of (A)

(*c*) (A) is true but (R) is false

(*d*) (A) is false and (R) is also false.

Q. 13. Assertion (A) : Material used in the construction of a standard resistor is constantan or manganin.

Reason (R) : Temperature coefficient of constantan is very small.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A).

Q. 14. Assertion (A) : A bar magnet experiences a torque when placed in a magnetic field.

Reason (R) : A bar magnet exerts a torque on itself due to its own magnetic field.

Ans. (*c*) (A) is true but (R) is false.

Q. 15. Assertion (A) : Balmer series lies in the visible region of electromagnetic spectrum.

Reason (R) : For Balmer series

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n_1^2}\right) \text{ where } n_i = 3, 4, 5, ...$$

Ans. (*b*) Both (A) and (R) are true and (R) is not the correct explanation of (A).

Q. 16. Assertion : Electron has higher mobility than hole in a semiconductor.

Reason : The mass of electron is less than the mass of the hole.

Ans. (*a*) Both (A) and (R) are true and (R) is the correct explanation of (A).

SECTION – B

Q. 17. A parallel plate capacitor with air between the plates is charged. A dielectric is inserted between the plates. What will happen to its electrostatic potential ? Give reasons for your answer.

Ans. When the capacitor is charged, the charge on it remains the same. Let this charge be Q. On the insertion of a dielectric constant K, the capacitance becomes $C = K C_0$. Now we know that $C = Q/V$ or $V = Q/C$. Since charge remains constant, $V \propto \frac{1}{C}$. As C increases, there is a decrease in the potential between the plates.

Q. 18. The electron drift arises due to the force experienced by electrons in the electric field inside the conductor but force should cause acceleration. Why then do the electrons acquire a steady average drift speed ?

Ans. Each free electron does accelerate, increasing its drift speed until it collides with a positive ion of the metal. It loses its drift speed after collision but starts to accelerate and increases its drift speed again only to suffer a collision again and so on. On the average, therefore, electrons acquire only a drift speed.

Q. 19. Which one of the two, an ammeter or a milliammeter, has a higher resistance and why ?

OR

Define current sensitivity and voltage sensitivity of a galvanometer.

Ans. The shunt required to convert a galvanometer into an ammeter or a milliammeter is given by the expression $S = \frac{I_g G}{I - I_g}$, where G is galvanometer resistance, I total current through G and S, and I_g galvanometer current. Incase of milliammeter, I is small. Therefore $S_{milliammeter} > S_{ammeter}$. Hence, resistance of a milliammeter is greater than that of an ammeter.

OR

Current Sensitivity : The current sensitivity of the galvanometer is the deflection produced in the galvanometer per unit current.

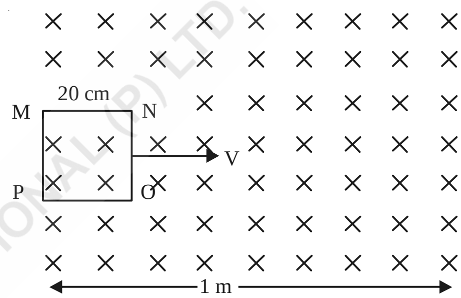
Voltage sensitivity : The voltage sensitivity of the galvanometer is the deflection produced in the galvanometer when unit voltage is applied across it.

Q. 20. An ammeter of resistance 0.80 Ω can measure current up to 1.0 A. What must be the value of shunt resistance to enable the ammeter to measure current up to 5.0 A ?

Ans. Given $G = 0.80\ \Omega$, $I_g = 1.0$ A, $I = 5.0$ A, $S = ?$
Using the expression

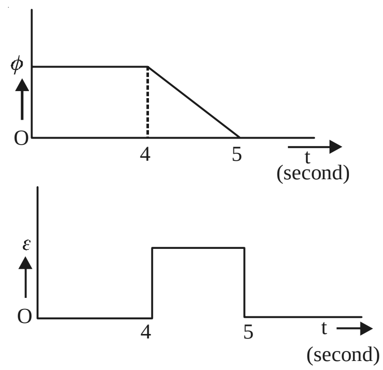
$$S = \frac{I_g G}{I - I_g} = \frac{1 \times 0.8}{5 - 1} = 0.2\ \Omega.$$

Q. 21. A square loop MNOP of side 20 cm is placed horizontally in a uniform magnetic field acting vertically downwards as shown in the figure. The loop is pulled with a constant velocity of 20 cm s^{-1} till it goes out of the field.



Plot a graph showing the variation of magnetic flux and induced emf as a function of time.

Ans. The graphs are as shown.



SECTION – C

Q. 22. A variable frequency AC source is connected to a capacitor. How will the displacement current change with decrease in frequency ?

OR

The electric field of an electromagnetic wave is represented as $E_x = E_o \sin(\omega t + kz)$. Now answer the following questions.

(*i*) **In which direction is the wave propagating ?**

(*ii*) **In which direction does the magnetic field oscillate ?**

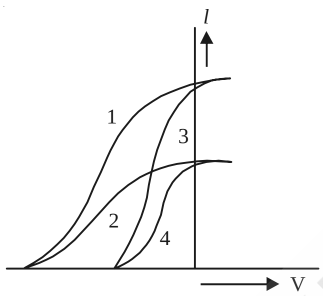
Ans. On decreasing the frequency, reactance $X_C = 1/2\pi fC$ will increase which will lead to decrease in conduction current. In this case $I_D = I_C$; hence displacement current will decrease.

OR

(*i*) The wave is propagating along the *z*-axis.

(*ii*) The magnetic field is along the *y*-axis.

Q. 23. The given graphs show the variation of photoelectric current (I) with the applied voltage (V) for two different materials and for two different intensities of the incident radiations. Identify the pairs of curves that correspond to different materials but same intensity of incident radiations.



Ans. Pairs 1–2 and 3–4.

Q. 24. Light of frequency 7.21×10^{14} Hz is incident on a metal surface. Electrons with a maximum speed of 6.0×10^5 m s^{-1} are ejected from the surface. What is the threshold frequency for photoemission of electrons ?

Ans. Given $n = 7.21\times 10^{14}$ Hz, $v = 6.0 \times 10^5$ m s^{-1}, $v_o = ?$

Using the relation

$h(v - v_o) = \frac{1}{2} mv^2$

We have

$$v_o = v - \frac{mv^2}{2h} = 7.21\times10^{14} - \frac{9.1\times10^{-31}\times(6\times10^5)^2}{2\times6.63\times10^{-34}}$$

$v_o = 4.73 \times 10^{14}$ Hz.

Q. 25. Two identical cells of emf 1.5 V each joined in parallel supply energy to an external circuit consisting of two resistances of 7 Ω each joined in parallel. A very high resistance voltmeter reads the terminal voltage of cells to be 1.4 V. Calculate the internal resistance of each cell.

Ans. Given $\varepsilon = 1.5$ V as they are in parallel, V = 1.4 V, $R_1 = R_2 = 7$ ohm,

Let *r* be the internal resistance of each cell.

Hence net internal resistance $= r_N = r/2$

Net external resistance $R_N = R/2 = 7/2 = 3.5$ ohm

$$\text{Now } r_N = \frac{(\varepsilon - V)R_N}{V} = \frac{(1.5-1.4)\times 3.5}{1.4} = 0.25\,\Omega$$

Hence $r = 2r_N = 2 \times 0.25 = 0.5$ ohm.

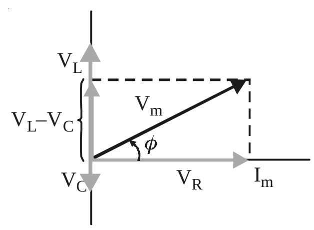
Q. 26. You are given three circuit elements X, Y and Z. When the element X is connected across an a.c. source of a given voltage, the current and the voltage are in the same phase. When the element Y is connected in series with X across the source, voltage is ahead of the current in phase by π/4. But the current is ahead of the voltage in phase by π/4 when Z is connected in series with X across the source. Identify the circuit elements X, Y and Z.

When all the three elements are connected in series across the same source, determine the impedance of the circuit.

Draw a plot of the current versus the frequency of applied source and mention the significance of this plot.

Ans. X – Resistor, Y – Inductor, Z – Capacitor

The voltages across the various elements are drawn as shown in figure below.



From the diagram we observe that the vector sum of the voltage amplitudes $\mathbf{V_R}$, $\mathbf{V_L}$ and $\mathbf{V_C}$ equals a phasor whose length is the maximum applied voltage v_m, where the 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

$$V_m = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$= \sqrt{(I_m R)^2 + (I_m X_L - I_m X_C)^2} \quad ...(1)$$

$$\text{or } \sqrt{R^2 + (X_L - X_C)^2} \quad ...(2)$$

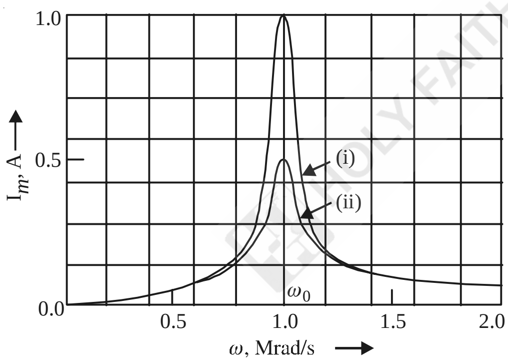
where $X_L = \omega L$ and $X_C = 1/\omega C$, therefore we can express the maximum current as

$$I_m = \frac{V_m}{\sqrt{R^2 + (X_L - X_C)^2}} \quad ...(3)$$

The impedance Z of the circuit is defined as

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

The plot is as shown.

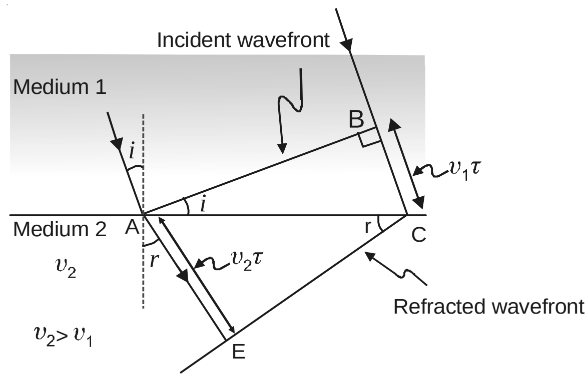


Significance, at $\omega = \omega_0$ (resonance frequency) current is maximum.

Q. 27. (*i*) Derive Snell's law on the basis of Huygen's wave theory when light is travelling from a denser to a rarer medium.

(*ii*) Draw the sketches to differentiate between plane wavefront and spherical wavefront.

Ans. (*i*) The ray diagram is as shown.



Now $\sin i = \dfrac{BC}{AC}$ and $\sin r = \dfrac{AE}{AC}$

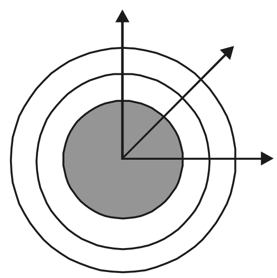
Or $\dfrac{\sin i}{\sin r} = \dfrac{BC}{AC} \times \dfrac{AC}{AE} = \dfrac{BC}{AE} = \dfrac{v_1\tau}{v_2\tau} = \dfrac{v_1}{v_2} = \dfrac{n_2}{n_1}$

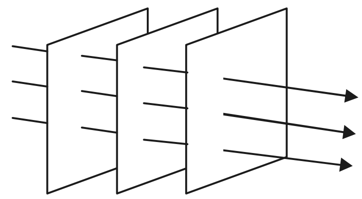
Or $\dfrac{\sin i}{\sin r} = \dfrac{n_2}{n_1}$

Or $n_2 \sin r = n_1 \sin i$

which is Snell's law.

(*ii*) Spherical wavefront and Plane wavefront.





Q. 28. (*i*) A screen is placed at a distance of 100 cm from an object. The image of the object is formed on the screen by a convex lens for two different locations of the lens separated by 20 cm. Calculate the focal length of the lens used.

(*ii*) A converging lens is kept coaxially in contact with a diverging lens - both the lenses being of equal focal length.

What is the focal length of the combination ?

OR

(*a*) A small telescope has an objective lens of focal length 140 cm and an eye piece of focal length 5.0 cm. Find the magnifying power of the telescope for viewing distant objects when

(*i*) the telescope is in normal adjustment and

(*ii*) the final image is formed at the least distance of distinct vision.

(*b*) Also find the separation between the objective and the eye piece.

Ans. Given $u + v = 100$ or $v = 100 - u$

Using lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ we have

(*i*) $\frac{1}{f} = \frac{1}{(100-u)} - \frac{1}{-u} = \frac{1}{(100-u)} + \frac{1}{u}$ ...(1)

(*ii*) $\frac{1}{f} = \frac{1}{(80-u)} - \frac{1}{-(u+20)} = \frac{1}{(80-u)} + \frac{1}{u+20}$ ...(2)

Solving 1 and 2 we have

$u = -40$ cm.

Hence using 1 we have

$$\frac{1}{f} = \frac{1}{(100-40)} - \frac{1}{-40} = \frac{1}{60} + \frac{1}{40}$$

Or $f = 24$ cm

(*i*) Infinity, $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{-f_2} = 0$

OR

Given $f_0 = 140$ cm, $f_{ee} = 5.0$ cm

(*i*) $M = f_0 / f_3 = 140 / 5 = 28$

(*ii*) For distance of least vision we have

$$M = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$= \frac{140}{5}\left(1 + \frac{5}{25}\right) = 28 \times 1.2 = 33.6$$

(*iii*) In normal adjustment

$L = f_0 + f_e = 140 + 5 = 145$ cm

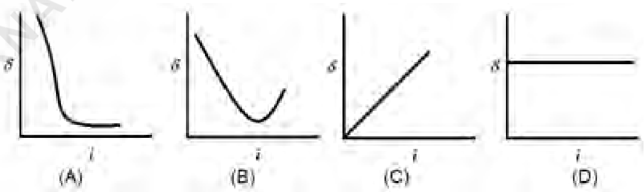
SECTION – D

Questions number 29 to 30 are case study based questions.

Read the following paragraph and answer the questions.

Q. 29. A prism is a solid transparent medium bounded by three rectangular faces with a triangular base and a top. A ray of light incident at angle *i* on one face of a prism suffers two refractions on passing through a prism. Hence, it deviates through a certain angle δ from its original path. The angle of deviation becomes minimum ($\delta = \delta_m$) for a certain value of angle *i*. In such a condition, the refracted ray inside the prism becomes parallel to its base. An expression for refractive index μ of the material of the prism can be obtained in terms of angle A and angle δ_m.

(*i*) A graph is plotted between the angle of deviation (δ) and angle of incidence (*i*) for a prism. The nearly correct graph is :



Ans. (*c*)

(*ii*) For a prism of small angle A, with angle of minimum deviation δm, the refractive index *μ* of its material can be written as.

(*a*) $\mu = 1 + \delta_m/A$

(*b*) $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{A/2}$

(*c*) $\mu = \frac{1}{\sin A}$

(*d*) cannot be found.

Ans. (*a*) We know that $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{A/2}$

For small angle, we have sin θ , therefore we have

$$\mu = \frac{\left(\frac{A+\delta_m}{2}\right)}{A/2}$$

$$\mu = \frac{A+\delta_m}{A} = 1 + \frac{\delta_m}{A}.$$

(c) A ray of light passes through an equilateral prism such that both the angle of incidence and the angle of emergence are equal to the angle of prism A. Find the refractive index of the material of the prism, in terms of A.

(*a*) cot (A/2) (*b*) 2cos(A/2)
(*c*) tan (A/2) (*d*) sin (A/2).

Ans. (*b*) $i + e = A$, Now $= r_1 + \pi_2 = 2r$

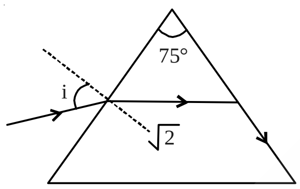
$r = A/2$

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin A}{\sin A/2}$$

$$\mu = \frac{2\sin(A/2)\cos(A/2)}{\sin(A/2)} = 2\cos(A/2)$$

OR

A ray of light passes through a prism of angle 75°, as shown in the figure. The refractive index of the material of the prism, with respect to its surrounding is $\sqrt{2}$ the angle of incidence *i* will be :



(*a*) 45° (*b*) 60°
(*c*) 30° (*d*) 75°.

Ans. (*b*) Now $\frac{\sin i}{\sin r} = \sqrt{2} = \frac{\sin r_2}{\sin 90°} = \sqrt{2}$

$$\sin r_2 = \frac{1}{\sqrt{2}} \text{ or } r_2 = 45°$$

Now $r_1 + r_2 = A$ or $r_1 + 45° = 75°$

Or $r_1 = 30°$

$$\frac{\sin i}{\sin 30°} = \sqrt{2} \text{ or } \sin i = \sqrt{2} \times \frac{1}{2} = \frac{1}{\sqrt{2}}$$

Hence $i = 45°$.

(d) The refractive index of prism is $\mu = \sqrt{3}$ and the ratio of the angle of minimum deviation to the angle of prism is one. The value of angle of prism is :

(*a*) 30° (*b*) 60°
(*c*) 45° (*d*) Insufficient data.

Ans. (*b*) 60°.

Q. 30. The belief before the nineteenth century was that magnetic properties of substances were confined to a few substances only viz. iron, nickel and cobalt. Madame Curie and Michael Faraday discovered that all the materials in the universe are magnetic to some extent. They classified these substances into three categories: Diamagnetic, substances feebly repelled by a magnet, paramagnetic, substances feebly attracted by a magnet and ferromagnetic, substances strongly attracted by a magnet. According to the theory of magnetism, the magnetic property of a substance is due to circulating electrons in the atoms. Each electron has a magnetic moment in a direction perpendicular to the plane of circulation. In magnetic materials all these magnetic moments due to the orbital and spin motion of all the electrons in any atom, add up vectorially add to produce a resultant magnetic moment. The magnitude and direction of the resultant magnetic moment is responsible for the behaviour of the materials. For diamagnetic substances susceptibility (χ_m) is small and negative for paramagnetic substances susceptibility (χ_m) is small and positive and for ferromagnetic substances susceptibility (χ_m) is positive and large.

Based on the passage and your knowledge of Magnetism answer any four of the following questions.

(i) The universal (or inherent) property among all substances is ;

(*a*) diamagnetism (*b*) paramagnetism
(*c*) ferromagnetism (*d*) both (*a*) & (*b*).

Ans. (*a*) diamagnetism.

(ii) When a bar placed near a strong magnetic field is repelled by it. The substance is :

(*a*) diamagnetic (*b*) ferromagnetic
(*c*) Paramagnetic
(*d*) anti-ferromagnetic.

Ans. (*a*) diamagnetic.

(*iii*) Magnetic susceptibility of a diamagnetic substance :

(*a*) decreases with temperature

(*b*) is not affected by temperature

(*c*) increases with temperature

(*d*) first increases then decreases with temperature.

Ans. (*b*) is not affected by temperature.

(*iv*) For a paramagnetic material, magnetic susceptibility χ_m is related to the absolute temperature as :

(*a*) $\chi_m \propto T$ (*b*) $\chi_m \propto \frac{1}{T^2}$

(*c*) $\chi_m \propto \frac{1}{T}$

(*d*) χ_m is independent of temperature.

Ans. (*c*) $\chi_m \propto \frac{1}{T}$.

OR

(*iv*) A substance has susceptibility of – 0.025. The substance is :

(*a*) diamagnetic (*b*) paramagnetic

(*c*) ferromagnetic (*d*) superconductor.

Ans. (*a*) diamagnetic.

SECTION – E

Q. 31. (*a*) Define electric dipole moment. Is it a scalar or a vector ? Derive the expression for the electric field of a dipole at a point on the equatorial plane of the dipole.

(*b*) Draw the equipotential surfaces due to an electric dipole. Locate the points where the potential due to the dipole is zero.

OR

Using Gauss' law deduce the expression for the electric field due to a uniformly charged spherical conducting shell of radius R at a point (*i*) outside and (*ii*) inside the shell.

Plot a graph showing variation of electric field as a function of *r* > R and *r* < R.

(*r* being the distance from the centre of the shell)

Ans. (*a*) It is defined as the product of the magnitude of either of the two charges and the distance between them. It is a vector quantity having direction from the – ve to the + ve charge.

Consider an electric dipole consisting of charges –q and +q separated by a distance **2a** as shown in figure below. Let the point of observation P lie on the right bisector of the dipole AB at a distance *r* from its midpoint O. Let E_A and E_B be the electric field intensities at point P due to charges at A and B respectively.

The two electric fields have magnitudes

$$E_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+d^2)} \quad ...(1)$$

in the direction of AP

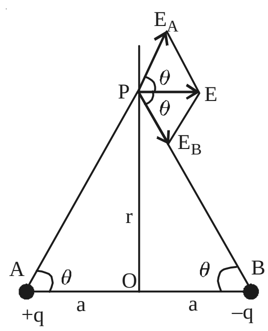
$$E_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+d^2)} \quad ...(2)$$

in the direction of PB

The two fields are equal in magnitude, but have different directions. Resolving the two fields E_A & E_B into their rectangular components *i.e.* perpendicular to and parallel to AB. The components perpendicular to AB *i.e* $E_A \sin\theta$ and $E_B \sin\theta$ being equal and opposite cancel out each other while the components parallel to AB *i.e.* $E_A \cos\theta$ and $E_B \cos\theta$ being in the same direction add up as shown in the Fig. Hence the resultant electric field at point P is given by

$$E = E_A \cos\theta + E_B \cos\theta$$

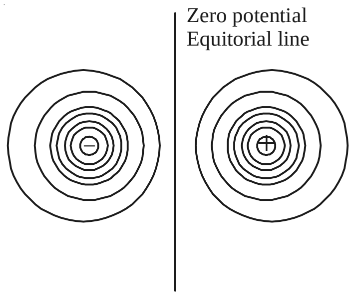
$$= 2E_A \cos\theta = \frac{1}{4\pi\varepsilon_0}\frac{2q}{(r^2+d^2)}\cos\theta \quad ...(3)$$



$$E = \frac{1}{4\pi\varepsilon_0}\frac{2qd}{(r^2+d^2)^{3/2}} = \frac{1}{4\pi\varepsilon_0}\frac{P}{(r^2+d^2)^{3/2}}$$

$$\because \cos\theta = \frac{a}{(r^2+d^2)^{1/4}} \text{ and } q\,2d = p$$

(*b*) The equipotential surfaces are as shown.



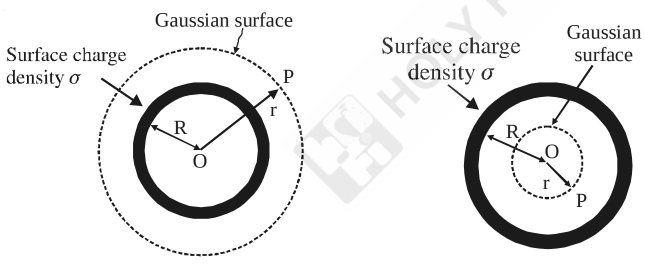
The zero potential points lie on the equatorial line.

OR

Consider a thin spherical shell of radius R and centre at O. Let σ be the uniform surface charge density (charge per unit surface area) and q be the total charge on it .The charge distribution is spherically symmetric. Three cases arise

(*i*) At a point outside the spherical shell

In order to find the electric field at a point P outside the shell let us consider a Gaussian surface in the form of a sphere of radius r ($r >> R$).



(*a*) (*b*)

By symmetry we find that the electric field acts radically outwards and has a normal component at all points on the Gaussian sphere. Therefore by definition of electric flux we have

$\phi = E \times A$ where A is the surface area of the Gaussian sphere therefore

$\phi = E \times 4\pi r^2$ ...(1)

But by Gauss's law

$$\phi = \frac{Q}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0} = \frac{\sigma \times 4\pi R^2}{\varepsilon_0} \quad ...(2)$$

from equation 1 and 2 it follows that

$$E \times 4\pi r^2 = \frac{\sigma \times 4\pi R^2}{\varepsilon_0} \quad ...(3)$$

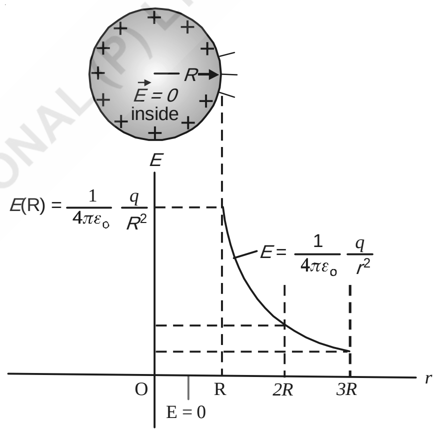
or $$E = \frac{\sigma R^2}{\varepsilon_0 r^2} \quad ...(4)$$

(*ii*) At a point inside the spherical shell

In this case, the Gaussian surface drawn inside the shell does not enclose any charge hence

$E \times 4\pi r^2$ or $E = 0$

The graph is as shown.



Q. 32. (*a*) A point object is placed in front of a double convex lens (of refractive index $n = n_2/n_1$ with respect to air) with its spherical faces of radii of curvature R_1 and R_2. Show the path of rays due to refraction at first and subsequently at the second surface to obtain the formation of the real image of the object.

Hence obtain the lens-maker's formula for a thin lens.

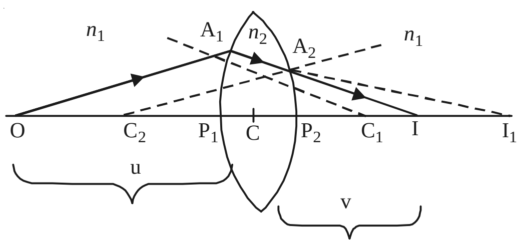
(*b*) A double convex lens having both faces of the same radius of curvature has refractive index 1.55. Find out the radius of curvature of the lens required to get the focal length of 20 cm.

OR

(*a*) **Draw a labelled ray diagram showing the image formation of a distant object by a refracting telescope. Deduce the expression for its magnifying power when the final image is formed at infinity.**

(*b*) **The sum of focal lengths of the two lenses of a refracting telescope is 105 cm. The focal length of one lens is 20 times that of the other. Determine the total magnification of the telescope when the final image is formed at infinity.**

Ans. (*a*) The diagram is as shown.



Let C be the optical centre of the lens. Suppose an object is placed at **O** at a distance **'u'** from the pole $\mathbf{P_1}$ of the surface $\mathbf{XP_1Y}$ This surface forms the real image of O at I_1 (if we assume the material of the lens extends beyond the face $\mathbf{XP_1Y}$**).** Hence for refraction at the spherical surface $\mathbf{XP_1Y}$**,** we have

$$\frac{n_2}{P_1I_1}+\frac{n_1}{P_1O}=\frac{n_2-n_1}{P_1C_1} \text{ or } \frac{n_2}{CI_1}+\frac{n_1}{CO}=\frac{n_2-n_1}{CC_1} \quad ...(1)$$

The approximations are taken because the lens is thin.

Consider the second surface $\mathbf{XP_2Y}$**.** Actually, the material of the lens does not extend beyond $\mathbf{XP_1Y}$**.** Therefore, before the refracted ray from A_1 could meet the principal axis, it will suffer refraction at point A_2 on the second face $\mathbf{XP_2Y}$ and the light ray will finally meet the principal axis at **I.** Such that **I** is the final image**.** Thus point **I** is the real image of the **virtual object** $\mathbf{I_1}$**.** Hence for refraction at the surface $\mathbf{XP_2Y}$ we have

$$\frac{n_1}{P_2I}-\frac{n_2}{P_2I_1}=\frac{n_2-n_1}{P_2C_2} \text{ or } \frac{n_1}{CI}-\frac{n_2}{CI_1}=\frac{n_2}{CC_2} \quad ...(2)$$

Adding equations 1 and 2 we have

$$\frac{n_2}{CI_1}+\frac{n_1}{CO}+\frac{n_1}{CI}-\frac{n_2}{CI_1}=\frac{n_2-n_1}{CC_1}+\frac{n_2-n_1}{CC_2} \quad ...(3)$$

or we have

$$\frac{n_1}{CO}+\frac{n_1}{CI}=(n_2-n_1)\left(\frac{1}{CC_1}+\frac{1}{CC_2}\right) \quad ...(4)$$

Using sign conventions *i.e.*

$CO = -u$, $CI = +v$, $CC_1 = +R_1$ and $CC_2 = -R_2$

The above equation becomes

$$\frac{n_1}{-u}+\frac{n_1}{+v}=(n_2-n_1)\left(\frac{1}{+R_1}+\frac{1}{-R_2}\right) \quad ...(5)$$

$$\text{or } \frac{1}{-u}+\frac{1}{+v}=\left(\frac{n_2}{n_1}-1\right)\left(\frac{1}{+R_1}+\frac{1}{-R_2}\right) \quad ...(6)$$

But $n_2/n_1 = n$, the absolute refractive index of the material of the lens, therefore the above equation takes the form

$$\frac{1}{v}-\frac{1}{u}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

But by lens formula we have $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

Therefore, from the above two equations we have

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(7)$$

This is the Lens maker's equation or formula

(*b*) Given $R_1 = R_2 = R$, $f = 20$ cm, $n = 1.55$

Using the expression $\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

We have

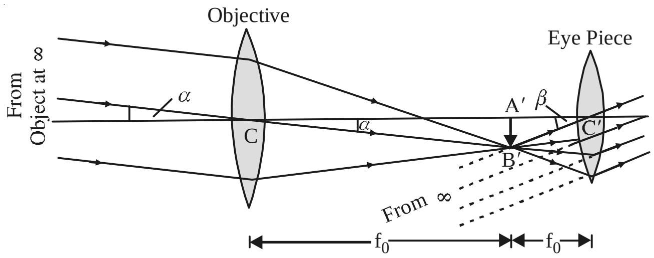
$$\frac{1}{20}=(1.55-1)\left(\frac{2}{R}\right)$$

Solving for R we have

R = 22 cm

OR

(*a*) The diagram is as shown.



From right triangle ABC and ABC′ as shown in figure, we have

$$\tan\alpha = \frac{AB}{CB} = \frac{-h}{f_0} \text{ and } \tan\beta = \frac{AB}{C'A} = \frac{-h}{f_e}$$

From the above we have

$$\text{we have } M = \frac{\beta}{\alpha} = \frac{-h}{f_e} \times \frac{f_0}{-h} = \frac{f_0}{f_e}$$

(*b*) L = 105 cm, $f_0 = 20\, f_e$,

Now $L = f_0 + f_e = 21\, f_e$

Or $f_e = 105/21 = 5$ cm

Hence $f_0 = 20 \times f_e\ 20 \times 5 = 100$ cm

Hence $M = f_0/f_e = 100/5 = 20$

Q. 33. (*a*) Explain briefly with the help of a labelled diagram, the principle and working of a moving coil galvanometer.

(*b*) Define the term 'current sensitivity' of a galvanometer. How is it that increasing current sensitivity may not necessarily increase its voltage sensitivity? Explain.

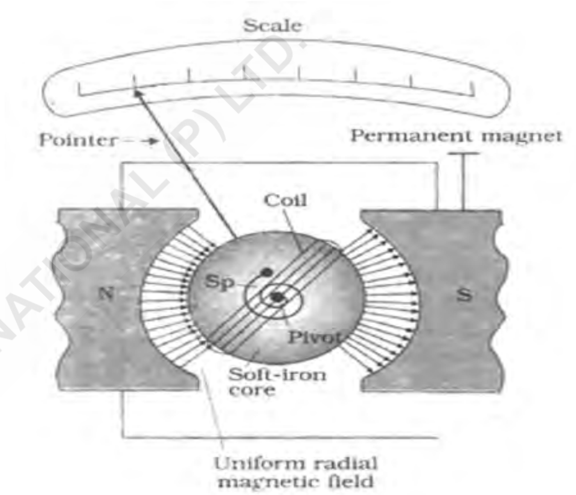
Or

(*a*) State Biot - Savart law. Deduce the expression for the magnetic field due to a circular current carrying loop at a point lying on its axis.

(*b*) Two long parallel wires carry currents I_1 and I_2 flowing in the same direction. When a third current carrying wire is placed parallel and coplanar in between the two, find the condition when the third wire would experience no force due to these two wires.

Ans. (*a*) It is an instrument used to detect weak currents in a circuit.

Principle : It is based on the principle that, whenever a loop carrying current is placed in a magnetic field, it experiences a torque, which tends to rotate it.



Working : When the closed loop is suspended in the magnetic field, it experiences a torque, which tends to rotate it along a vertical axis. This torque, called the deflecting torque, is given by

$$\tau_d = B\, I\, n\, A \qquad ...(1)$$

As a result of this torque the coil gets deflected. This produces a twist in the suspension wire, due to which the coil is acted upon by another torque called restoring torque. This torque tends to take the coil back to its original position. If 'C' is the restoring torque per unit angular twist and is the angle through which the wire has deflected then the restoring torque is given by

$$\tau_r = C\,\theta \qquad ...(2)$$

The closed loop is twisted till the restoring torque becomes equal to the deflecting torque.

Therefore, in equilibrium, from equations 1 and 2 we have

$$B\,I\,n\,A = C\,\theta$$

$$I = \frac{C}{n\,B\,A}\theta \qquad ...(3)$$

(*b*) Current Sensitivity: The current sensitivity of the galvanometer is the deflection produced in the galvanometer per unit current.

Voltage and current sensitivities are related as

$$VS = \frac{CS}{R}.$$

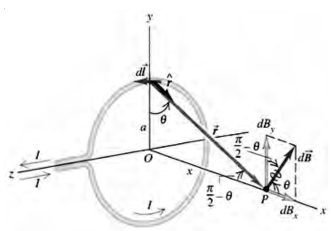
An increase in current sensitivity may lead to an increase in the resistance of the coil. Thus the factor CS/R may not be affected.

OR

Biot Savart's law states that for a small current element $\overline{dB} = \frac{\mu_0}{4\pi}\frac{I(\overline{dL}\times\hat{r})}{r^2}$

Consider a circular loop of wire of radius R located in the YZ plane and carrying a steady current I as shown in figure below. Let us calculate the magnetic field at an axial point P a distance x from the centre of the loop. From the figure it is clear that any element dL is perpendicular to $\hat{r}$, furthermore all the elements around the loop are at the same distance r from P, where $r^2 = x^2 + R^2$. Hence by Biot Savart's law the magnetic field at point P due to the current element dL is given by

$$dB = \frac{\mu_0}{4\pi}\frac{I|\overline{dL}\times\hat{r}|}{r^2} = \frac{\mu_0}{4\pi}\frac{I\,dL}{(x^2+R^2)} \qquad ...(1)$$



The direction of the magnetic field dB due to the element dL is perpendicular to the plane formed by $\hat{r}$ and dL as shown in figure above. The vector dB can be resolved into components dB_x along the X axis and dBy which is perpendicular to the X-axis. When the components perpendicular to the X-axis are assumed over the whole loop, the result is zero. That is, by symmetry any element on one side of the loop will set up a perpendicular component that cancels the component set up by an element diametrically opposite it. Therefore it is obvious that the resultant magnetic field at P will be along the X-axis. This result can be obtained by integrating the components $dB_x = dB\cos\theta$. Therefore, we have

$$B = \oint dB\cos\theta = \frac{\mu_0 I}{4\pi}\oint\frac{dL\cos\theta}{x^2+R^2} \qquad ...(2)$$

where the integral is to be taken over the entire loop since θ, x and R are constants for all elements of the loop and since

$\cos\theta = \frac{R}{\sqrt{x^2+R^2}}$ therefore, we have

$$B = \frac{\mu_0 IR}{4\pi(x^2+R^2)^{3/2}}\oint dL = \frac{\mu_0 IR^2}{2(x^2+R^2)^{3/2}}$$

(*b*) Two current carrying wires carrying current in the same direction attract and those carrying current in the opposite direction repel. The current in the third wire at the center should be opposite to the current in the two wires.

The conditions should be

(*i*) The centre wire should carry current in the opposite direction to the two wires and

(*ii*) The centre wire should be closer to the wire carrying lesser current.

Holy Faith New Style Sample Paper—8

(Based on the Latest Design `& Syllabus issued by C.B.S.E.)

CLASS – 12th

PHYSICS (Theory)

Time allowed : 3 hours **Maximum Marks : 70**

General Instructions : Same as in MTP – 1

SECTION – A

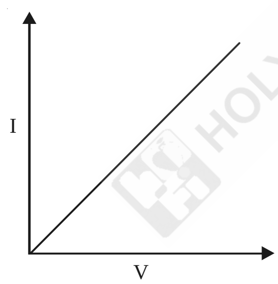
Q. 1. A charge Q is placed at the centre of the line joining two charges q and q. The system of the three charges will be in equilibrium if Q is :

(*a*) $+\frac{q}{3}$ (*b*) $-\frac{q}{3}$

(*c*) $+\frac{q}{4}$ (*d*) $-\frac{q}{4}$.

Ans. (*d*) $-\frac{q}{4}$.

Q. 2. The given figure shows I – V graph of a copper wire whose length and area of cross-section are L and A respectively. The slope of this curve becomes :



(*a*) less if the length of the wire is increased
(*b*) more if the length of the wire is increased
(*c*) more if a wire of steel of same dimension is used
(*d*) more if the temperature of wire is increased

Ans. (*a*) less if the length of the wire is increased.

Q. 3. When a potential difference V is applied across a conductor at temperature T, the drift velocity of the electrons is proportional to :

(*a*) T (*b*) $\sqrt{T}$

(*c*) V (*d*) $\sqrt{V}$.

Ans. (*c*) V.

Q. 4. A diamagnetic substance is brought near the north or South Pole of a bar magnet. It will be :

(*a*) repelled by both the poles
(*b*) attracted by both the poles
(*c*) repelled by the north pole and attracted by the south pole
(*d*) attracted by the north pole and repelled by the south pole.

Ans. (*a*) repelled by both the poles.

Q. 5. In an ac circuit the applied voltage and resultant current are $E = E_o \sin \omega t$ and $I = I_o \sin (\omega t + \pi/2)$ respectively. The average power consumed in the circuit is :

(*a*) E_oI_o (*b*) $\frac{E_oI_o}{2}$

(*c*) $\frac{E_oI_o}{\sqrt{2}}$ (*d*) zero.

Ans. (*d*) zero.

Q. 6. In a series LCR circuit, at resonance the current is equal to :

(*a*) V/R (*b*) V/X_C

(*c*) $\frac{V}{X_L \sim X_C}$ (*d*) $\frac{V}{\sqrt{R^2+(X_L \sim X_C)^2}}$.

Ans. (*a*) V/R.

Q. 7. **In electromagnetic wave the phase difference between electric and magnetic field vectors $\vec{E}$ and $\vec{B}$ is :**

(*a*) 0 (*b*) $\pi/2$
(*c*) π (*d*) $\pi/4$.

Ans. (*a*) 0.

Q. 8. In an experiment on photoelectric effect, the slope of the cut-off voltage versus frequency of incident light is found to be 4.12×10^{-15} V s. The value of Planck's constant is :

(*a*) 6.59×10^{-34} J s (*b*) 6.59×10^{-31} J s
(*c*) 9.31×10^{-31} J s (*d*) 1.6×10^{-19} J s.

Ans. (*a*) 6.59×10^{-34} J s.

Q. 9. The threshold frequency for a certain metal is 3.3×10^{14} Hz. If light of frequency 8.2×10^{14} Hz is incident on the metal, predict the cut-off voltage for the photoelectric emission.

(*a*) 0.203 V (*b*) 2.03 V
(*c*) 20.3 V (*d*) 0.0203 V.

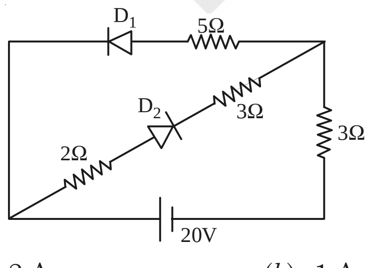
Ans. (*b*) 2.03 V.

Q. 10. The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons. This is because

(*a*) of the electrons not being subject to a central force
(*b*) of the electrons colliding with each other
(*c*) of screening effects
(*d*) the force between the nucleus and an electron will no longer be given by Coulomb's law.

Ans. (*a*) of the electrons not being subject to a central force.

Q. 11. In the given circuit, all diodes are ideal. The current through battery is :



(*a*) 2 A (*b*) 1 A
(*c*) 3 A (*d*) 4 A.

Ans. (*a*) 2 A.

Q. 12. To reduce the ripples in a rectifier circuit with capacitor filter which one is false ?

(*a*) R_L should be increased
(*b*) input frequency should be decreased
(*c*) input frequency should be increased
(*d*) capacitors with high capacitance should be used.

Ans. (*b*) input frequency should be decreased.

Questions number 13 to 16 are Assertion (A) and Reason (R) type questions

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (*a*), (*b*), (*c*) and (*d*) as given below.

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

Q. 13. Assertion (A) : Heater wire must have high resistance and high melting point.

Reason (R) : If resistance is high, the electric conductivity will be less.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

Q. 14. Assertion (A) : For making permanent magnets steel is preferred over soft iron.

Reason (R) : As retentivity of steel is smaller.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

Q. 15. Assertion (A) : An electron in hydrogen atom passes from $n = 4$ to $n = 1$ level. The maximum number of photons that can be emitted is 6.

Reason (R) : No. of photons emitted can never be more than 5.

Ans. (*c*) (A) is true but (R) is false.

Q. 16. Assertion (A) : An N- type semiconductor has a large number of electrons but still it is electrically neutral.

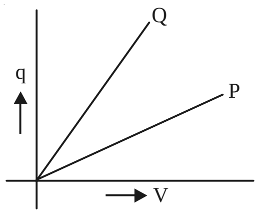
Reason (R) : An N-type semiconductor is obtained by doping an intrinsic semiconductor with a pentavalent impurity.

Ans. (*b*) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

SECTION – B

Q. 17. The given graph shows variation of charge '*q*' versus potential difference '*V*' for two capacitors C_1(Q) and C_2(P). Both

the capacitors have same plate separation but plate area of C_2 is greater than that of C_1. Which line (A or B) corresponds to C_1 and why ?



Ans. Now $C = \varepsilon_0 A/d$, since area for C_2 is more, therefore capacitance of C_2 is more. From the graph greater the slope greater is the capacitance, therefore, graph Q belongs to capacitor C_2. While graph P belongs to capacitance C_1.

Q. 18. Are the paths of electrons straight lines between successive collisions (with the positive ions of the metal) in the (*i*) absence of electric field and (*ii*) presence of electric field ?

Ans. In the absence of electric field, the paths are straight lines. In the presence of electric field, the paths are, in general, curved.

Q. 19. You are given a low resistance R_1, a high resistance R_2 and a moving coil galvanometer. Suggest how you would use these to have an instrument that will be able to measure (*i*) current and (*ii*) potential differences.

OR

What is meant by the current sensitivity of a moving coil galvanometer ? On what factors does it depend ?

Ans. (*i*) For measuring current, we need an ammeter. An ammeter is formed by connecting a low resistance in parallel with the galvanometer. Therefore resistance R_1 should be connected in parallel with the galvanometer to measure current.

(*ii*) For measuring potential differences, we need a voltmeter. A voltmeter is formed by connecting a high resistance in series with the galvanometer. Therefore resistance R_2 should be connected in series with the galvanometer to measure potential differences.

OR

Current sensitivity of a moving coil galvanometer is defined as the deflection produced in the galvanometer per unit current passed through it. It is given by C.S= deflection/current = NBA/k

From the above relation, it is clear that current sensitivity of a galvanometer depends on

(*i*) number of turns N in the coil

(*ii*) magnetic field B

(*iii*) area A of the coil and

(*iv*) the restoring torque per unit twist, *i.e.* k.

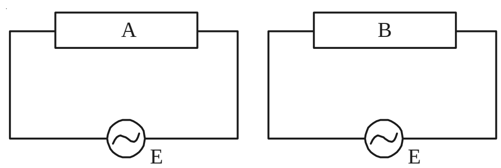
Q. 20. Calculate the value of resistance needed to convert a galvanometer of resistance 120 Ω, which gives a full-scale deflection for a current of 5 mA, into a voltmeter of 0 – 50 V range.

Ans. Given $G = 120\ \Omega$, $Ig = 5 \times 10^{-3}$ A, $V = 50$ V, $R = ?$

Using the relation $R = \frac{V}{I_g} - G$

we have $R = \frac{V}{I_g} - G = \frac{50}{5\times10^{-3}} - 120 = 9880\ \Omega$

Q. 21. Devices A and B are connected independently to a variable frequency alternating voltage source as shown. The current in A is ahead of the applied voltage, whereas it lags behind the voltage in B.



(*i*) Identify the devices A and B.

(*ii*) How will the current in each of these devices change on decreasing the frequency of the applied voltage ? Give reason to support your answer in each case.

Ans. (*i*) Device A is a capacitor. Device B is an inductor.

(*ii*) For a capacitor $I = \frac{V}{X_C} = V2\pi fC$

When the frequency is decreased, the current through the circuit will decrease.

For an inductor $I = \frac{V}{X_L} = \frac{V}{2\pi fL}$

When the frequency is decreased, the current through the circuit will increase.

SECTION – C

Q. 22. Gamma rays and radio waves travel with the same velocity in free space. Distinguish between them in terms of their origin and the main application.

OR

Identify the electromagnetic waves whose wavelengths vary as

(*a*) 10^{-12} m < λ < 10^{-8} m

(*b*) 10^{-3} m < λ < 10^{-1} m

Write one of their uses.

Ans. The distinction

Gamma rays	Radio waves
Emitted by a nucleus	Produced by electronic circuit
Cancer treatment	communication

OR

(*a*) X-rays: study of crystal structure

(*b*) Microwaves: radar and communication

Q. 23. Electrons are emitted from a photosensitive surface when it is illuminated by green light, but electron emission does not take place by yellow light. Will the electrons be emitted when the surface is illuminated by (*a*) red light and (*b*) blue light ?

Ans. (*a*) No electron will be emitted when illuminated by red light.

(*b*) Electron emission takes place with blue light.

Q. 24. The KE of a beam of electrons, accelerated through a potential V, equals the energy of a photon of wavelength 5460 nm. Find the de Broglie wavelength associated with this beam of electrons.

Ans. The de-Broglie wavelength is given by

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$\text{Now } E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{5460\times10^{-9}}$$

$= 3.6 \times 10^{-20}$ J

$$\lambda = \frac{h}{\sqrt{2mE}} = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times3.6\times10^{-20}}}$$

$\lambda = 2.58 \times 10^{-9}$ m = 2.58 nm

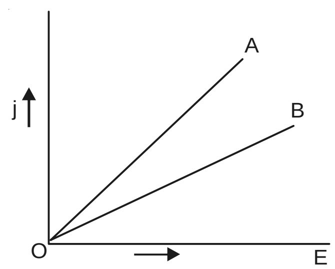
Q. 25. Plot a graph showing the variation of current density (j) versus the electric field (E) for two conductors of different materials. What information from this plot regarding the properties of the conducting material, can be obtained which can be used to select suitable materials for use in making (*i*) standard resistance and (*ii*) connecting wires in electric circuits ?

Electron drift speed is estimated to be of the order of mm s^{-1}. Yet large current of the order of few amperes can be set up in the wire. Explain briefly.

Ans. We know that J = σE

Therefore, the graph between J and E will be a straight line passing through the origin.

This is as shown



The slope of the graph = conductivity (σ)

Hence, material with less slope (smaller conductivity) is used for making standard resistors and material with greater slope (higher conductivity) for making connecting wires.

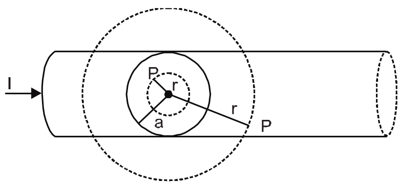
It is due to the reason that the electron number density is enormous, 10^{29} m^{-3}.

Q. 26. State Ampere's circuital law. Use this law to find magnetic field due to straight

infinite current carrying wire. How are the magnetic field lines different from the electrostatic field lines ?

Ans. **Statement :** "The line integral of B around any closed path equals $\mu_0 I$, where I is the total steady current passing through any surface bounded by the closed path."

Consider a long circular wire of radius '*a*' carrying a steady current (dc) that is uniformly distributed along the cross section of the wire as shown in figure. Let us calculate the magnetic field in the regions and **r < a.** In region 1 let us choose a circular path of radius r centred at the wire. From symmetry, we find that B is perpendicular to **dL** at every point on the circular path.



Since total current linked with the circular path 1 is I_0, therefore by Ampere's law we have

$$\oint B.dL = B\oint dL = B\,(2\pi r) = \mu_0 I_0 \qquad ...(1)$$

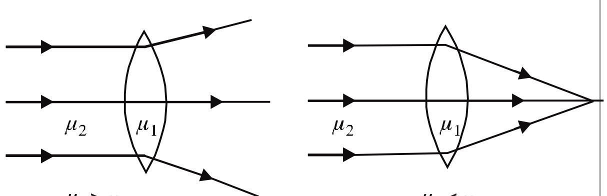
$$\text{or } B = \frac{\mu_0 I_0}{2\pi r} \qquad ...(2)$$

for $r \geq a$

Magnetic field lines form closed loops while electrostatics field lines do not.

Q. 27. An equiconvex lens of refractive index m_1 focal length '*f*' and radius of curvature 'R' is immersed in a liquid of refractive index m_2. For (*i*) $m_2 > m_1$, and (*ii*) $m_2 < m_1$, draw the ray diagrams in the two cases when a beam of light coming parallel to the principal axis is incident on the lens. Also find the focal length of the lens in terms of the original focal length and the refractive index of the glass of the lens and that of the medium.

Ans. (*i*)



$\mu_2 > \mu_1$ $\quad$ $\mu_2 < \mu_1$

(*ii*) Given As the lens is equiconvex therefore $R_1 = R_2 = R$, ${}_am_g = m_1$, ${}_am_l = m_2$ $f_a = f$, $f_L = ?$

Using the expression

$$\frac{f_L}{f_a} = \frac{({}_a\mu_g - 1)}{\left(\frac{{}_a\mu_g}{{}_a\mu_L} - 1\right)} = \frac{\mu_1 - 1}{\left(\frac{\mu_1}{\mu_2} - 1\right)}$$

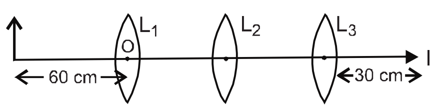
$$f_L = \frac{(\mu_1 - 1)\mu_2}{(\mu_1 - \mu_2)} \times f_a\,.$$

Q. 28. (*a*) Monochromatic light of wavelength 589 nm is incident from air on a water surface. If m 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.

OR

Three lenses L_1, L_2, and L_3 each of focal length 30 cm are placed coaxially as shown in the figure. An object is held at 60 cm from the optic centre of L_1. The final image is formed at the focus of L_3. Calculate the separation between (i) L_1 and L_2 and (ii) L_2 and L_3.



Ans. (*a*) Given λ_a = 589 nm, μ_a = 1, μ_w = 1.33 , λ_w = ? and v = ?

Using the relation $\lambda_a \mu_a = \lambda_w \mu_w$ hence

$$\lambda_w = \frac{\lambda_a \mu_a}{\mu_w} = \frac{589 \times 1}{1.33} = 442.9 \text{ nm}$$

There is no change in the frequency of light

$$\text{hence } \nu = \frac{c}{\lambda_a} = \frac{3 \times 10^8}{589 \times 10^{-9}} = 5 \times 10^{14} \text{ Hz}$$

Now speed of light of the refracted light

$$v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.33} = 2.25 \times 10^8 \text{ m s}^{-1}$$

(*b*) Given m = 1.55, $R_1 = R_2$ = R(say), f = 20 cm

Using the expression

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = (\mu - 1)\left(\frac{2}{R}\right)$$

or R = (μ – 1) 2f = (1.55 – 1) 2 × 20 = 22 cm

OR

Given $f_1 = f_2 = f_3 = 30$ cm

For lens L_1, u_1 = 60 cm = $2f_1$, therefore the image will be formed at $2f$ on the other side of the lens L_1.

Since the final image for lens L_3 is formed at the focus, therefore the rays of light falling on lens L_3 should come from infinity. This is possible if the image of L_1 lies at the focus of L_2

Thus distance L_1L_2 = 60 + 30 = 90 cm

Also distance L_2L_3 can have any value as the rays between L_2 and L_3 will be parallel.

SECTION – D

Questions number 29 to 30 are case study based questions

Q. 29. The British physicist Thomas Young explained the interference of light using the principle of superposition of waves. He observed the interference pattern on the screen, in his experimental set-up, known now as Young's double slit experiment. The two slits S_1 and S_2 were illuminated by light from a slit S. The interference pattern consists of dark and bright bands of light. Such bands are called fringes. The distance between two consecutive bright and dark fringes is called fringe' width.

(*i*) If the screen is moved closer to the plane of slits S_1 and S_2, then the fringe width :

(*a*) will decrease, but the intensity of bright fringe remains the same

(*b*) will increase, but the intensity of bright fringe decreases

(*c*) will decrease, but the intensity of bright fringe increases

(*d*) and the intensity both remain the same.

Ans. (*c*) will decrease, but the intensity of bright fringe increases.

(*ii*) What will happen to the pattern on the screen, when the two slits S_1 and S_2 are replaced by two independent but identical sources ?

(*a*) The intensity of pattern will increase

(*b*) The intensity of pattern will decrease

(*c*) The number of fringes will become double

(*d*) No pattern will be observed on the screen.

Ans. (*d*) No pattern will be observed on the screen.

(*iii*) Two sources of light are said to be coherent, when both emit light waves of :

(*a*) same amplitude and have a varying phase difference

(*b*) same wavelength and a constant phase difference

(*c*) different wavelengths and same intensity

(*d*) different wavelengths and a constant phase difference.

Ans. (*b*) same wavelength and a constant phase difference.

(*iv*) The fringe width in a Young's double slit experiment is 'β'. If the whole set-up is immersed in a liquid of refractive index 'μ', then the new fringe width will be :

(*a*) β (*b*) $\beta\mu$

(*c*) $\frac{\beta}{\mu}$ (*d*) $\frac{\beta}{\mu^2}$.

Ans. (*c*) $\frac{\beta}{\mu}$.

OR

The total path difference between two waves meeting at points P_1 and P_2 on the screen are $\left(\frac{3\lambda}{2}\right)$ and 2l respectively. Then :

(*a*) bright fringes are formed at both points.

(*b*) dark fringes are formed at both points

(*c*) a bright fringe is formed at P_1 and a dark fringe is formed at P_2

(*d*) a bright fringe is formed at P_2 and a dark fringe is formed at P_1

Ans. (*d*) a bright fringe is formed at P_2 and a dark fringe is formed at P_1.

Q. 30. When p side of p-n junction is connected to positive terminal of battery and n side of p-n junction is connected to negative terminal of battery then the p-n junction is said to be in forward bias mode or forward biased. In addition, when p side of p-n junction is connected to negative terminal of battery and n side of p-n junction is connected to positive terminal of battery then the p-n junction is said to be in reverse bias mode or reverse biased. The diode used to rectify an AC voltage is called as rectifier. Zener diode is also a p-n junction diode, which works in reverse bias condition and used as voltage regulator. In addition, p-n junction diodes are used in solar cells, which is used to convert light energy into electrical energy. Light emitting diodes are also p-n junction diodes, which are used to produce light.

(*i*) Zener diode and photodiode works in the ....

(*a*) forward bias mode
(*b*) reverse bias mode
(*c*) both (*a*) and (*b*)
(*d*) none.

Ans. (*b*) reverse bias mode.

(*ii*) The semiconductor which are used to make visible LEDs must have band gap of ....

(*a*) 3 eV (*b*) 0 eV
(*c*) 1.8 eV (*d*) 5 eV.

Ans. (*c*) 1.8 eV.

(*iii*) The rectifier in which the rectified output is only for half of the input AC wave is called as ....

(*a*) Full wave rectifier
(*b*) Half wave rectifier
(*c*) Transformer
(*d*) Bridge rectifier.

Ans. (*b*) Half wave rectifier.

(*iv*) What is dynamic resistance ?

(*a*) The ratio of small change in voltage ΔV to a small change in current ΔI
(*b*) The ratio of small change in current ΔI to a small change in voltage ΔV
(*c*) The product of small change in voltage ΔV and a small change in current ΔI
(*d*) Cannot be defined.

Ans. (*a*) The ratio of small change in voltage ΔV to a small change in current ΔI.

Or

What is barrier potential ?

(*a*) The electric potential required to restrict the movement of electron from n-side to p-side across p-n junction
(*b*) A fictitious battery with positive on the p side and negative on the n side
(*c*) The electric potential required to restrict the movement of holes from n-side to p-side across p-n junction
(*d*) None of these

Ans. (*a*) The electric potential required to restrict the movement of electron from n-side to p-side across p-n junction.

OR

(*iv*) How can you increase the magnetic field inside a toroid ?

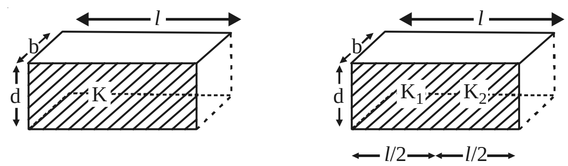
(*a*) by increasing the radius
(*b*) by decreasing the current
(*c*) by introducing a soft iron core inside a toroid
(*d*) by decreasing the total number of turns.

Ans. (*c*) by introducing a soft iron core inside a toroid.

SECTION – E

Q. 31. (*a*) Obtain the expression for the potential due to an electric dipole of dipole moment p at a point 'x' on the axial line.

(*b*) Two identical capacitors of plate dimensions: *l* × b and plate separation *d* have dielectric slabs filled in between the space of the plates as shown in the figures.



Obtain the relation between the dielectric constants K, K_1 and K_2.

OR

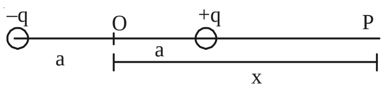
(*a*) **Distinguish with the help of a suitable diagram, the difference in the behaviour of a conductor and a dielectric placed in an external electric field. How does polarized dielectric modify the original external field' ?**

(*b*) **A capacitor of capacitance C is charged fully by connecting it to a battery of emf E. It is then disconnected from the battery. If the separation between the plates of the capacitor is now doubled, how will the following change' ?**

(*i*) **charge stored by the capacitor.**
(*ii*) **field strength between the plates.**
(*iii*) **energy stored by the capacitor.**

Justify your answer in each case.

Ans. (*a*) Consider an electric dipole of length $2a$ and having charges +q and – q. Let us find the potential on the axial line at point P at a distance OP = x from the centre of the dipole.



Now potential at point P is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{x-a} + \frac{1}{4\pi\varepsilon_0}\frac{-q}{x+a}$$

$$\text{Or } V = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{x-a} - \frac{1}{x+a}\right) = \frac{q}{4\pi\varepsilon_0}\left(\frac{2a}{(x^2-a^2)}\right)$$

$$V = \frac{p}{4\pi\varepsilon_0\left(x^2-a^2\right)}$$

(*b*) When there is no dielectric then

$$C = \frac{\varepsilon_0 lb}{d}$$

For the first capacitor

$$C' = \frac{K\varepsilon_0 lb}{d} = KC$$

The second case is a case of two capacitors connected in parallel, therefore

$$C_1 = \frac{K_1\varepsilon_0 lb}{2d} \text{ and } C_2 = \frac{K_2\varepsilon_0 lb}{2d}$$

These two are connected in parallel, therefore we have

$$C'' = C_1 + C_2 = C_1 = \frac{K_1\varepsilon_0 lb}{2d} + \frac{K_2\varepsilon_0 lb}{2d}$$

$$= C\left(\frac{K_1+K_2}{2}\right)$$

If the capacitance in each case be same,

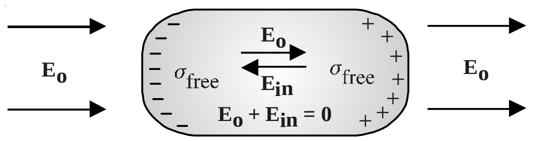
$$\text{then } K = \left(\frac{K_1+K_2}{2}\right)$$

OR

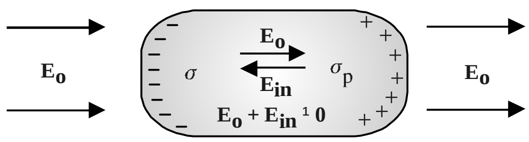
(*a*) When a conductor is placed in an external electric field. The free charge carriers move and charge distribution in the conductor adjusts itself in such a way that the electric field due to induced charges opposes the external field within the conductor. This happens until, in the static situation, the two fields cancel each other and the net electrostatic field in the conductor is zero.

In a dielectric, this free movement of charges is not possible. It turns out that the external field induces dipole moment by stretching or re-orienting molecules of the dielectric. The collective effect of all the molecular dipole moments is net charges on the surface of the dielectric which produce a field that opposes the external field. Unlike in a conductor, however, the opposing field so induced does not exactly cancel the external field. It only reduces it. The extent of the effect depends on the nature of the dielectric.

This is diagrammatically shown as under.



Conductor



Dielectric

(*b*) (*i*) Charge does not depend upon the distance between plates, therefore there is no change in it.

(*ii*) Now $C = \frac{\varepsilon_0 A}{d}$ as d is doubled capacitance becomes half.

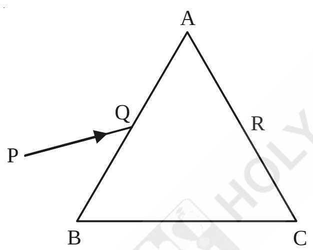
Thus potential V = Q/C becomes double.

Now $E = V/d = 2V_0/2d = V_0/d$ remains same.

(*iii*) Now $U = \frac{1}{2}CV^2$ as C becomes half and V is doubled, U becomes 2 times.

Q. 32. (*a*) Two thin convex lenses L_1 and L_2 of focal lengths f_1 and f_2 respectively, are placed coaxially in contact. An object is placed at a point beyond the focus of lens L_1. Draw a ray diagram to show the image formation by the combination and hence derive the expression for the focal length of the combined system.

(*b*) A ray PQ incident on the face AB of a prism ABC, as shown in the figure, emerges from the face AC such that AQ = AR.



Draw the ray diagram showing the passage of the ray through the prism. If the angle of the prism is 60° and refractive index of the material of the prism is $\sqrt{3}$, determine the values of angle of incidence and angle of deviation.

OR

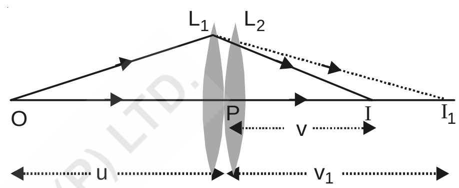
(*a*) Draw a ray diagram showing the image formation by a compound microscope. Obtain expression for total magnification when the image is formed at infinity.

(*b*) How does the resolving power of a compound microscope get affected, when

(*i*) focal length of the objective is decreased.

(*ii*) the wavelength of light is increased ? Give reasons to justify your answer.

Ans. (*a*) A wave front is defined as the locus of all adjacent points at which the phase of vibration of a physical quantity associated with the wave is the same. It is in two dimesion while a ray is in one dimension.



The first lens L_1 produces an image at I_1. Since image I_1 is real, it serves as a virtual object for the second lens L_2, producing the final image at I. Since the lenses are thin, we assume the optical centres of the lenses to be coincident. Let this central point be denoted by P.

For the image formed by the first lens L_1, we get

$$\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1} \quad ...(i)$$

For the image formed by the second lens L_2, we get

$$\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_1} \quad ...(ii)$$

Adding equations (*i*) and (*ii*) we have

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

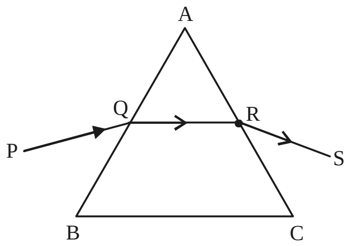
If the two lens-system is regarded as equivalent to a single lens of focal length *f*, we have

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

Therefore form equations (*iii*) and (*iv*) we get

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

(*b*) The ray diagram is as shown



The prism, in this situation, is in the minimum deviation position, therefore we have

$$r = \frac{A}{2} = \frac{60}{2} = 30°$$

Hence $n = \frac{\sin i}{\sin r} = \frac{\sin i}{\sin 30°} = \sqrt{3}$

This gives $i = 60^0$

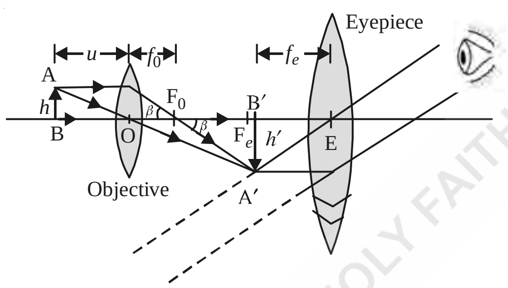
Hence from

$$i = \frac{A + D_m}{2} \text{ we have}$$

$D_m = 2i - A = 2 \times 60 - 60 = 60^0$

OR

(*a*) The ray diagram is as shown.



$$M = M_e \times M_0 = \frac{v_0}{u_0} \times \left(\frac{D}{f_e}\right) = \frac{L}{f_0} \times \left(\frac{D}{f_e}\right)$$

(*b*) The resolving power of a microscope is given by the expression $RP = \frac{2n \sin\theta}{\lambda}$

(*i*) There is no effect of the increase in the focal length of the objective on the resolving power of the microscope.

(*ii*) If the wavelength of the incident light is increased, the resolving power of the microscope also decreases.

Q. 33. (*a*) Using Biot - Savart's law, derive the expression for the magnetic field in the vector form at a point on the axis of a circular current loop.

(*b*) What does a toroid consist of ? 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. Show that the magnetic field in the open space inside and exterior to the toroid is zero.

Or

A metallic rod of length *l* and resistance R 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 and uniform magnetic field B parallel to the axis is present everywhere.

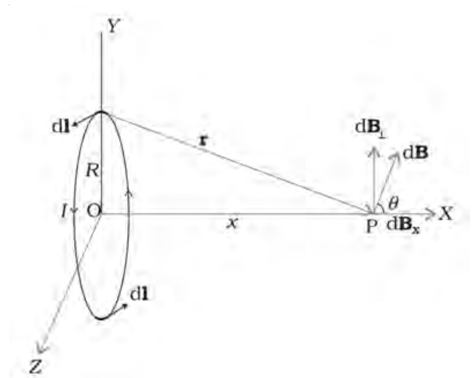
(*a*) Derive the expression for the induced emf and the current in the rod.

(*b*) Due to the presence of the current in the rod and of the magnetic field, find the expression for the magnitude and direction of the force acting on this rod.

(*c*) Hence obtain the expression, for the power required to rotate the rod.

Ans. (*a*) Consider a circular loop of wire of radius R located in the YZ plane and carrying a steady current I as shown in figure below. Let us calculate the magnetic field at an axial point P a distance x from the centre of the loop. From the figure it is clear that any element dL is perpendicular to $\hat{r}$, furthermore all the elements around the loop are at the same distance r from P, where $r^2 = x^2 + R^2$. Hence by Biot Savart's law the magnetic field at point P due to the current element dL is given by

$$dB = \frac{\mu_0}{4\pi} \frac{I|\overline{dL} \times \hat{r}|}{r^2} = \frac{\mu_0}{4\pi} \frac{I\ dL}{(x^2 + R^2)} \qquad ...(1)$$



The direction of the magnetic field dB due to the element dL is perpendicular to the plane formed by $\hat{r}$ and dL as shown in figure above. The vector dB can be resolved into components dB_x along the X axis and dBy which is perpendicular to the X-axis. When the components perpendicular to the X-axis are assumed over the whole loop, the result is zero. That is, by symmetry any element on one side of the loop will set up a perpendicular component that cancels the component set up by an element diametrically opposite it. Therefore it is obvious that the resultant magnetic field at P will be along the X-axis. This result can be obtained by integrating the components $dB_x = dB\cos\theta$. Therefore, we have

$$B = \oint dB\cos\theta = \frac{\mu_0 I}{4\pi}\oint \frac{dL\cos\theta}{x^2+R^2} \qquad ...(2)$$

where the integral is to be taken over the entire loop since θ, x and R are constants for all elements of the loop and since $\cos\theta = \frac{R}{\sqrt{x^2+R^2}}$

therefore, we have

$$B = \frac{\mu_0 IR}{4\pi(x^2+R^2)^{3/2}}\oint dL = \frac{\mu_0 IR^2}{2(x^2+R^2)^{3/2}}\hat{i}$$

(*b*) A toroid is a hollow circular ring on which a large number of turns of a wire are closely wound.

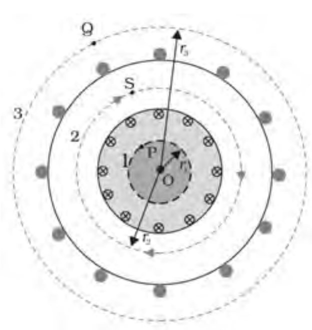
Consider the magnetic field at S as shown in the figure. We find, $L = 2\pi r$.

The current enclosed I is (for N turns of toroidal coil) N I.

Therefore

$B\ (2pr) = \mu_0\ NI$

Or $B = \frac{\mu_0 NI}{2\pi r}$.



Let the magnetic field along loop 1 be B_1 in magnitude. Then in Ampere's circuital law, $L = 2\pi r_1$

However, the loop encloses no current, so $I_e = 0$. Thus,

$B_1\ (2\pi r) = \mu_0\ (0)$, or $B_1 = O$

Thus, the magnetic field at any point P in the open space inside the toroid is zero.

We shall now show that magnetic field at Q is likewise zero. Let the magnetic field along loop 3 be B_3. Once again from Ampere's law $L = 2\pi r$

However, from the sectional cut, we see that the current coming out of the plane of the paper is cancelled exactly by the current going into it. Thus, $I_e = 0$, and $B = 0$.

OR

As the rod is rotated, free electrons in the rod move towards the outer end due to Lorentz force and get distributed over the ring. Thus, the resulting separation of charges produces an emf across the ends of the rod. At a certain value of emf, there is no more flow of electrons and a steady state is reached. Now the magnitude of the emf generated across a length dl of the rod as it moves at right angles to the magnetic field is given by

$d\varepsilon = B\ v\ dl$. Hence,

$$\varepsilon = \int_0^1 Bv\ dl = \int_0^1 B\omega l dl = \frac{1}{2}B\omega l^2$$

(*b*) Now force experienced by the rod F = BIl

Or $F = B\frac{\varepsilon}{R}l = \frac{B^2\omega l^3}{2R}$. It is directed perpendicular to both the magnetic field and the current induced in the rod.

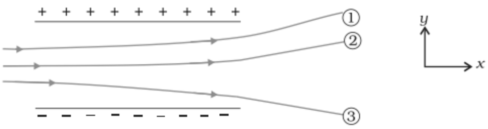
(*c*) $P = \frac{\varepsilon^2}{R} = \frac{B\omega l^2}{2R}$.

MODEL TEST PAPER 9
PHYSICS

Time allowed: 3 hours **Maximum Marks: 70**

SECTION – A

Q.1. Figure below shows tracks of three charged particles in a uniform electrostatic field. Give the signs of the three charges



(a) -ve, +ve and + ve (b) -ve, -ve and + ve
(c) +ve, +ve and - ve (d) +ve, -ve and + ve

Ans:(b)

Q:2. The potential difference applied across a given conductor is doubled. The mobility of the electrons in the conductor
(a) is doubled. (b) is halved.
(c) remains unchanged. (d) becomes four times.

Ans: (b)

Q:3. The resistances of two wires having same length and same area of cross-section are 2 Ω and 8 Ω respectively. If the resistivity of 2 Ω wire is $2{\cdot}65 \times 10^{-8}$ Ω-m then the resistivity of 8 Ω wire is:
(a) $10{\cdot}60 \times 10^{-8}$ Ω-m (b) $8{\cdot}32 \times 10{-}8$ Ω-m
(c) $7{\cdot}61 \times 10^{-8}$ Ω-m (d) $5{\cdot}45 \times 10^{-8}$ Ω-m

Ans: (a)

Q:4. Which one of the following statement is not correct about the magnetic field?
(a) Inside the magnet the lines go from north pole to south pole of the magnet.
(b) Tangents to the magnetic lines give the direction of the magnetic field.
(c) The magnetic lines form a closed loop
(d) Magnetic lines of force do not cut each other

Ans: (a)

Q:5. A metal detector is based on:
(a) Self-induction (b) Mutual induction
(c) Electrical resonance (d)Power transmission

Ans: (c)

Q:6. The reactance of a capacitor of capacitance C connected to an ac source of frequency ω is 'X'. If the capacitance of the capacitor is doubled and the frequency of the source is tripled, the reactance will become
(a) X/6 (b) 6X (c) 2X/3 (d) 3X/2

Ans: (a)

Q:7. The relation between electric field E and magnetic field induction B in an electromagnetic waves-

(a) $E = \sqrt{\frac{\mu_o}{\varepsilon_o}} B$ (b) E = cB

(c) $E = \frac{B}{c}$ (d) $E = \frac{B}{c^2}$

Ans: [b]

Q:8. A photo cell is illuminated by a small bright source placed 1 m away. When the same source of light is placed 2 m away, the electrons emitted by photo cathode
(a) carry one quarter of their previous energy
(b) carry one quarter of their previous momenta
(c) are half as numerous
(d) are one quarter as numerous

Ans: (d)

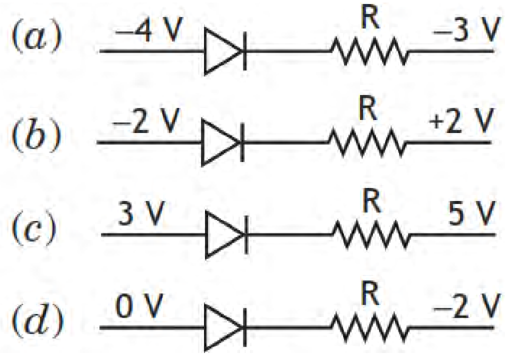
Q:9. The photoelectric threshold wavelength of silver is 3250×10^{-10} m. The velocity of the electron ejected from a silver surface by ultraviolet light of wavelength 2536×10^{-10} m is (Given h = 4.14×10^{-15} eV and c = 3×10^{8} m s^{-1})
(a) 0.6×10^{5} m s^{-1} (b)61×10^{3} m s^{-1}
(c) 0.3×10^{6} m s^{-1} (d) 6×10^{5} m s^{-1}

Ans: (d)

Q:10. The ground state energy of hydrogen atom is −13.6 eV. What are the kinetic and potential energies of the electron in this state?
(a) -13.6 eV, 27.2 eV (b) 13.6 eV, -13.6 eV
(c) 13.6 eV, -27.2 eV (d) 27.2 eV, -27.2 eV

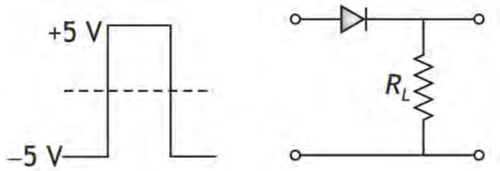
Ans:. (c)

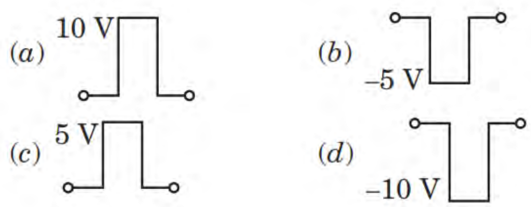
Q:11. Which of the following represents forward biased diode?



Ans: (d)

Q:12. If in a p-n junction, a square input signal of 10 V is applied as shown in the figure, then output across R_L will be.





Ans: (c)

Question number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both (A) and (R) are true and (R) is the correct explanation of (A)

(b) Both (A) and (R) are true and (R) is NOT the correct explanation of (A)

(c) (A) is true but (R) is false

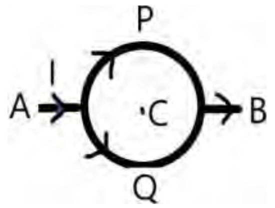
(d) (A) is false and (R) is also false.

Q:13. **Assertion (A):** Electromotive force is a force, which helps the electrons to flow and produce current.

Reason (R): Electromotive force is independent of the voltage across the cell.

Ans: (c)

Q:14. Assertion (A): The magnetic field at the centre of the current carrying circular coil shown in the fig. is zero.



Reason (R): The magnitudes of magnetic fields are equal and the directions of magnetic fields due to both the semicircles are opposite.

Ans: (a)

Q:15. **Assertion**: Total energy of revolving electron in any stationary orbit is negative.

Reason: Energy is scalar quantity, which can be +ve or –ve.

Ans: (b)

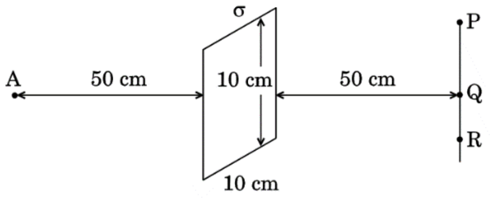
Q:16. **Assertion**: Silicon is preferred for making semiconductor devices over germanium

Reason: The energy gap for germanium is more than the energy gap for silicon.

Ans: **(c)**

SECTION B

Q:17. Consider a straight line with three points P, Q and R, placed 50 cm from the charged sheet on the right side as shown in the figure. At which of these points, does the magnitude of the electric field due to the sheet remain the same as that at point A and why?



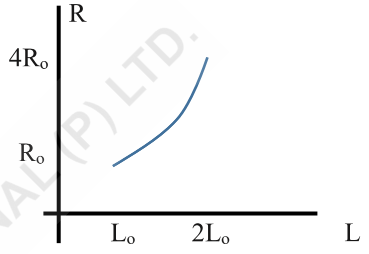
Ans. At Point Q: Because at 50 cm, the charge sheet acts as a finite sheet and thus the magnitude remains same towards the middle region of the planar sheet.

Q:18 A wire of length L_0 has a resistance R_0. It is gradually stretched till its length becomes $2L_0$.

(a) Plot a graph showing variation of its resistance R with its length during stretching.

(b) What will be its resistance when its length becomes 2 L_0?

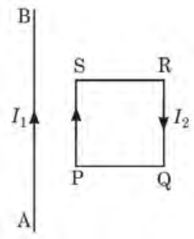
Ans: (a) The graph is as shown.



(b) When the length of a wire is made n times the original length its new resistance becomes $R_N = n^2 R$

$R_N = 2^2 R_0 = 4 R_0$

Q:19. In the figure, the straight wire AB is fixed while the loop is free to move under the influence of the electric currents flowing in them. In which direction does the loop begin to move? Give reason for your answer.



OR

A coil of 'N' turns and radius 'R' carries a current 'I'. It is unwound and rewound to make a square coil of side 'a' having same number of turns (N). Keeping the current 'I' same, find the ratio of the magnetic moments of the square coil and the circular coil.

Ans. Since the straight wire AB is fixed and the loop PQRS is free to move, the direction of motion of the loop can be determined by finding the direction of net force on the loop. Since the side SP of the loop carries current in the same direction as in the wire AB, it will be attracted towards the wire. The side RQ of the loop, however, will be repelled by the wire AB as the current in RQ is in opposite direction. Moreover since SP is nearer to AB than RQ, the force of attraction on the loop is more than the force of repulsion on it. So the loop will move towards AB.

OR

The magnetic moment of a current loop is given by the relation M = nIA

For the circular loop $M_C = NI\pi R^2$ ...(1)

Now 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 is

$M_S = NI\,a^2 = NI\,(\pi R/2)^2 = Ni\pi^2R^2/4$ ...(2)

From 1 and 2 we have

$$\frac{M_S}{M_C} = \frac{NI\pi^2R^2/4}{NI\pi R^2} = \frac{\pi}{4}$$

Q:20. An alpha particle is projected with velocity $\vec{v} = (3.0\times10^5 \text{ m s}^{-1})\hat{i}$ into a region in which magnetic field $\vec{B} = [(0.4\text{ T})\hat{i} + (0.3\text{ T})\hat{j}]$ exists. Calculate the acceleration of the particle in the region. $\hat{i}, \hat{j}$ and $\hat{k}$ are unit vectors along x, y and z axis respectively and charge to mass ratio for alpha particle is 4.8×10^7 C kg^{-1}.

Ans: $\vec{F} = q(\vec{v}\times\vec{B})$ =

$q(3\times10^5\hat{i}\times(0.4\hat{i}+0.3\hat{j})) = q(0.9\times10^5\hat{k})$

$\vec{F} = m\vec{a} = q(0.9\times10^5\hat{k})$

$a = \frac{\vec{F}}{m} = \frac{q}{m}(0.9\times10^5\,\hat{k})$

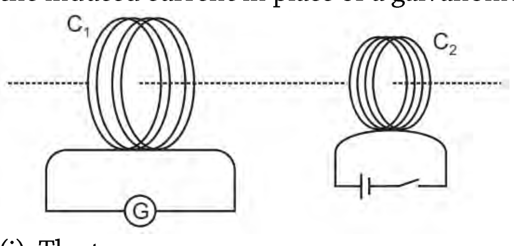
$a = 4.8\times10^7\times0.9\times10^5$

$a = 4.32\times10^{12}\,\hat{k}\text{ m s}^{-2}$

Q:21. A current is induced in coil C_1, due to the motion of current carrying coil C_2.

(i) Write any two ways by which a large deflection can be obtained in the galvanometer G.

(ii) Suggest an alternative device to demonstrate the induced current in place of a galvanometer.



Ans: (i) The two ways are

(a) Passing large current through coil C_2 and

(b) Moving coil C_2 quickly towards coil C_1.

(ii) A magnetic compass can be placed at the centre of coil C_1. Whenever current will be induced it will show a deflection.

SECTION C

Q:22. Electromagnetic radiations with wavelength :

(i)λ_1 are used to kill germs in water purifiers.

(ii)λ_2 are used in TV communication systems.

Name the part of electromagnetic spectrum to which these radiations belong. Arrange these wavelengths in decreasing order of their magnitude.

OR

A capacitor, made of two parallel plates each of plate area A and separation 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.

Ans: (i) Ultraviolet radiations (λ_1).

(ii) Radiowaves (λ_2).

In decreasing order of magnitude, these wavelengths are :$\lambda_2 > \lambda_1$.

OR

Electric field between the capacitor plates is given by

$$E = \frac{\sigma}{\varepsilon_0} = \frac{q}{\varepsilon_0 A}$$

where q is the charge accumulated on the positive plate. The electric flux through this plate is

$\phi_E = EA = \frac{q}{\varepsilon_0 A}.A = \frac{q}{\varepsilon_0}$

∴ Displacement current,

$I_D = \varepsilon_0\frac{d\phi}{dt} = \varepsilon_0\frac{d}{dt}\left[\frac{q}{\varepsilon_0}\right] = \frac{dq}{dt} = I$

Q:23. If the frequency of incident light on a metal surface is doubled, will the kinetic energy of the photoelectrons be doubled ? Give reason.

Ans: Let W_0 be the work function of the metal. Let E_1 and E_2 be the kinetic energies of photoelectrons corresponding to frequencies v and 2v of the incident radiation.

Using Einsten's photoelectric equation, we find

$h\nu = E_1 + W_0$

and $2h\nu = E_2 + W_0$

On dividing,

$2 = \frac{E_2+W_0}{E_1+W_0}$

or $2E_1 + 2W_0 = E_2 + W_0$

or $E_2 = 2E_1 + W_0$

Thus, kinetic energy of photoelectrons is increased more than double on doubling the frequency of incident radiation.

Q:24. The equivalent wavelength of a moving electron has the same value as that of a photon having an energy of 6×10^{-17} J. Calculate the momentum of the electron.

Ans: Energy of a photon, $E = h\nu = \frac{hc}{\lambda}$

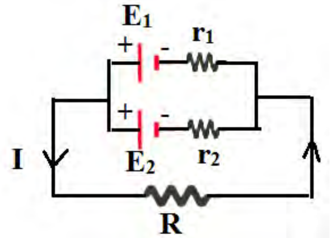
Wavelength of the photon, $\lambda = \frac{hc}{E}$

Momentum of the moving electron,

$p = \frac{h}{\lambda} = \frac{hE}{hc} = \frac{E}{c} = \frac{6\times10^{-17}}{3\times10^{8}} = 2 \times 10^{-25}$ kg m s^{-1}.

Q:25. A student connects a cell, of emf E_2 and internal resistance r_2 with a cell of emf E_1 and internal resistance r_1, such that their combination has a net internal resistance less than r_1. This combination is then connected across a resistance R. Draw a diagram of the 'set up' and obtain an expression for the current flowing through the resistance R.

Ans. The setup is as shown.



Since the two cells are connected in parallel therefore their combined emf is

$$E = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

Now total resistance

$$R_T = R + \frac{r_1 r_2}{r_1 + r_2}$$

Hence current in the circuit is

$$I = \frac{E}{R_T} = \frac{E_1 r_2 + E_2 r_1}{(r_1 + r_2)\left[R + r_1 r_2/(r_1 + r_2)\right]} = \frac{(E_1 r_2 + E_2 r_1)}{R(r_1 + r_2) + r_1 r_2}$$

Q:26. (a) State Biot — Savart law and express this law in the vector form.

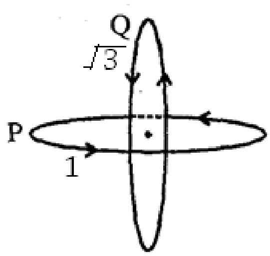
(b) Two identical circular coils, P and Q each of radius R, carrying currents 1 A and $\sqrt{3}$ A respectively, are placed concentrically and perpendicular to each other lying in the XY and YZ planes. Find the magnitude and direction of the net magnetic field at the centre of the coils.

Ans. (a) It states that the magnetic field due to a current element dl at a distance r from it is given by the expression

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

In vector form we have $\overrightarrow{dB} = \frac{\mu_0}{4\pi} \frac{I\,(\overrightarrow{dL} \times \hat{r})}{r^2}$

(b) The diagram is as shown.



The magnetic field at the centre of a circular coil carrying a current I is given by $B = \frac{\mu_0 I}{2r}$

The magnetic field due to coil P is $B = \frac{\mu_0 \times 1}{2r} = \frac{\mu_0}{2r}$

The magnetic field due to coil Q is $B = \frac{\mu_0 \times \sqrt{3}}{2r} = \frac{\sqrt{3}\mu_0}{2r}$

The magnetic fields due to these coils will be perpendicular to each other. Due to coil P directed upwards and due to coil Q directed towards the right. Therefore the net magnetic field at the centre is

$$B = \sqrt{B_P^2 + B_Q^2} = \sqrt{\left(\frac{\mu_0}{2r}\right)^2 + \left(\frac{\sqrt{3}\mu_0}{2r}\right)^2} = \frac{\mu_0}{r}$$

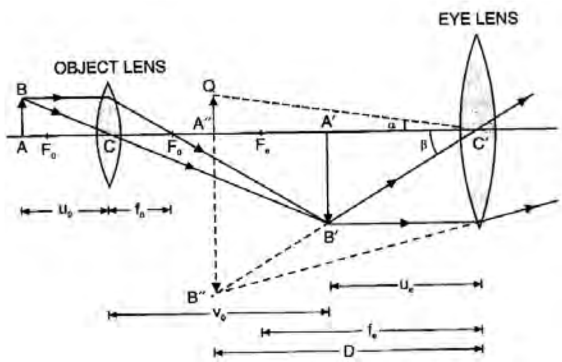
$$\tan\theta = \frac{B_P}{B_Q} = \frac{1}{\sqrt{3}} = 30^0 \text{ in the XY plane.}$$

Q:27. (a) Draw a ray diagram for the formation of image by a compound microscope.

(b) You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct compound microscope?

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

Ans. (a) The ray diagram is as shown.



(b) The objective should have a short focal length and small aperture while the eye piece should have a short focal length and moderate aperture. Thus for objective lens L_3 should be used and for eye piece lens L_1 should be used.

Q:28. A person with a normal near point (25 cm) using a compound microscope with an objective of focal length 8.0 mm and eyepiece of focal length 25 cm can bring an object placed 9.0 mm from the objective in sharp focus. What is the separation between the two lenses? How much is the magnifying power of the microscope?

OR

A beam of light converges to a point P. A lens is placed in the path of the convergent beam 12 cm from P. At what point does the beam converge if the lens is (a) a convex lens of focal length 20 cm, (b) a concave lens of focal length 16 cm?

Ans. Here $f_0 = 0.8$ cm, $u_0 = -0.9$ cm, $v_0 = ?$

As $\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$

$\therefore \frac{1}{v_0} = \frac{1}{f_0} + \frac{1}{u_0} = \frac{1}{0.8} - \frac{1}{0.9}$

$= \frac{0.9 - 0.8}{0.9 \times 0.8} = \frac{0.1}{0.8 \times 0.9}$

or $v_0 = \frac{0.8 \times 0.9}{0.1} = 7.2\ cm$

Now for the eyepiece, we have

$f_e = 2.5$ cm, $v_e = -D = -25$ cm, $u_e = ?$

$\therefore \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = -\frac{1}{25} - \frac{1}{2.5} = \frac{-1-10}{25} = \frac{-11}{25}$

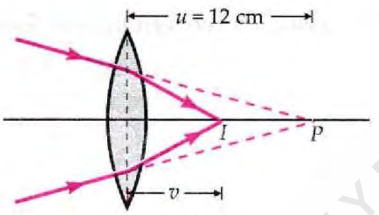
or $u_e = -\frac{25}{11} = -2.27 cm$

Hence, the separation between the two lenses $= v_0 + |u_e| = 7.2 + 2.27 = 9.47$ cm Magnifying power,

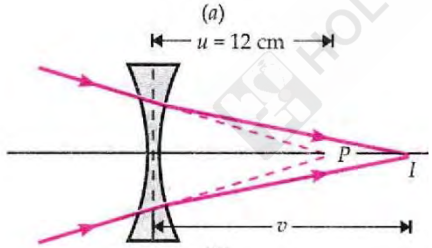
$$m = m_0 \times m_e = \frac{v_0}{|u_0|}\left(1 + \frac{D}{f_e}\right)$$
$$= \frac{7.2}{0.9}\left(1 + \frac{25}{2.5}\right) = 88$$

OR

Here the point P on the right of the lens acts as a virtual object but the image 1 is real, as shown in Figs. (a) and (b).



(a)



(b)

(a) For convex lens : u = + 12 cm, f = + 20 cm

Now $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ $\quad\therefore \frac{1}{v} - \frac{1}{12} = \frac{1}{20}$

or $\frac{1}{v} = \frac{1}{20} + \frac{1}{12} = \frac{3+5}{60} = \frac{8}{60}$

or $v = \frac{15}{2} = 7.5\ cm$

Thus, the beam converges at a point 7.5 cm to the right of the lens.

(b) For concave lens : u = + 12 cm, f = - 16 cm

Now $\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{-16} + \frac{1}{12} = \frac{-3+4}{48} = \frac{1}{48}$

$\therefore$ v = 48 cm

Thus, the beam converges at point 48 cm to the right of the lens.

SECTION D

Questions number 29 to 30 are case study-based questions

Q:29. Optical fibres: Now-a-days optical fibres are extensively used for transmitting audio and video signals through long distances. Optical fibres too make use of the phenomenon of total internal reflection. Optical fibres are fabricated with high quality composite glass/quartz fibres. Each fibre consists of a core and cladding. The refractive index of the material of the core is higher than that of the cladding. When a signal in the form of light is directed at one end of the fibre at a suitable angle, it undergoes repeated total internal reflections along the length of the fibre and finally comes out at the other end. Since light undergoes total internal reflection at each stage, there is no appreciable loss in the intensity of the light signal. Optical fibres are fabricated such that light reflected at one side of inner surface strikes the other at an angle larger than the critical angle. Even if the fibre is bent, light can easily travel along its length. Thus, an optical fibre can be used to act as an optical pipe.

(i) Which of the following statement is not true.

(a) Optical fibres is based on the principle of total internal reflection.

(b) The refractive index of the material of the core is less than that of the cladding.

(c) an optical fibre can be used to act as an optical pipe.

(d) there is no appreciable loss in the intensity of the light signal while propagating through an optical fibre

Ans: (b)

(ii) What is the condition for total internal reflection to occur?

(a) angle of incidence must be equal to the critical angle.

(b) angle of incidence must be less than the critical angle.

(c) angle of incidence must be greater than the critical angle.

(d) None of the above.

Ans: (c)

(iii) Which of the following is not an application of total internal reflection?

(a) Mirage

(b) Sparkling of diamond

(c) Splitting of white light through a prism.

(d) Totally reflecting prism.

Ans: (c)

(iv) Optical fibers are used extensively to transmit

(a) Optical Signal

(b) current

(c) Sound waves
(d) None of the above

Ans: (a)

Q:30. Consider a thin p-type silicon (p-Si) semiconductor wafer. By adding precisely a small quantity of pentavalent impurity, part of the p-Si wafer can be converted into n-Si. There are several processes by which a semiconductor can be formed. The wafer now contains p-region and n- region and a metallurgical junction between p-, and n- region. Two important processes occur during the formation of a p-n junction: diffusion and drift. We know that in an n-type semiconductor, the concentration of electrons (number of electrons per unit volume) is more compared to the concentration of holes. Similarly, in a p-type semiconductor, the concentration of holes is more than the concentration of electrons. 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). This motion of charge carries gives rise to diffusion current across the junction.

(i). How can a p-type semiconductor be converted into n- type semiconductor?
(a) adding pentavalent impurity
(b) adding trivalent impurity
(c) not possible
(d) heavy doping

Ans: (a)

(ii). Which of the following is true about n type semiconductor?
(a) concentration of electrons is less than that of holes.
(b) concentration of electrons is more than that of holes.
(c)concentration of electrons equal to that of holes.
(d)None of these

Ans: (b)

(iii). Which of the following is true about p type semiconductor?
(a) concentration of electrons is less than that of holes.
(b)concentration of electrons is more than that of holes.
(c)concentration of electrons equal to that of holes.
(d)None of these

Ans: (a)

(iv). Which of the following is the reason about diffusion current?
(a) diffusion of holes from p to n
(b)diffusion of electrons from n to p
(c) both (a) and (b)
(d) None of these

Ans: (c)

OR

(iv). What are the processes that occur during formation of a p-n junction?
(a) drift
(b) diffusion
(c) both (a) and (b)
(d) None of these

Ans: (c)

SECTION E

Q:31. (a) (i) Derive an expression for potential energy of an electric dipole $\vec{p}$ in an external uniform electric field $\vec{E}$. When is the potential energy of the dipole (1) maximum, and (2) minimum?
(ii) An electric dipole consists of point charges –1.0 pC and + 1.0 pC located at (0,0) and (3 mm, 4 mm) respectively in x-y plane. An electric field $\vec{E} = 1000\hat{i}\ V\ m^{-1}$ is switched on in the region. Find the torque $\vec{\tau}$ acting on the dipole.

OR

(b) (i) An electric dipole (dipole moment $\vec{p} = p\hat{i}$) consisting of charges -q and +q, separated by distance 2a, is placed along the x-axis with its centre at the origin. Show that the potential V, due to this dipole at a point x, (x >> a) is equal to $\frac{1}{4\pi\varepsilon_o}\frac{\vec{p}.\hat{i}}{x^2}$
(ii) Two isolated metallic spheres S_1 and S_2 of radii 1 cm and 3 cm respectively are charged such that both have the same charge density $\left(\frac{2}{\pi}\times 10^{-9}\right) C\ m^{-2}$. They are placed far away from each other and connected by a thin wire. Calculate the new charge on sphere S_1.

Ans: (a) (i) The torque acting on the dipole in a uniform electric field tends to align it in the direction of the electric field. If the dipole is moved against this torque, work will have to be done. This work is stored in the dipole as its potential energy. If θ is the angle between the dipole moment and the electric field, then the torque acting on the dipole is given by

$$\tau = pE \sin\theta \qquad \text{------ (1)}$$

Suppose the dipole is rotated through an infinitesimally small angle dθ against the torque then the small work done is

$$dW = \tau\, d\theta = pE \sin\theta\, d\theta \qquad \text{----- (2)}$$

The net work done in rotating the dipole from its initial position θ_1 to its final position θ_2 is given by

$$W = \int_{\theta_1}^{\theta_2} pE\sin\theta\, d\theta = pE\left|-\cos\theta\right|_{\theta_1}^{\theta_2}$$

or $W = pE\,(\cos\theta_1 - \cos\theta_2)$ ------ (3)

This work done is stored in the dipole in the form of its potential energy. Hence

$U = pE\,(\cos\theta_1 - \cos\theta_2)$ ------- (4)

If the dipole is initially oriented perpendicular to the direction of the electric field and then brought to the orientation making an angle θ with the electric field, then the potential energy is obtained by putting

$\theta_1 = 90^0$ and $\theta_2 = \theta^0$ in equation 4 we have

$U = pE\,(\cos 90^o - \cos\theta) = -\,pE\cos\theta$

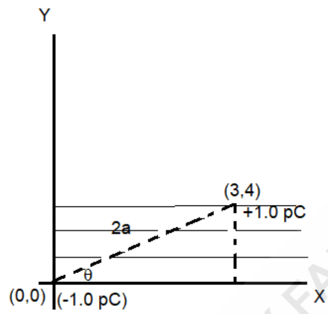
(1)If the dipole is antiparallel to the electric field i.e. $\theta = 180^0$ then $U = pE$ i.e., the potential energy is a maximum.

(2) If the dipole is parallel to the electric field i.e. $\theta = 0^0$ then $U = -\,pE$ i.e. the potential energy is minimum.

(ii) Given $q = 1.0\ pC = 1.0 \times 10^{-12}\ C$, $\vec{E} = 1000\hat{i}\ V\,m^{-1}$

Now $\tau = pE\sin\theta = 2aqE\sin\theta$.

Consider the diagram



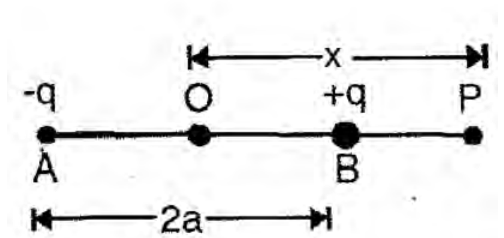
Here $2a = 5\ mm = 5 \times 10^{-3}\ m$, $\sin\theta = 4/5$

$\tau = 5 \times 10^{-3} \times 1 \times 10^{-12} \times 1000 \times 4/5$

$\tau = 4 \times 10^{-12}$ N m along –ve Z axis.

OR

(b) Consider an electric dipole consisting of -q and +q charges separated by a distance 2a as shown in figure below. Let P be the point of observation where the electric potential has to be found. Let it be at a distance 'x' from the centre O (origin) of the dipole. Let us suppose that the dipole is placed in vacuum.



Now potential at point P due to charge at A

$$V_A = -\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{x+a}\right]$$

Now potential at point P due to charge at B

$$V_B = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{x-a}\right]$$

Net potential at P is $V_P = V_A + V_B$

Or $V = -\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{x+a}\right] + \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{x-a}\right]$ solving we have

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{p}{x^2 - a^2}\right]$$

If x >>a then we have

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{p}{x^2}\right]$$

In vector form we have

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{\vec{p}.\hat{i}}{x^2}\right]$$

(ii) Given $R_1 = 1\ cm = 1 \times 10^{-2}\ m$, $R_2 = 3\ cm = 3 \times 10^{-2}\ m$,

Charge on sphere of radius S_1.

$Q_1 = 4\pi R_1^2\sigma$ = $\left(\frac{2}{\pi}\times 10^{-9}\right)\times 4\pi\left(1\times 10^{-2}\right)^2 = 8\times 10^{-13}\ C$

Charge on sphere of radius S_2

$Q_2 = 4\pi R_2^2\sigma$ = $\left(\frac{2}{\pi}\times 10^{-9}\right)\times 4\pi\left(3\times 10^{-2}\right)^2 = 72\times 10^{-13}\ C$

Now

$C_1 = 4\pi\varepsilon_0 R_1 = \frac{1}{9\times 10^9}\times 10^{-2} = \frac{1}{9}\times 10^{-11}\ F$

$C_2 = 4\pi\varepsilon_0 R_2 = \frac{1}{9\times 10^9}\times 3\times 10^{-2} = \frac{1}{3}\times 10^{-11}\ F$

So, common potential

$$V = \frac{Q_1 + Q_2}{C_1 + C_2} = \frac{80\times 10^{-13}}{\left(\frac{1}{9}+\frac{1}{3}\right)\times 10^{-11}} = 1.8\ V$$

So, new charge on sphere S_1

$Q_1 = C_1 V = \frac{1}{9}\times 10^{-11}\times 1.8 = 2\times 10^{-12}\ C$

Q:32. (a) (i) A ray of light passes through a triangular prism. Show graphically, how the angle of deviation varies with the angle of incidence? Hence define the angle of minimum deviation.

(ii) A ray of light is incident normally on a refracting face of a prism of prism angle A and suffers a deviation of angle δ. Prove that the refractive index n of the material of the prism is given by= $n = \frac{\sin(A+\delta)}{\sin A}$.

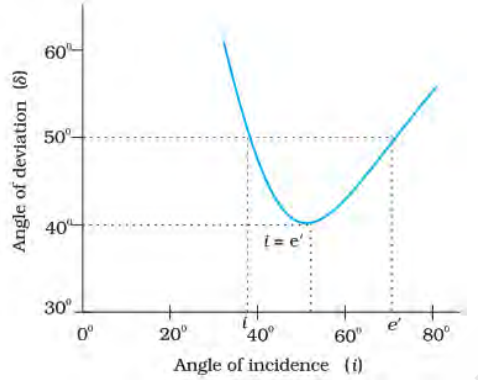
(iii) The refractive index of the material of a prism is $\sqrt{2}$. If the refracting angle of the prism is 60°, find the

(1) Angle of minimum deviation, and
(2) Angle of incidence.

OR

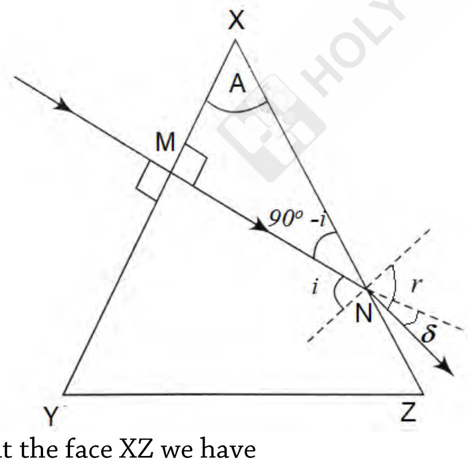
(b) (i) State Huygens' principle. A plane wave is incident at an angle i on a reflecting surface. Construct the corresponding reflected wavefront. Using this diagram, prove that the angle of reflection is equal to the angle of incidence.
(ii) What are the coherent sources of light? Can two independent sodium lamps act like coherent sources? Explain.
(i) A beam of light consisting of a known wavelength 520 nm and an unknown wavelength λ, used in Young's double slit experiment produces two interference patterns such that the fourth bright fringe of unknown wavelength coincides with the fifth bright fringe of known wavelength. Find the value of λ.

Ans: (a) (i) The graph is as shown.



It is the minimum angle by which the emergent ray deviates from the incident ray.

(ii) The diagram is as shown.



At the face XZ we have

$n \sin i = 1 \times \sin r$ -----(i)

$r = i + \delta$ (from diagram) ------ (ii)

In Δ XMN

$A + (90^\circ - i) + 90^\circ = 180$

Or $A = i$ -----(iii)

Putting equations (ii) and (iii) in equation (i) we have

$n \sin A = \sin (i + \delta)$

or $\dfrac{\sin(i+\delta)}{\sin A}$

(iii) $n = \sqrt{2}$, $A = 60^\circ$,

(1)Using the formula $n = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\dfrac{A}{2}}$

$$\sqrt{2} = \frac{\sin\left(\dfrac{60+\delta_m}{2}\right)}{\sin 30^\circ} = 2\sin\left(\frac{60+\delta_m}{2}\right)$$

$$\frac{1}{\sqrt{2}} = \sin\left(\frac{60+\delta_m}{2}\right)$$

$90 = 60 + \delta_m$

$\delta_m = 30^\circ$

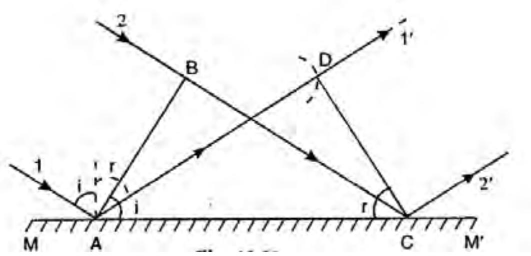
(2) $i = \dfrac{A+\delta_m}{2} = \dfrac{60+30}{2} = 45^\circ$

OR

(b) (i) HUYGEN'S PRINCIPLE: It is based upon the following two assumptions (i) All points on a given wave front are taken as point sources for the production of spherical secondary waves, called wavelets, which propagate outward with speeds characteristic of waves in that medium.
(ii) After some time has elapsed, the new position of the wave front is the surface tangent to the wavelets or the envelope of the wavelets in the forward direction.

Consider a plane wavefront AB incident obliquely on a plane reflecting surface MM$'$. Let us consider the situation when one end A of wavefront strikes the mirror at an angle i but the other end B has still to cover distance BC. Time required for this will be t = BC/ c

According to Huygen's principle point A starts emitting secondary wavelets and in time t, these will cover a distance c t = BC and spread. Hence, with point A as centre and BC as radius, draw a circular arc. Draw tangent CD on this arc from the point C. Obviously, CD is the reflected wavefront inclined at an angle r. As incident wavefront and reflected wavefront both are in the plane of paper, 1st law of reflection is proved.



To prove second law of reflection, consider Δ ABC and Δ ADC. BC = AD (by construction)

$\angle ABC = \angle ADC = 90^0$

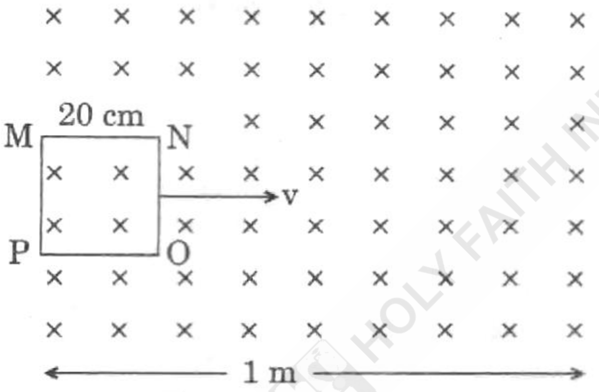
and AC is common.
Therefore, the two triangles are congruent and, hence, $\angle BAC = \angle DCA$ or $\angle i = \angle r$ i.e., the angle of reflection is equal to the angle of incidence, which is the second law of reflection.
(ii) Two light sources are said to be coherent if they are emitting light of same wavelength such that the originating phase difference between them is either zero or has a fixed constant value.
No, because light from these sources will not be in phase throughout the interference.
(iii)Using the formula $y = \frac{nD\lambda}{d}$

We have $\frac{4D\lambda}{d} = \frac{5D \times 520}{d}$

4 λ = 2600

λ = 650 nm

Q:33. (a) Define self-inductance of a coil. Obtain an expression for the energy stored in a solenoid of self-inductance 'L' when the current through it grows from zero to 'I'.
(b) A square loop MNOP of side 20 cm is placed horizontally in a uniform magnetic field acting vertically downwards as shown in the figure. The loop is pulled with a constant velocity of 20 cm s^{-1} till it goes out of the field.



(i) Depict the direction of the induced current in the loop as it goes out of the field. For how long would the current in the loop persist?
(ii) Plot a graph showing the variation of magnetic flux and induced emf as a function of time.

OR

(a) Draw the magnetic field lines due to a circular loop of area $\vec{A}$ carrying current I. Show that it acts as a bar magnet of magnetic moment $\vec{m} = I\vec{A}$.
(b) Derive the expression for the magnetic field due to a solenoid of length '2l', radius 'a' having 'n' number of turns per unit length and carrying a steady current 'I' at a point on the axial line, distant 'r' from the centre of the solenoid. How does this expression compare with the axial magnetic field due to a bar magnet of magnetic moment 'm'?

Ans. (a) Self-inductance of a coil is numerically equal to induced e.m.f. produced in it when rate of change of current is unity in it.
When current passes through an inductor, the emf induced in it is given by $\varepsilon = -L\frac{dI}{dt}$

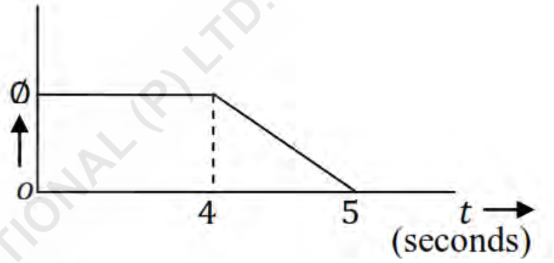
Therefore work done in a small time dt is given by

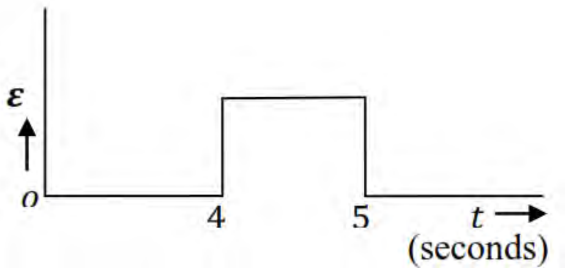
$dW = \varepsilon I dt = LI\, dI$

Hence total work done in increasing the current from 0 to I is

$W = \int_0^I LI\, dI = \frac{1}{2}LI^2$

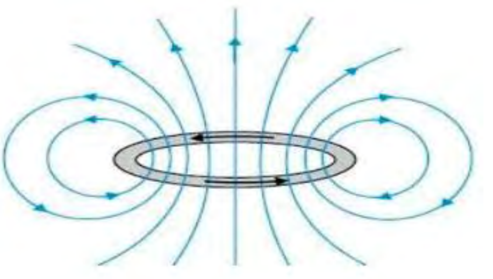
This is stored as energy.
(b) (i) Direction of induced current – clockwise (MNOP), the duration of induced current is 1s .
(ii) The graph is as shown.





OR

(a) The magnetic field lines are as shown



Magnetic field due to circular loop on its axis at far off points

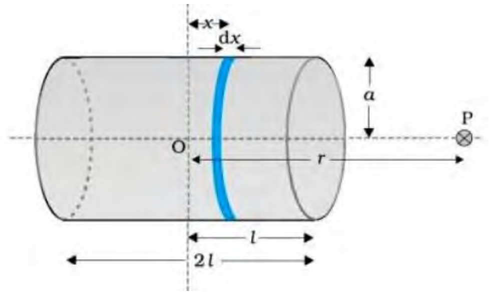
$$B = \frac{\mu_0}{4\pi}\frac{2IA}{x^3}$$

Magnetic field due to a bar magnet at its axial point is

$$B = \frac{\mu_0}{4\pi}\frac{2m}{x^3}$$

Comparing the above two we have m = IA
(b) By Biot Savarts law, magnetic field at point P on the axis of the solenoid due to a small element

of length dx at a distance 'x' from the centre of the solenoid is



$$dB = \frac{\mu_0 n\, dx\, I\, a^2}{2\left[(r-x)^2 + a^2\right]^{3/2}}.$$

Hence total magnetic field is given by

$$B = \int dB = \frac{\mu_0 I a^2 n}{2} \int_{-L}^{+L} \frac{dx}{\left[(r-x)^2 + a^2\right]^{3/2}}$$

For r >>> a(R >> L)

We have

$$B = \int dB = \frac{\mu_0 I a^2 n}{2r^3} \int_{-L}^{+L} dx = \frac{\mu_0 In}{2} \frac{2La^2}{r^3}$$

Magnetic moment of a solenoid m = (n × 2L) I (πa^2)

Therefore

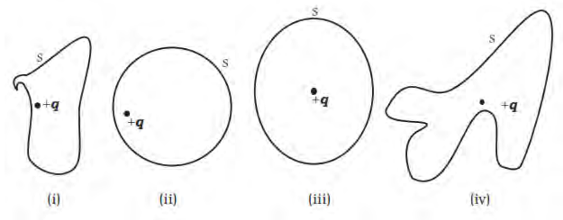
$$B = \frac{\mu_0}{4\pi} \frac{2m}{r^3}$$ is same as that of a bar magnet.

MODEL TEST PAPER 10
PHYSICS

Time allowed: 3 hours **Maximum Marks: 70**

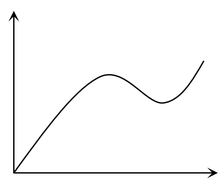
SECTION – A

Q.1. The Electric flux through the surface
(a) in Fig. (iv) is the largest.
(b) in Fig. (iii) is the least.
(c) in Fig (ii) is same as Fig. (iii) but is smaller than Fig. (iv)
(d) is the same for all the figures.



Ans: (d)

Q:2. From the graph between current i & voltage V shown, identity the portion corresponding to negative resistance



(a) DE
(b) CD
(c) BC
(d) AB

Ans: (b)

Q:3. Equal potentials are applied on an iron and copper wire of same length. In order to have same current flow in the wire, the ratio $\left(\frac{r_{iron}}{r_{copper}}\right)$ of their radii must be [Given that specific resistance of iron = $1.0 \times 10^{-7}\ \Omega$ m and that of copper = $1.7 \times 10^{-8}\ \Omega$ m]
(a) About 1.2 (b) About 2.4
(c) About 3.6 (d) About 4.8

Ans: (b)

Q:4. A bar magnet of magnetic moment M is placed at right angles to a magnetic induction B. If a force F is experienced by each pole of the magnet, the length of the magnet will be
(a) MB/F (b) BF/M (c) MF/B (d) F/MB

Ans: (c)

Q:5. At what time (From zero) the alternating voltage becomes $\frac{1}{\sqrt{2}}$ times of it's peak value. Where T is the periodic time
(a) T/2 s (b) T/4 s (c) T/8 s (d) T/12 s

Ans: (c)

Q:6. The peak value of an alternating emf E is given by $E = E_o \cos \omega t$ is 10 volts and its frequency is 50 Hz At time t = 1/600 s the instantaneous emf is
(a) 10 V (b) $5\sqrt{3}V$ (c) 5 V (d) 1V

Ans: (b)

Q:7. The Maxwell's equation:
$\oint \vec{B}.d\vec{l} = \mu_o\left(i + \varepsilon_o \frac{d\phi_E}{dt}\right)$ is a statement of-
(a) Faraday's law of induction
(b) Modified Ampere's law
(c) Gauss's law of electricity
(d) Gauss's law of magnetism

Ans: [b]

Q:8. A proton, a neutron, an electron and an α-particle have same energy. Then, their de-Broglie wavelengths compare as
(a) $\lambda_p = \lambda_n > \lambda_e > \lambda_\alpha$ (b) $\lambda_\alpha < \lambda_p = \lambda_n > \lambda_e$
(c) $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$ (d) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

Ans: (b)

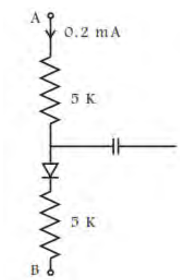
Q:9. An electron is moving with an initial velocity $\vec{v} = v_0\hat{i}$ and is in a magnetic field $\vec{B} = B_0\hat{j}$. Then, its de-Broglie wavelength
(a) remains constant
(b) increases with time
(c) decreases with time
(d) increases and decreases periodically

Ans: (a)

Q:10. Obtain approximately the ratio of the nuclear radii of the gold isotope ${}_{79}Au^{197}$ and the silver isotope ${}_{49}Au^{107}$
(a) 197 :107 (b) 107 : 197
(c) 1.23 (d) 0.23

Ans:. (c)

Q:11. In the circuit shown in Fig, if the diode forward voltage drop is 0.3 V, the voltage difference between A and B is



(a) 1.3 V (b) 2.3 V
(c) 0 V (d) 0.5 V

Ans: (b)

Q:12. When an electric field is applied across a semiconductor
(a) electrons move from lower energy level to higher energy level in the conduction band.
(b) electrons move from higher energy level to lower energy level in the conduction band.
(c) holes in the valence band move from higher energy level to lower energy level.
(d) holes in the valence band move from lower energy level to higher energy level.

Ans: (a, c)

Question number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both (A) and (R) are true and (R) is the correct explanation of (A)

(b) Both (A) and (R) are true and (R) is NOT the correct explanation of (A)

(c) (A) is true but (R) is false

(d) (A) is false and (R) is also false.

Q:13. **Assertion:** Ohm's law is universally applicable for all conducting elements

Reason: All conducting elements show straight line graphic variation on (I-V)plot.

Ans: (d)

Q:14. Assertion (A): The voltage sensitivity may not necessarily increase on increasing the current sensitivity.

Reason (R): Current sensitivity increases on increasing the number of turns of the coil.

Ans: (b)

Q:15. **Assertion**: In outer most stationary orbit, energy of electron is least negative.

Reason: In such an orbit, electron is at maximum distance from the nucleus.

Ans: (b)

Q:16. **Assertion:** In semiconductors, thermal collisions are responsible for taking a valence electron to the conduction band.

Reason: The number of conduction electrons go on increasing with time as thermal collisions continuously take place.

Ans: (c)

SECTION B

Q:17. (*a*) Electric field inside a conductor is zero. Explain.

(*b*) The electric field due to a point charge at any point near it is given as $E=\lim_{q\to 0}\frac{F}{q}$. What is the physical significance of this limit?

Ans. (*a*) By Gauss's Theorem $\oint \vec{E}.d\vec{S}=\frac{q}{\varepsilon_o}$. Since there is no charge inside a conductor therefore in accordance with the above equation the electric field inside the conductor is zero.

(*b*) It indicates that the test charge should be infinitesimally small so that it may not disturb the electric field of source charge.

Q:18 A battery is connected first across the series combination and then across the parallel combination, of three resistances R, 2R and 3R. In which of the three resistances will power dissipated, be maximum in the two cases? Justify your answer.

Ans. For series: Power dissipated will be maximum for 3R. Because current is same and power is proportional to resistance.

For parallel: Power dissipated will be maximum for R. Because voltage is same and power is inversely proportional to resistance.

Q:19. Write the expression for Lorentz magnetic force on a particle of charge 'q' moving with velocity v in a magnetic field B. Show that no work is done by this force on the charged particle.

OR

A stream of electrons travelling with speed *v* at right angles to a uniform magnetic field '*B*' is deflected in a circular path of radius '*r*'. Prove that $\frac{e}{m}=\frac{v}{rB}$

Ans. The expression for force is $\vec{F}=q\left(\vec{v}\times\vec{B}\right)$. This force always acts perpendicular to the direction of motion of the charged particle. Therefore the angle between $\vec{F}$ and $\vec{r}$ is 90°. Hence work done is W = Fr cos 90° = 0

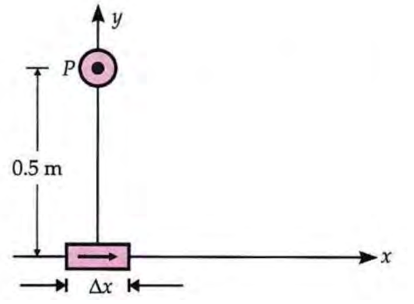
OR

Let a stream of electrons be travelling with speed *v* at right angles to a uniform magnetic field *B* then force due to magnetic field provides the requisite centripetal force which deflects the electron beam along a circular path of radius '*r*' such that

$$Bev=\frac{mv^2}{r}\Rightarrow\frac{e}{m}=\frac{v}{Br}$$

Q:20. An element $\Delta\vec{l}=\Delta x\hat{i}$ is placed at the origin and carries a large current I =10 A What is the magnetic field on the y-axis at a distance of 0.5 m. Δx =1 cm

Ans: Here dl = Δx -1 cm - 10^{-2}m, I =10 A, r = y = 0.5 m, θ=90°, $\mu_0/4\pi = 10^{-7}$ Tm A^{-1}



According to Biot-Savart law,

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

$$=\frac{10^{-7}\times 10\times 10^{-2}\times \sin 90^\circ}{(0.5)^2}$$

$$=4\times 10^{-8}\text{T}$$

The direction of the field $\overrightarrow{dB}$ will be the direction of vector $\overrightarrow{dl}\times\vec{r}$. But

$$\overrightarrow{dl} \times \vec{r} = \Delta x\hat{\imath} \times y\hat{\jmath} = \Delta xy(\hat{\imath} \times \hat{\jmath}) = \Delta xy\hat{k}$$

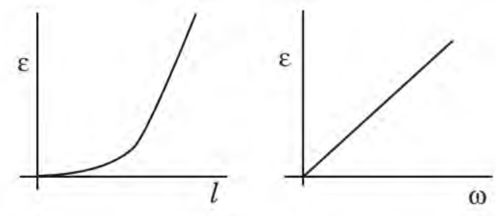
Hence field $\overrightarrow{dB}$ is in the + z-direction.

Q:21. A conductor of length '*l*' is rotated about one of its ends at a constant angular speed '' in a plane perpendicular to a uniform magnetic field B. Plot graphs to show variations of the emf induced across the ends of the conductor with (*i*) angular speed and (*ii*) length of the conductor *l*.

Ans: The emf induced is given by the expression

$\varepsilon = \frac{1}{2}B\omega l^2$.

Thus, the two graphs are as shown.



SECTION C

Q:22. Arrange the following electromagnetic waves in the order of their increasing wavelength :

(a) γ-rays (b) Microwaves

(c)X-rays (d) Radio waves

What role does infra-red radiation play in (i) maintaining the Earth's warmth and (ii) physical therapy ?

OR

Why are infrared radiations referred to as heat waves also? Name the radiations, which are next to these radiations in electromagnetic spectrum having:

(i) shorter wavelength ; (ii) longer wavelength.

Ans: In the order of increasing wavelength, the e.m. waves are

γ-rays, < X-rays < Microwaves < Radiowaves

(i) Infrared rays maintain earth's warmth through green house effect.

(ii) Infrared lamps are used in physical therapy because of the heat produced by infrared rays.

OR

Infrared radiations get readily absorbed by water molecules in most materials. This increases their thermal motion and heats them up. That is why infrared radiations are often referred to as heat waves.

(i) Visible light has shorter wavelength next to infrared radiations.

(ii) Microwaves have longer wavelength next to infrared radiations.

Q:23. Radiation of frequency 10^{13} Hz is incident on three photo-sensitive surfaces A, B and C. Following observations are recorded:

Surface A : No photo-emission occurs.

Surface B : Photo-emission occurs but the photo-electrons have zero kinetic energy.

Surface C: Photo-emission occurs and photo-electrons have some K.E.

Based on Einstein's photo-electric equation, explain the three observations.

Ans: From the observations made (parts A and B) on the basis of Einstein's photoelectric equation, we draw following conclusions :

1. For surface A, the threshold frequency is more than 10^{15} Hz, hence no photo-emission is possible.

2. For surface B, the threshold frequency is equal to the frequency of given radiation. Thus, photo-emission takes place but kinetic energy of photo-electrons is zero.

3. For surface C, the threshold frequency is less than 10^{15} Hz. So photo-emission occurs and photoelectrons have some kinetic energy.

Q:24. The kinetic energy of the electron orbiting in the first excited state of hydrogen atom is 3.4 eV. Determine the de-Broglie wavelength associated with it.

Ans: K.E. of the electron,

$K = 3.4 \text{ eV} = 3.4 \times 1.6 \times 10^{-19}$ J

de-Broglie wavelength associated with the electron,

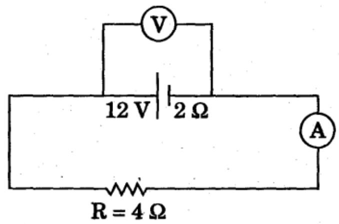
$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK}}$

$= \frac{6.63\times10^{-34}}{\sqrt{(2\times9.1\times10^{-31}\times3.4\times1.6\times10^{-19})}}$

$= 6.63 \times 10^{-10}$ m

Q:25. (a) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change?

(b) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having an internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings.



Ans. (a) The heat produce across a resistor is given by

$H = \frac{V^2}{R}t$

$H_1 = H$, $H_2 = 9H$, $V_1 = V$, $V_2 = ?$

$\frac{H_2}{H_1} = \frac{V_2^2}{V_1^2}$ or $\frac{V_2}{V_1} = \sqrt{\frac{H_2}{H_1}} = \sqrt{\frac{9H}{H}} = 3$

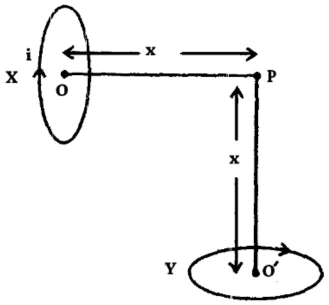
Therefore $V_2 = 3V_1$

(b) Given E = 12 V, r = 2 Ω, R = 4 Ω,
Now total resistance in the circuit, $R_T = r + R = 2 + 4 = 6\ \Omega$
Hence current in the circuit and through the ammeter is

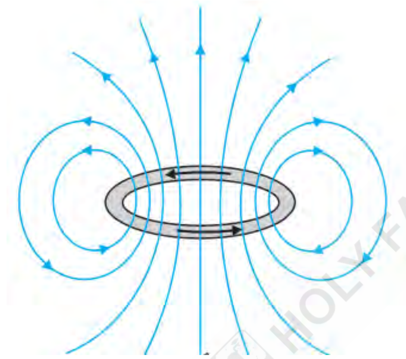
$$I = \frac{E}{r+R} = \frac{12}{6} = 2\ A$$

Now reading of voltmeter
V = E- Ir = 12 – 2 × 2 = 8 V

Q:26. (a) Draw the pattern of magnetic field lines for a circular coil carrying current.
(b) Two identical circular loops X and Y of radius R and carrying the same current are kept in perpendicular planes such that they have a common centre at P as shown in the figure. Find the magnitude and direction of the net magnetic field at the point P due to the loops.



Ans. (i) The magnetic field lines are as shown.



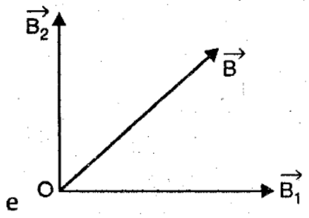
(ii) The magnetic field at O due to the circular loop X is $B_1 = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}$ directed away from the coil.

The magnetic field at O due to the circular loop Y is $B_2 = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}$ directed away from the coil.

The net magnetic field is therefore

$$B = \sqrt{B_1^2 + B_2^2} = \sqrt{2}B_1 = \frac{\mu_0 I R^2}{\sqrt{2}(x^2+R^2)^{3/2}}.$$

The direction of the net magnetic field is 45^0 with the axis of the loop as shown in the figure below.



Q:27. State the two features to distinguish between interference and diffraction phenomena. Two wavelengths of light 600 nm and 610 nm are used in turn, to study the diffraction at a single slit of size 2 mm. The distance between the slits and screen is 2 m. Calculate the separation between the positions of the second-order maximum of the diffraction pattern obtained in the two cases.

Ans. The two features are as shown in the table

Diffraction	Interference
The intensity of the consecutive bands goes on decreasing.	All bright fringes have the same intensity.
Fringes have poor contrast	Fringes have good contrast.
Diffraction fringes are not of the same width.	Fringes may or may not be of the same width.

Given $a = 2 \times 10^{-6}$ m, D = 1.5 m, λ_1 = 600 nm = 600×10^{-9} m, λ_2 = 610 nm = 610×10^{-9} m,

For first order maxima we have $a \sin\theta = \frac{5}{2}\lambda$ or

$$\theta_1 = \frac{5\lambda_1}{2a} = \frac{5 \times 600 \times 10^{-9}}{2 \times 2 \times 10^{-6}} = 0.75\ \text{rad}$$

$$\theta_2 = \frac{5\lambda_2}{2a} = \frac{5 \times 610 \times 10^{-9}}{2 \times 2 \times 10^{-6}} = 0.7625\ \text{rad}$$

Therefore angular separation 0.7625 - 0.75 = 0.125 rad

Q:28. A prism is made of glass of unknown refractive index. A parallel beam of light is incident on a face of the prism. The angle of minimum deviation is measured to be 40°. What is the refractive index of the material of the prism. The refracting angle of the prism is 60°. If the prism is placed in water (refractive index 1.33), predict the new angle of minimum deviation of a parallel beam of light.

OR

A small bulb is placed at the bottom of a tank containing water to a depth of 80 cm. What is the area of the surface of water through which light from the bulb can emerge out? Refractive index of water is 1.33. Consider the bulb to be a point source.

Ans. When the prism is placed in air :
$\delta_m = 40°$, A = 60°
∴ Refractive index of the prism material is

$$a_{\mu_g} = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}} = \frac{\sin\frac{60^\circ + 40^\circ}{2}}{\sin\frac{60^\circ}{2}}$$

$$= \frac{\sin 50^o}{\sin 30^o} = \frac{0.7660}{0.5000} = 1.532$$

When the prism is placed in water :

$$\omega_{\mu_g} = \frac{\sin\frac{A+\delta'_m}{2}}{\sin\frac{A}{2}}$$

or $\frac{a_{\mu_g}}{a_{\mu_\omega}} = \frac{\sin\frac{60^\circ+\delta'_m}{2}}{\sin\frac{60^\circ}{2}}$

or $\frac{1.532}{1.33} = \frac{\sin\frac{60^\circ+\delta'_m}{2}}{\sin 30^o}$

or $\sin\frac{\frac{60^\circ+\delta'_m}{2}}{2} = \frac{1.532}{1.33} \times 0.5 = 0.5759$

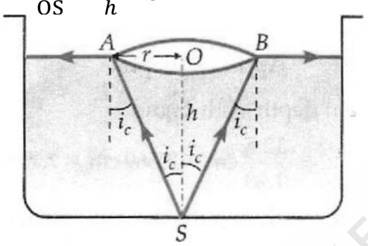
$\therefore 30^o + \frac{\delta'_m}{2} = \sin^{-1}(0.5759) = 35^o 10'$

or $\delta'_m = 10^o 20'$.

OR

The light rays from the small bulb S which are incident at an angle $i > i_c$ are totally internally reflected and cannot emerge out of water surface. The light from the bulb S comes out through a circular patch of radius r given by

$\tan i_c = \frac{OA}{OS} = \frac{r}{h}$ or $r = h \tan i_c$



$$\sin i_c = \frac{1}{\mu} = \frac{1}{1.33} = \frac{3}{4}$$

$$\cos i_c = \sqrt{1 - \left(\frac{3}{4}\right)^2} = \frac{\sqrt{7}}{4}$$

$$\tan i_c = \frac{3}{4} \times \frac{4}{\sqrt{7}} = \frac{3}{\sqrt{7}}$$

Area of the patch,

$= \pi r^2 = \pi h^2 \tan i_C$

$= 3.14 \times (0.80)^2 \times \frac{9}{7} m^2$

$= 2.58\ m^2 = 2.6\ m^2$.

SECTION D

Questions number 29 to 30 are case study-based questions

Q:29. The total internal reflection of the light is used in polishing diamonds to create a sparking brilliance. By polishing the diamond with specific cuts, it is adjusted the most of the light rays approaching the surface are incident with an angle of incidence more than critical angle. Hence, they suffer multiple reflections and ultimately come out of diamond from the top. This gives the diamond a sparking brilliance

(i). At critical angle for a diamond is

(a) 1.41 (b) Same as glass

(c) 2.42 (d) 1

Ans: (c)

(ii). The basic reason for the extraordinary sparkle of suitably cut diamond is that

(a) It has low refractive index

(b) It has high transparency

(c) It has high refractive index

(d) It is very hard

Ans: (c)

(iii). The extraordinary sparkling of diamond

(a) Does not depend on its shape

(b) Depends on its shape

(c) Has no fixed reason

(d) None

Ans: (b)

(iv). A diamond is immersed in a liquid with a refractive index greater than water. Then the critical angle for total internal reflection will

(a) Increase

(b) Decrease

(c) Depend on the nature of the liquid

(d) Remains the same

Ans. (a)

OR

(iv). Optical Fibre Cables work on the principle of

(a) Dispersion of light

(b) Refraction of light

(c) Total internal reflection

(d) Interference of light

Ans: (c)

Q:30. A Photodiode is again a special purpose p-n junction diode fabricated with a transparent window to allow light to fall on the diode. It is operated under reverse bias. When the photodiode is illuminated with light (photons) with energy (hν) greater than the energy gap (E) of the semiconductor, then electron- hole pairs are generated due to the absorption of photons. The diode is fabricated such that the generation of e-h pairs takes place in or near the depletion region of the diode. Due to electric field of the junction, electrons and holes are separated before they recombine. The direction of the electric field is such that electrons reach n-side and holes reach p-side. Electrons are collected on n-side and holes are collected on p-side giving rise to an emf. When an external load is connected, current flows. The magnitude of the photocurrent depends on the intensity of incident light.

(i) A Photo Diode is

(a) forward biased

(b) reverse biased
(c) Not biased
(d) None of these

Ans: (b)

(ii) Which of the following is true about photodiode?
(a) $E > h\nu$
(b) $E = h\nu$
(c) $E < h\nu$
(d) None of these

Ans: (a)

(iii). Magnitude of photocurrent depends on
(a) Intensity of light
(b) Biasing
(c) Potential
(d) None of these

Ans: (b)

(iv). Electrons and holes are separated before they recombine by:
(a) Diffusion current
(b) Drift current
(c) Electric field
(d) Electric potential

Ans: (b)

OR

(iv) Direction of electric field is such that
(a) electrons reach n- side
(b) holes reach p- side
(c) Both (a) and (b)
(d) holes reach n side

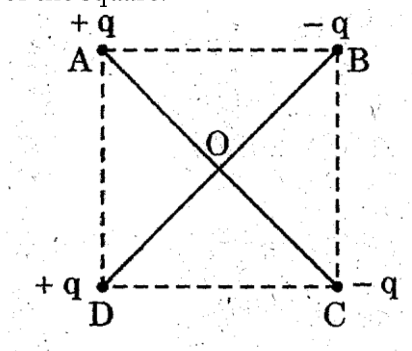
Ans: (c)

SECTION E

Q:31. (a) (i) State Coulomb's law in electrostatics and write it in vector form, for two charges.
(ii) Gauss's law is based on the, inverse-square dependence on distance contained in the Coulomb's law. Explain.
(iii) Two charges A (charge q) and B (charge 2q) are located at points (0, 0) and (a, a) respectively. Let i and j be the unit vectors along x-axis and y-axis respectively. Find the force exerted by A on B, in terms of i and j

OR

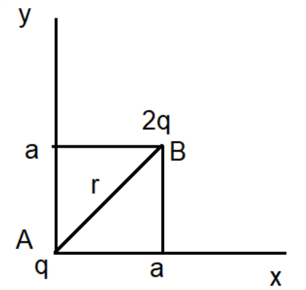
b) (i) Derive an expression for the electric field at a point on the equatorial plane of an electric dipole consisting of charges q and -q separated by a distance 2a.
(ii) The distance of a far off point on the equatorial plane of an electric dipole is halved. How will the electric field be affected for the dipole?
(iii) Two identical electric dipoles are placed along the diagonals of a square ABCD of side $\sqrt{2}$ m as shown in the figure. Obtain the magnitude and direction of the net electric field at the centre (O) of the square.



Ans:. (a) (i) Force between two point charges varies inversely with the square of distance between the charges and is directly proportional to the product of magnitude of the two charges and acts along the line joining the two charges. In vector form we have

ii) In derivation of Gauss's law, flux is calculated using Coulomb's law and surface area. Here coulomb's law involves $1/r^2$ factor and surface area involves r^2 factor. When product is taken, the two factors cancel out and flux becomes independent of r.

(iii) The diagram is as shown.



Now distance r is given by

$$\vec{r} = \overrightarrow{AB} = a\hat{i} + a\hat{j}$$

$$r = \left|\overrightarrow{AB}\right| = \sqrt{a^2 + a^2} = \sqrt{2}a$$

Hence force is given by

$$\vec{F} = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}\hat{r}$$

$$\vec{F} = \frac{1}{4\pi\varepsilon_o}\frac{q \times 2q}{\left(\sqrt{2}a\right)^2} \times \frac{\left(a\hat{i} + a\hat{j}\right)}{\sqrt{2}a}$$

Solving we have

$$\vec{F} = \frac{q^2}{4\sqrt{2}\pi\varepsilon_o a^2}\left(\hat{i} + \hat{j}\right)$$

(b) (i) Consider an electric dipole consisting of charges -q and +q separated by a distance **2a** as shown in figure below. Let the point of observation P lie on the right bisector of the dipole AB at a distance r from its midpoint O .Let E_A and E_B be the electric field intensities at point P due to charges at A and B respectively. The two electric fields have magnitudes

$$E_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(r^2+d^2\right)} \text{ ------- (3) in the}$$

direction of AP

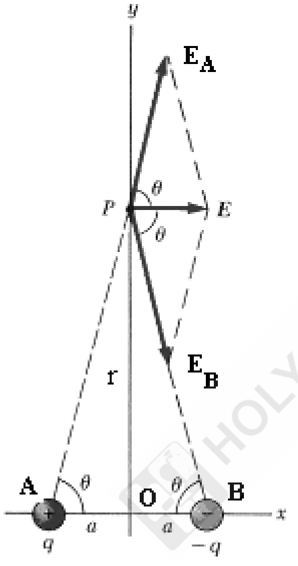
$$E_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(r^2+d^2\right)} \text{ -------- (4) in the}$$

direction of PB

The two fields are equal in magnitude, but have different directions. Resolving the two fields E_A & E_B into their rectangular components i.e. perpendicular to and parallel to AB. The components perpendicular to AB i.e $E_A \sin\theta$ and $E_B \sin\theta$ being equal and opposite cancel out each other while the components parallel to AB i.e. $E_A \cos\theta$ and $E_B \cos\theta$ being in the same direction add up as shown in the Fig. Hence the resultant electric field at point P is given by

$$E = E_A\cos\theta + E_B\cos\theta$$

$$= 2E_A\cos\theta = \frac{1}{4\pi\varepsilon_0}\frac{2q}{\left(r^2+d^2\right)}\cos\theta \text{ ----- (5)}$$



$$E = \frac{1}{4\pi\varepsilon_0}\frac{2qd}{\left(r^2+d^2\right)^{3/2}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{\left(r^2+d^2\right)^{3/2}}$$

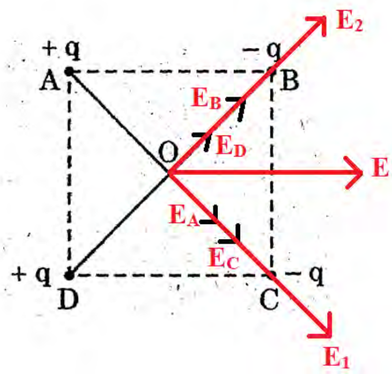
$$\because \cos\theta = \frac{a}{\left(r^2+d^2\right)^{1/2}} \text{ and } q\,2d = p$$

In vector form we have $\vec{E} = \frac{1}{4\pi\varepsilon_o}\frac{-\vec{p}}{\left(r^2+a_2\right)^{3/2}}$

(ii) At far off point the field reduces to $\vec{E} = \frac{1}{4\pi\varepsilon_o}\frac{-\vec{p}}{r^3}$

When distance is halved $\vec{E} = \frac{1}{4\pi\varepsilon_o}\frac{-\vec{p}}{(r/2)^3} = \frac{1}{4\pi\varepsilon_o}\frac{-8\vec{p}}{r^3}$ electric field becomes 8 times.

(iii) The diagram is as shown.



Side of square BC = $\sqrt{2}$ m Now AC = $\sqrt{2}\times\sqrt{2} = 2$ m Hence OC = 1 m

At O $E_A = E_B = E_C = E_D = \frac{kq}{(OC)^2} = \frac{kq}{(1)^2} = kq$

Now electric field at O along OC $E_1 = E_A + E_C =$ kq + kq = 2kq

Now electric field at O along OB $E_2 = E_D + E_B =$ kq + kq = 2kq

These two fields are perpendicular to each other. Hence net electric field at O is given by

$$E_{net} = \sqrt{E_1^2+E_2^2} = \sqrt{(2kq)^2+(2kq)^2} = 2\sqrt{2}kq$$

parallel to DC

Q:32. (a) (i) (1) Write two points of difference between an interference pattern and a diffraction pattern.

(2) Name any two factors, on which the fringe width in a Young's double-slit experiment depends.

(ii) In Young's double-slit experiment, the two slits are separated by a distance equal to 100 times the wavelength of light that passes through the slits. Calculate

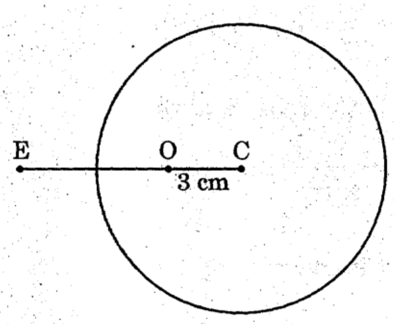
(1) the angular separation in radians between the central maximum and the adjacent maximum.

(2) the distance between these two maxima on a screen 50 cm from the slits.

OR

(b) (i) A spherical surface of radius of curvature R separates two media of refractive indices n_1 and n_2 A point object is placed in front of the surface at distance u in medium of refractive index n_1 and its image is formed by the surface at distance v, in the medium of refractive index n_2. Derive a relation between u and v

(ii) A solid glass sphere of radius 6.0 cm has a small air bubble trapped at a distance 3.0 cm from .its centre C as shown in the figure. The refractive index of the material of the sphere is 1.5. Find the apparent position of this bubble when seen through the surface of the sphere from an outside point E in air.



Ans: (a) (1) (a) The interference pattern has a number of equally spaced bright and dark bands while diffraction pattern has a central bright maximum which is twice as wide as the other maxima.

(b) In interference pattern the intensity of bright fringes remain same while in diffraction the intensity falls as we go to successive maxima away from the centre on either side.

(2) Wave length (λ), distance of screen from slits (D), separation between slits (d).

(ii) (1)Given d = 100 λ,

$d \sin\theta = n\lambda$

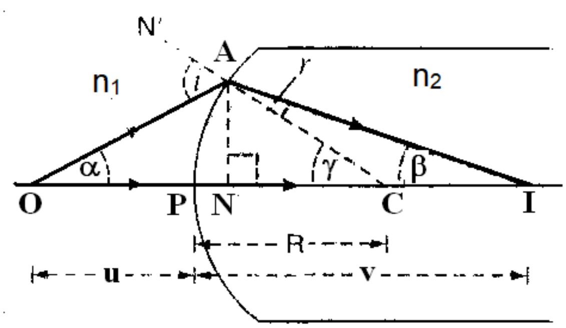
n = 1, therefore $\sin\theta = \frac{\lambda}{d}$

For small angle $\sin\theta \approx \theta = \frac{\lambda}{100\lambda} = \frac{1}{100}$ radian

(2) $\beta = \frac{D\lambda}{d} = \theta D = \frac{1}{100} \times 50 \times 10^{-2} = 5$ mm

OR

(b) (i) Let O be a point object in the rarer medium and situated on the principal axis. A ray of light OP incident normally on the retracting surface along the principal axis passes undeviated into the denser medium. Another ray of light OA incident at point A at an angle of incidence i, gets refracted towards the normal CAN'. Let r be the angle of refraction. The two rays meet at a point I on the principal axis and therefore I is the real image of the point object O as shown in Fig.



Let $\angle AOP = \alpha$, $\angle AIP = \beta$ and $\angle ACP = \gamma$. From point A, drop AN perpendicular to the principal axis of the spherical refracting surface. From triangle ΔAOC, we have

$$\mathbf{i = \alpha + \gamma} \qquad \text{------ (1)}$$

Since aperture of the spherical refracting surface is small, the point A will be close to the point P and hence angles α, β and γ will be small. As such, these angles may be replaced by their tangents.

Therefore, equation (1) may be written as

$$\mathbf{i = \tan\alpha + \tan\gamma} \qquad \text{------ (2)}$$

From right angled triangles ΔANO and ΔANC, we have

$$\tan\alpha = \frac{AN}{NO} \text{ and } \tan\gamma = \frac{AN}{NC}$$

Substituting for tan α and tan γ in equation (2), we have

$$i = \frac{AN}{NO} + \frac{AN}{NC} \qquad \text{----- (3)}$$

Again, as aperture of the refracting surface is small, point N will be close to point P, the pole of the refracting surface. Therefore,

NO ≈ PO and NC ≈ PC

Therefore, equation (3) becomes

$$i = \frac{AN}{PO} + \frac{AN}{PC} \qquad \text{------ (4)}$$

Now, from triangle ΔACI, $\boldsymbol{\gamma = r + \beta}$

or $\boldsymbol{r = \gamma - \beta}$

Since angles γ and β are small, we have

$\mathbf{r = \tan\gamma - \tan\beta}$ ------ (5)

From right angled triangles ΔANC and ΔANI, we have

$$\tan\gamma = \frac{AN}{NC} \approx \frac{AN}{PC} \text{ and } \tan\beta = \frac{AN}{NI} \approx \frac{AN}{PI}$$

Substituting for tan β and tan γ in equation 5 we have

$$r = \frac{AN}{PC} - \frac{AN}{PI} \qquad \text{------ (6)}$$

Now by Snell's law at point A we have

$n_1 \sin i = n_2 \sin r$

Since angles are small, therefore the above relation becomes

$$n_1 i = n_2 r \qquad \text{------ (7)}$$

Substituting the values of i and r from equations 4 and 6 we have

$$n_1\left(\frac{AN}{PO} + \frac{AN}{PC}\right) = n_2\left(\frac{AN}{PC} - \frac{AN}{PI}\right) \text{------ (8)}$$

$$\text{OR } \left(\frac{n_1}{PO} + \frac{n_1}{PC}\right) = \left(\frac{n_2}{PC} - \frac{n_2}{PI}\right)$$

Rewriting we have $\left(\frac{n_1}{PO} + \frac{n_1}{PC}\right) = \left(\frac{n_2}{PC} - \frac{n_2}{PI}\right)$

$$\text{or } \frac{n_1}{PO} + \frac{n_2}{PI} = \frac{n_2 - n_1}{PC} \qquad \text{------(9)}$$

Applying new Cartesian sign conventions:

PO = - u (distance of object is against incident light)

PI = + v (distance of image is along incident light)

PC = + R (distance of centre of curvature is along incident light)

we have $\frac{n_1}{-u}+\frac{n_2}{v}=\frac{n_2-n_1}{R}$ or $\frac{1}{-u}+\frac{n}{v}=\frac{n-1}{R}$

where $n = n_2/n_1$ ------ (10)

The above equation connects u, v and R to the absolute refractive indices of the material of the refracting surface and that of the rarer medium.

(ii) Using $\frac{n_1}{-u}+\frac{n_2}{v}=\frac{n_2-n_1}{R}$

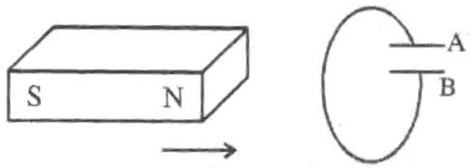
$R = -6$ cm, $u = -3$ cm, $n_1 = 1.5$, $n_2 = 1$

$\frac{1}{v}+\frac{1.5}{3}=\frac{1-1.5}{-6}$ solving for v we have

$v = -2.4$ cm

From the left side inside the sphere.

Q:33. (a) State Lenz's law. Use it to predict the polarity of the capacitor in the situation given below:



(b) A jet plane is travelling towards west at a speed of 1800 km h^{-1}.

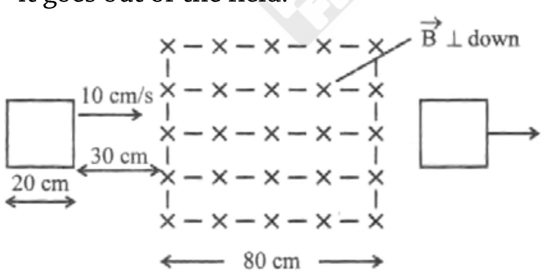
(i) Estimate voltage difference developed between the ends of the wing having a span of 25 m if the earth's magnetic field at the location has a magnitude of 5×10^{-4} T and dip angle is 30^0.

(ii) How will the voltage developed be- affected if the jet changes its direction from west to north?

OR

Define mutual inductance of a pair of coils and write on which factors does it depend.

A square loop of side 20 cm is initially kept 30 cm away from a region of uniform magnetic field of 0.1 T as shown in the figure. It is then moved towards the right with a velocity of 10 cm s^{-1} till it goes out of the field.



Plot a graph showing the variation of

(i) magnetic flux (ϕ) through the loop with time (t).

(ii) induced emf (ε) in the loop with time t.

(iii) induced current in the loop if it has resistance of 0.1 ohm.

Ans. (a) Lenz's law: The direction of induced emf is such that it opposes the cause of its production.

Plate A will be positive and plate B will be negative.

(b) (i) Given v = 1800 km h^{-1}, ε = ?,, L = 25 m, B = 5×10^{-4} T, $\delta = 30^0$

Now vertical component of earth's magnetic field is $B_V = B \times \sin 30^0 = 5 \times 10^{-4} \times 0.5 = 2.5 \times 10^{-4}$ T

Now using the expression $\varepsilon = B_V L v$

$\varepsilon = 2.5 \times 10^{-4} \times 25 \times 500 = 3.125$ V

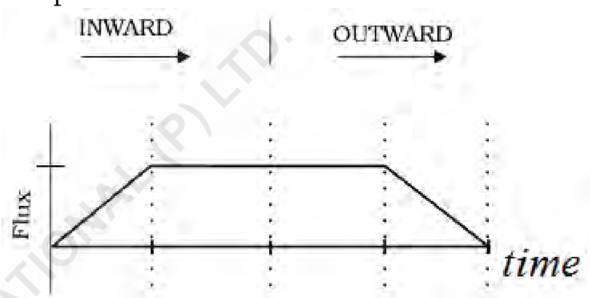
(ii) There will be no change in the emf induced.

OR

Mutual inductance of a pair of coils is numerically equal to the magnetic flux linked with the coil when the current in the neighbouring coil is unity.

It depends upon the following factors (i) Number of turns in the coil (ii) area of the coil (iii) nature of material on which coil is wound (iv) Relative orientation of the coil (v) shape of the coil.

The plot is as shown



The induced emf is as shown.

(iii) The emf induced in the loop

$E = Blv = 0.1 \times 0.2 \times 0.1 = 0.02$ V

$i = \frac{E}{R} = \frac{0.02}{0.1} = 0.2$ A

MODEL TEST PAPER 11
PHYSICS

Time allowed: 3 hours **Maximum Marks: 70**

SECTION – A

Q.1. When a negative charge (-Q) is brought near one face of a metal cube, the:
(a) cube becomes positively charged
(b) cube becomes negatively charged
(c) face near the charge becomes positively charged and the opposite face becomes negatively charged
(d) face near the charge becomes negatively charged and the opposite face becomes positively charged

Ans: (c)

Q:2. A thin plastic rod is bent into a circular ring of radius R. It is uniformly charged with charge density λ. The magnitude of the electric field at its centre is: **(AI 2024)**

(A) $\frac{\lambda}{2\varepsilon_o R}$ (B) zero (C) $\frac{\lambda}{4\pi\varepsilon_o R}$ (D) $\frac{\lambda}{4\varepsilon_o R}$

Ans:(B)

Q:3. Ten capacitors, each of capacitance 1 μF, are connected in parallel to a source of 100 V. The total energy stored in the system is equal to:
(A) 10^{-2} J (B) 10^{-3} J
(C) 0.5×10^{-3} J (D) 5.0×10^{-2} J

Ans: (D)

Q:4. An iron rod of susceptibility 599 is subjected to a magnetizing field of 1200 A m–1. The permeability of the material of the rod is ($\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1})
(a) $2.4\pi \times 10^{-4}$ T m A^{-1}
(b) 8.0×10^{-5} T m A–1
(c) $2.4\pi \times 10^{-5}$ T m A^{-1}
(d) $2.4\pi \times 10^{-7}$ T m A^{-1}

Ans: (a)

Q:5. The equation of an alternating current is $i = 50\sqrt{2} \times \sin 400\,\pi t$ ampere then the frequency and the root mean square of the current are respectively
(a) 200 *Hz*, 50 A (b) 400 π *Hz*, $50\sqrt{2}$ *A*
(c) 200 *Hz*, $50\sqrt{2}$ A (d)50 *Hz*, 200 *A*

Ans: (a)

Q:6. In an ac circuit, containing an inductance and a capacitor in series, the current is found to be maximum when the value of inductance is 0.5 henry and a capacitance of 8 μF. The angular frequency of the input ac voltage must be equal to
(a) 500 rad s^{-1} (b) 5×10^4 rad s^{-1}
(c) 4000 rad s^{-1} (d) 5000 rad s^{-1}

Ans: (a)

Q:7. A plane wave is incident on a concave mirror of radius of curvature R. The reflected wave is a spherical wave of radius:
(a)R/4 (b) R/4 (c) R (d) 2R

Ans: (b)

Q:8. The photoelectric cut-off voltage in a certain experiment is 1.5 V. What is the maximum kinetic energy of photoelectrons emitted?
(a) 2.4×10^{-10} J (b) 4.2×10^{-10} J
(c) 2.4×10^{-19} J (d) 4.2×10^{-19} J

Ans:. (c)

Q:9. An electron (mass m) with an initial velocity $\vec{v} = v_0\hat{i}$ ($v_0 > 0$) is in an electric field $\vec{E} = E_0\hat{i}$ (E_0 = constant > 0). Its de-Broglie wavelength at time t is given by

(a) $\frac{\lambda_0}{\left[1+\frac{eE_0t}{mv_0}\right]}$ (b) $\lambda_0\left[1+\frac{eE_0t}{mv_0}\right]$

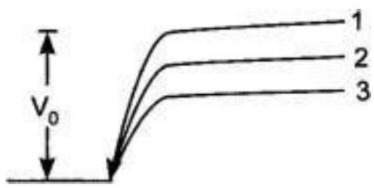
(c) λ_0 (d) $\lambda_0 t$

Ans: (a)

Q:10. The ratio of kinetic energy to the total energy of an electron in a Bohr orbit of the hydrogen atom, is :
(a) 1 : 1 (b) 1 : –1 (c) 2 : –1 (d) 1 : –2

Ans: (b)

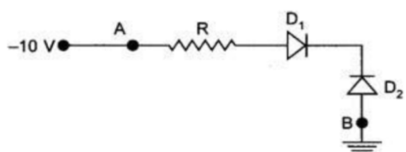
Q:11. No battery is connected across the junction. In the given figure V_0 is the potential barrier across a p-n junction,(Represented by 2) when



(a) 1 and 3 both correspond to forward bias of junction.
(b) 3 corresponds to forward bias of junction and 1 corresponds to reverse bias of junction.
(c) 1 corresponds to forward bias and 3 corresponds to reverse bias of junction.
(d) 3 and 1 both correspond to reverse bias of junction.

Ans: (b)

Q:12. In figure given, assuming the diodes to be ideal



(a) D_1 is forward biased and D_2 is reverse biased and hence current flows from A to B.

(b) D_2 is forward biased and D_1 is reverse biased and hence no current flows from B to A and vice versa.

(c) D_1 and D_2 are both forward biased and hence current flows from A to B.

(d) D_1 and D_2 are both reverse biased and hence no current flows from A to B and vice versa.

Ans: (b)

Question number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both (A) and (R) are true and (R) is the correct explanation of (A)

(b) Both (A) and (R) are true and (R) is NOT the correct explanation of (A)

(c) (A) is true but (R) is false

(d) (A) is false and (R) is also false.

Q:13. Assertion (A): Electric field is always normal to equipotential surfaces and along the direction of decreasing order of potential

Reason(R): Negative gradient of electric potential is electric field.

Ans: (a)

Q:14. **Assertion (A):** Two long parallel wires, freely suspended and connected in series to a battery, move apart.

Reason (R): Two wires carrying current in opposite directions repel each other.

Ans: (A)

Q:15. **Assertion:** Density of all the nuclei is same. **Reason:** Radius of nucleus is directly proportional to the cube root of mass number.

Ans: (a)

Q:16. Assertion: An N-type semiconductor has a large number of electrons but still it is electrically neutral.

Reason: An N-type semiconductor is obtained by doping an intrinsic semiconductor with a pentavalent impurity.

Ans: (b)

SECTION B

Q:17. A point charge +Q is placed at the centre O of an uncharged hollow spherical conductor of inner radius 'a' and outer radius 'b'. Find the following:

(i) The magnitude and sign of the charge induced on the inner and outer surface of the conducting shell.

(ii) The magnitude of electric field vector at a distance (i) r =a/2, and (ii) r = 2b, from the centre of the shell.

Ans. (i) The +Q charge will induce a charge of -Q on the inner side of radius 'a' and a charge +Q on the outer side of radius 'b'.

(ii)The electric field at a point distance 'r' from a point charge is given by $E=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$, when r = a/2 we have

$$E=\frac{1}{4\pi\varepsilon_0}\frac{q}{(a/2)^2}=\frac{1}{4\pi\varepsilon_0}\frac{4Q}{a^2}$$

when r = 2b we have

$$E=\frac{1}{4\pi\varepsilon_0}\frac{q}{(2b)^2}=\frac{1}{4\pi\varepsilon_0}\frac{Q}{4b^2}$$

Q:18 A variable resistor R is connected across a cell of emf E and internal resistance r.

a) Draw the circuit diagram.

b) Plot the graph showing variation of potential drop across R as function of R.

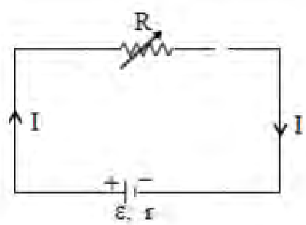
OR

A storage battery is of emf 8 V and internal resistance 0.5 ohm is being charged by d.c supply of 120 V using a resistor of 15.5 ohm

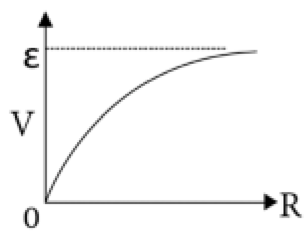
a) Draw the circuit diagram.

b) Calculate the potential difference across the battery.

Ans. (a)The circuit diagram is as shown

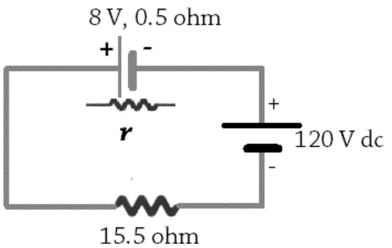


(b) The graph



OR

(a) The circuit diagram is as shown.



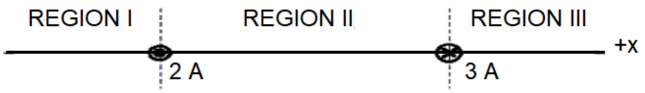
(b) E = 8 V, internal resistance R_1=0.5 Ω
V=120 V, resistance R_2=15.5 Ω
Effective voltage
V'= V−E=120 − 8 = 112 V

$$I = \frac{V'}{R_1 + R_2} = \frac{112}{0.5 + 15.5} = 7\ A$$

Voltage across R_1=I R_1= 7 × 0.5 = 3.5 V

Terminal voltage across cell = 8 + 3.5 = 11.5 V

Q:19. Two straight infinitely long wires are fixed in space so that the current in the left wire is 2 A and directed out of the plane of the page and the current in the right wire is 3 A and directed into the plane of the page. In which region(s) is/are there a point on the x-axis, at which the magnetic field is equal to zero due to these currents carrying wires? Justify your answer.



Ans The magnetic field due to the two straight wires is given by $B = \frac{\mu_o I}{2\pi r}$

Region I: The fields due to the two wires is oppositely directed. Since the current in the right wire is more therefore the magnitude of magnetic fields due to the two wires can be equal. Hence magnetic field can be zero towards the left of wire carrying 2 A i.e., in region I.

Region II: The two field are in the same direction, therefore they cannot cancel each other.

Region III: The two fields are opposite but their magnitude cannot be same in this region.

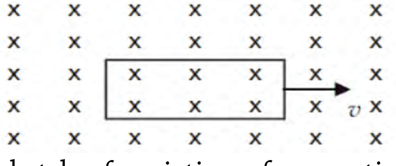
Q:20. A coil of wire enclosing an area 100 cm^2 is placed with its plane making an angle 60° with the magnetic field of strength 10^{-1}T. What is the flux through the coil? If magnetic field is reduced to zero in 10^{-3} s, then find the induced emf?

Ans: Given A = 100 cm^2 = 10^{-2} m^2 , θ = 60° , B = 10^{-1} T, t = 10^{-3} s

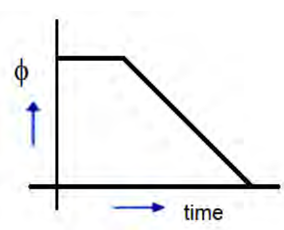
$$\varepsilon = -\frac{d\phi}{dt} = -A\cos\theta\frac{dB}{dt}$$

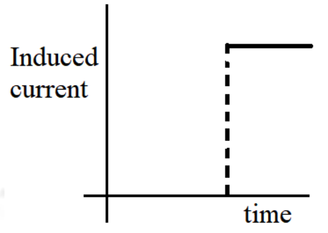
$$\text{Or } \varepsilon = -10^{-2} \times \cos 60^{\circ}\left(\frac{10^{-1} - 0}{10^{-3}}\right) = 0.5\ V$$

Q:21. A rectangular loop, which was initially inside the region of uniform and time - independent magnetic field, is pulled out with constant velocity *v* as shown in the figure. Sketch the variation of magnetic flux, the induced current, and power dissipated as Joule heat as function of time.



Ans: The sketch of variation of magnetic flux with time is as shown. Initially the flux is constant then it decreases as the loop comes out of the magnetic field.





The graph for induced current and power is same as P = I^2Rt

SECTION C

Q:22. The magnetic field in a plane electromagnetic wave is given by:

$B_y = 12 \times 10^{-8} \sin(1.20 \times 10^7 z + 3.60 \times 10^{15} t)$ T.

Calculate the

(i) Energy density associated with the Electromagnetic wave

(ii) Speed of the wave

Ans..(i) energy density is given by

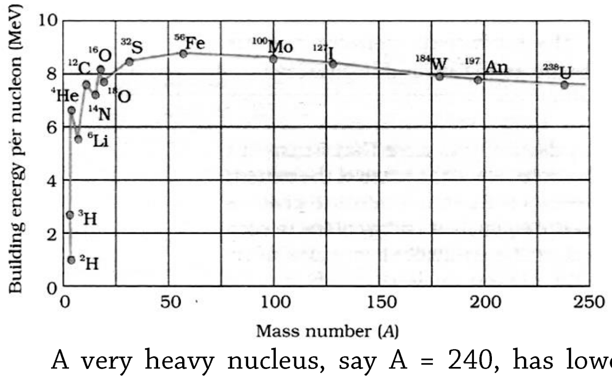
$$u = \frac{B^2}{\mu_0} = \frac{(12\times10^{-8})^2}{4\pi\times10^{-7}} \text{ or}$$

u= 11.5 × 10^{-9} J m^{-3}.

$$\text{(ii) speed} = \frac{\omega}{k} = \frac{3.60\times10^{15}}{1.2\times10^{7}} = 3\times10^{8}\ m\ s^{-1}$$

Q:23. Draw a graph showing the variation of binding energy per nucleon versus the mass number A. Explain with the help of this graph, the release of energy in the process of nuclear fission and fusion.

Ans. The diagram is as shown



A very heavy nucleus, say A = 240, has lower binding energy per nucleon compared to that of a nucleus with A = 120. Thus, if a nucleus A = 240 breaks into two A = 120 nuclei, nucleons get more tightly bound. This implies energy would be released in the process. This explains the process of fission.

Consider two very light nuclei (A < 10) joining to form a heavier nucleus. The binding energy per nucleon of the fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. This means that the final system is more tightly bound than the initial system.

Again, energy would be released in such a process of fusion.

Q:24. a) Give one point of difference between nuclear fission and nuclear fusion.

b) Suppose we consider fission of a $^{56}_{26}Fe$ into two equal fragments of $^{28}_{13}Al$ nucleus. Is the fission energetically possible? Justify your answer by working out Q value of the process. Given (m) $^{56}_{26}Fe$ = 55.93494 u and (m) $^{28}_{13}Al$ = 27.98191

Ans: (a) Nuclear fission: (i) May or may not be a chain reaction. (ii) Temperature independent

Nuclear fusion: (i) Always a chain reaction (ii) Temperature dependent.

(b)Now Q of the process is Q = $\{m(^{56}_{26}Fe) - 2\,m(^{28}_{13}Al)\}\times 931.5$ MeV

Q = $\{55.93494 - 2 \times 27.98191\}\times 931.5$ MeV = -26.90 MeV

Since, the energy is negative, therefore this fission is not possible.

Q:25. The following table gives the length of three copper wires, their diameters, and the applied potential difference across their ends. Arrange the wires in increasing order according to the following:

(a) The magnitude of the electric field within them,

(b) The drift speed of electrons through them, and

(c) The current density within them.

Wire no.	Length	Diameter	Potential Difference
1	L	3d	V
2	2L	d	V
3	3L	2d	2V

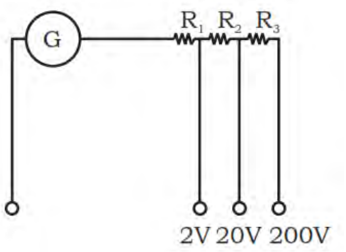
Ans13. (a) The strength of the electric field is given by the expression $E = \frac{V}{L}$, therefore we have $E_1 = \frac{V}{L}, E_2 = \frac{V}{2L}, E_3 = \frac{2V}{3L}$, hence we have $E_2 < E_3 < E_1$.

(b)Now drift velocity is given by the expression $v_d = -\frac{eE}{m}\tau$ i.e., $v_d \propto E$, hence we have $v_{d2} < v_{d3} < v_{d1}$.

(c) The current density is given by $J = nev_d$,

Therefore, we have $J_2 < J_3 < J_1$.

Q:26. A multirange voltmeter can be constructed by using a galvanometer circuit as shown in the figure. We want to construct a voltmeter that can measure 2 V, 20 V and 200 V using a galvanometer of resistance 10 Ω and that produces maximum deflection for current of 1 mA. Find the value of R_1, R_2 and R_3 that have to be used.



Ans14. Greater the range greater will be the resistance connected in series. Thus

$i_G(G + R_1) = 2$ for 2 V range

$i_G(G + R_1 + R_2) = 20$ for 20 V range

and $i_G(G + R_1 + R_2 + R_3) = 200$ for 200 V range

Solving for R_1, R_2 and R_3

Gives $R_1 = 1990\ \Omega$

$R_2 = 18\ k\Omega$ and $R_3 = 180\ k\Omega$

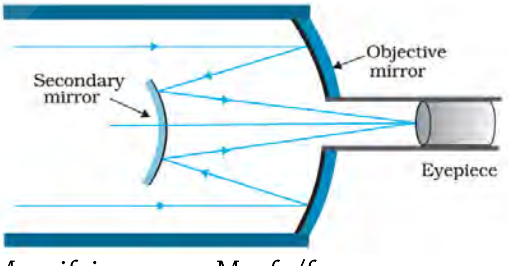
Q:27. a) State two main considerations taken into account while choosing the objective of astronomical telescope.

b) Draw a ray diagram of reflecting type telescope. State its magnifying power.

c) State the advantages of reflecting type telescope over the refracting type?

Ans. (a) (i) Large focal length and (ii) Large aperture

(b) The diagram is as shown.



Magnifying power $M = f_o / f_e$

(c) Three distinct advantages of the reflecting type over the refracting type telescope are

(i) Less chromatic aberration in a mirror.

(ii) A mirror can be made which has a much larger size than a lens, thus high resolving power and light gathering power.

(iii) Mechanical support is much less of a problem since a mirror weighs much less than a lens of equivalent optical quality supported over its entire back surface, not just over its rim.

Q:28. In a double slit experiment, the distance between the slits is 3 mm and the slits are 2 m away from the screen. Two interference patterns can be seen on the screen one due to light with wavelength 480 nm, and the other due to light with wavelength 600 nm. What is the separation on the screen between the fifth order bright fringes of the two interference patterns?

OR

An astronomical telescope has an angular magnification of magnitude 5 for distant objects.

The separation between the objective and an eye piece is 36 cm and the final image is formed at infinity. Calculate the focal length of the objective and the focal length of the eye piece?

Ans. Given d = 3 mm, λ_1 = 480 nm, λ_2 = 600 nm, D = 2 m , $y_{25} - y_{15}$ = ?

The distance of the nth bright fringe is given by

$y_n = nD\lambda/d$

Hence

$$y_{15} = \frac{5D\lambda_1}{d} = \frac{5\times2\times480\times10^{-9}}{3\times10^{-3}} = 1.6\times10^{-3}\ \text{m}$$

Or y_{15} = 1.6 mm

$$y_{25} = \frac{5D\lambda_2}{d} = \frac{5\times2\times600\times10^{-9}}{3\times10^{-3}} = 2.0\times10^{-3}\ \text{m}$$

Or y_{25} = 2.0 mm

Therefore, separation between the two

$y_{25} - y_{15} = 2.0 - 1.6 = 0.4$ mm

OR

Given M = 5, L = 36 cm, f_0 = ?, f_e =?

Now $M = f_o/f_e$

$f_o = 5 f_e$

$L = f_o + f_e$

$36 = 5f_e + f_e$ or

$f_e = 36/6 = 6$ cm

Hence f_o = 30 cm

SECTION D

Questions number 29 to 30 are case study-based questions

Q:29. A convex or converging lens is thicker at the centre than at the edges. It converges a beam of light on refraction through it. It has a real focus. Convex lens is of three types: Double convex lens, Plano convex lens and Concavo-convex lens. Concave lens is thinner at the centre than at the edges. It diverges a beam of light on refraction through it. It has a virtual focus. Concave lenses are of three types: Double concave lens, Plano concave lens and Convexo-concave lens. When two thin lenses of focal lengths f_1 and f_2 are placed in contact with each other along their common principal axis, then the two lens system is regarded as a single lens of focal length *f* and $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

If several thin lenses of focal length $f_1, f_2, \dots f_n$ are placed in contact, then the effective focal length of the combination is given by $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \dots \frac{1}{f_n}$

and in terms of power, we can write

$P = P_1 + P_2 + \dots + P_n$

The value of focal length and power of a lens must be used with proper sign consideration.

(i) Two thin lenses are kept coaxially in contact with each other and the focal length of the combination is 80 cm. If the focal length of one lens is 20 cm, the focal length of the other would be

(a) -26.7 cm (b) 60cm

(c) 80cm (d) 30cm

Ans: (a)

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

Given f = 80 cm and f_1 = 20 cm

(ii) A spherical air bubble is embedded in a piece of glass. For a ray of light passing through the bubble, it behaves like a

(a) converging lens (b) diverging lens

(c) mirror (d) thin plane sheet of glass

Ans: (b)

It is placed in a medium having higher refractive index.

(iii) Lens generally used in magnifying glass is

(a) single concave lens

(b) single convex lens

(c) combination of convex lens of lower power and concave lens of lower focal length

(d) Plano-concave lens

Ans: (b)

A magnifying glass is a single convex lens with a small focal length.

(iv) The magnification of an image by a convex lens is positive only when the object is placed

(a) at its focus F

(b) between F and 2F

(c) at 2F

(d) between F and optical centre

Ans: (d)

Image formed is virtual

OR

(iv) A convex lens of 20 cm focal length forms a real image which is three times magnified. The distance of the object from the lens is

(a) 13.33 cm (b) 14 cm

(c) 26.66 cm (d) 25 cm

Ans: (c)

$$m = \frac{v}{u} = \frac{f}{f+u}$$

Q:30. Consider a thin p-type silicon (p-Si) semiconductor wafer. By adding precisely a small quantity of pentavalent impurity, part of the p-Si wafer can be converted into n-Si. There are several processes by which a semiconductor can be formed. The wafer now contains p-region and n- region and a metallurgical junction between p-, and n- region. Two important processes occur during the formation of a p-n junction: diffusion and drift. We know that in an n-type semiconductor, the concentration of electrons (number of electrons per unit volume) is more compared to the concentration of holes. Similarly, in a p-type semiconductor, the concentration of holes is more than the concentration of electrons. 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). This motion of charge carries gives rise to diffusion current across the junction.

(i). How can a p-type semiconductor be converted into n- type semiconductor?
(a) adding pentavalent impurity
(b) adding trivalent impurity
(c) not possible
(d) heavy doping

Ans: (a)

(ii). Which of the following is true about n type semiconductor?
(a) concentration of electrons is less than that of holes.
(b) concentration of electrons is more than that of holes.
(c)concentration of electrons equal to that of holes.
(d)None of these

Ans: (b)

(iii). Which of the following is true about p type semiconductor?
(a) concentration of electrons is less than that of holes.
(b)concentration of electrons is more than that of holes.
(c)concentration of electrons equal to that of holes.
(d)None of these

Ans: (a)

(iv). Which of the following is the reason about diffusion current?
(a) diffusion of holes from p to n
(b)diffusion of electrons from n to p
(c) both (a) and (b)
(d) None of these

Ans: (c)

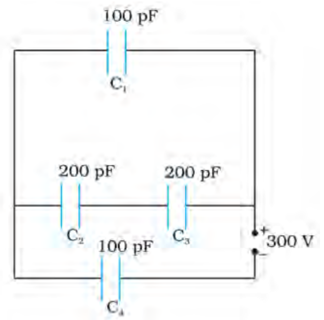
OR

(iv). What are the processes that occur during formation of a p-n junction?
(a) drift
(b) diffusion
(c) both (a) and (b)
(d) None of these

Ans: (c)

SECTION E

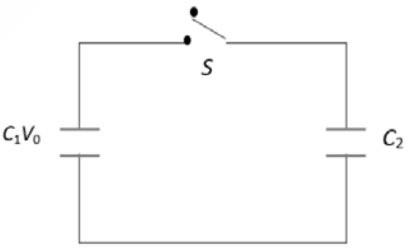
Q:31. Derive an expression for the capacitance of a parallel plate capacitor with air present between the two plates. Obtain the equivalent capacitance of the network shown in figure. For a 300 V supply, determine the charge on each capacitor.



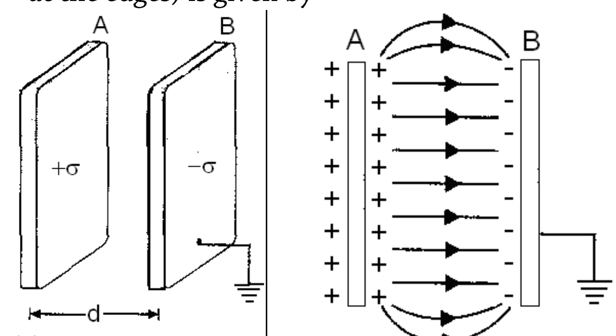
OR

(i) A dielectric slab of thickness 't' is kept between the plates of a parallel plate capacitor with plate separation 'd' ($t < d$). Derive the expression for the capacitance of the capacitor.

(ii) A capacitor of capacity C_1 is charged to the potential of V_0. On disconnecting with the battery, it is connected with an uncharged capacitor of capacity C_2 as shown in the adjoining figure. Find the ratio of energies before and after the connection of switch S.



Ans: (i) Suppose Q is the charge on the capacitor, and σ is the uniform surface charge density on each plate as shown in figure. Therefore, by Gauss's theorem the electric field between the plates of the capacitor (neglecting fringing of electric field at the edges) is given by



(a) (b)

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A} \quad \text{------ (1)}$$

The field is uniform, and the distance between the plates is d , so the potential difference between the two plates is

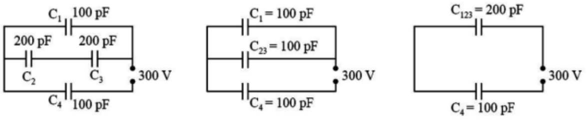
$$V = Ed = \frac{1}{\varepsilon_0}\frac{Qd}{A} \qquad \text{------ (2)}$$

Therefore, by the definition of capacitance we have

$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d} \qquad \text{------- (3)}$$

This gives the capacitance of a parallel plate capacitor with air between plates.

(ii)



The equivalent capacitance of the combination is =200/3 pF

Now charge on C_4 = 200/3 $\times 10^{-12}$ × 300= 2 × 10^{-8} C, potential difference across

C_4 = $\frac{200\times10^{-12}\times300}{3\times100\times10^{-12}} = 200$ V

potential difference across C_1 = 300 – 200 = 100 V

charge on C_1 = 100 × 10^{-12} × 100 = 1 × 10^{-8} C

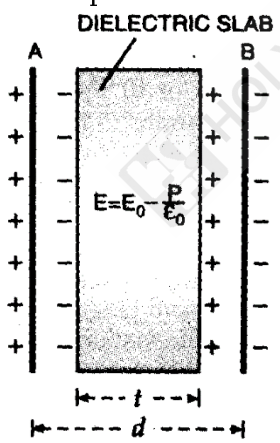
potential difference across C_2 and C_3 series combination = 100 V

potential difference across C_2 and C_3 each = 50 V

charge on C_2 and C_3 each = 200 × 10^{-12} × 50 = 1 × 10^{-8} C

OR

(i) Suppose that when the capacitor is connected to a battery, electric field of strength E_0 is produced between the two plates of the capacitor. Further, suppose that when dielectric slab of thickness t (t <d) is introduced between the two plates of the capacitor as shown in figure, the electric field reduces to E due to polarisation of the dielectric.



Therefore between the two plates of the capacitor; over a distance t, the strength of the electric field is E and over the remaining distance (d-t) the strength is E_0. If V is the potential between the plates of the capacitor, then

$$V = Et + E_0 (d-t) \qquad \text{-----(1)}$$

Since E = E_0/K where K is the dielectric constant, therefore the above equation becomes

$$V = \frac{E_0}{K}t + E_0(d-t) = E_0\left(d - t + \frac{t}{K}\right) \qquad \text{--- (2)}$$

The electric field between the plates of the capacitor is given by

$E_0 = \sigma / \varepsilon_0 = Q/ A \varepsilon_0$ ----- (3)

Hence the potential between the two plates becomes

$$V = E_0\left(d - t + \frac{t}{K}\right) = \frac{Q}{\varepsilon_0 A}\left(d - t + \frac{t}{K}\right) \qquad \text{----- (3)}$$

Hence, the capacitance of the parallel plate capacitor is given by

$$C = \frac{Q}{V} = \frac{Q}{\frac{Q}{\varepsilon_0 A}\left(d - t + \frac{t}{K}\right)} = \frac{\varepsilon_0 A}{d - t(1 - 1/K)}$$

(ii) Before the connection of switch S, the energy stored is $U_i = \frac{1}{2}C_1V_0^2 + \frac{1}{2}C_2 \times 0 = \frac{1}{2}C_1V_0^2$

After the connection of switch S the common potential is

$$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} = \frac{C_1V_0}{C_1 + C_2}$$

Final energy

$$U_f = \frac{1}{2}(C_1 + C_2) \times \frac{(C_1V_o)^2}{(C_1 + C_2)^2} = \frac{1}{2}\frac{C_1^2V_0^2}{(C_1 + C_2)}$$

$U_f : U_i = C_1/(C_1+C_2)$

Q:32. (i) Draw a ray diagram for the formation of image of a point object by a thin double convex lens having radii of curvature R_1 and R_2. Hence, derive lens maker's formula.

(ii) A converging lens has a focal length of 10 cm in air. It is made of a material of refractive index 1.6. If it is immersed in a liquid of refractive index 1.3, find its new focal length.

OR

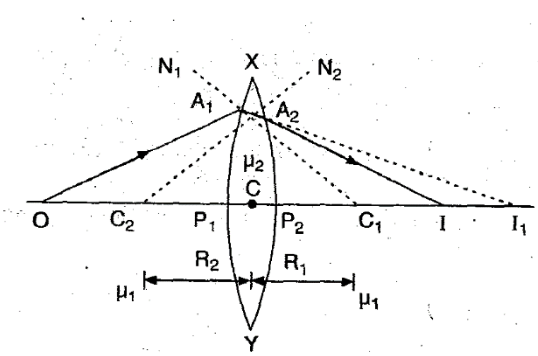
(i) Define a wavefront. How is it different from a ray?

(ii) Using Huygens's construction of secondary wavelets draw a diagram showing the passage of a plane wavefront from a denser to a rarer medium. Using it verify Snell's law.

(iii)In a double slit experiment using light of wavelength 600 nm and the angular width of the fringe formed on a distant screen is 0.1°. Find the spacing between the two slits.

(iv) Write two differences between interference pattern and diffraction pattern.

Ans: (i)The course of rays through the lens is as shown. For refraction at the spherical surface XP_1Y, we have



$$\frac{n_2}{P_1I_1}+\frac{n_1}{P_1O}=\frac{n_2-n_1}{P_1C_1} \quad \text{or} \quad \frac{n_2}{CI_1}+\frac{n_1}{CO}=\frac{n_2-n_1}{CC_1}$$

--(1) (since lens is thin)

Consider the second surface **XP_2Y.** Actually the material of the lens does not extend beyond **XP_1Y.** Therefore, before the refracted ray from A_1 could meet the principal axis, it will suffer refraction at point A_2 on the second face **XP_2Y** and the light ray will finally meet the principal axis at **I.** Such that **I** is the final image**.** Thus point **I** is the real image of the **virtual object I_1.** Hence for refraction at the surface **XP_2Y** we have

$$\frac{n_1}{P_2I}-\frac{n_2}{P_2I_1}=\frac{n_2-n_1}{P_2C_2} \quad \text{or} \quad \frac{n_1}{CI}-\frac{n_2}{CI_1}=\frac{n_2-n_1}{CC_2}$$

--(2)

Adding equations 1 and 2 we have

$$\frac{n_2}{CI_1}+\frac{n_1}{CO}+\frac{n_1}{CI}-\frac{n_2}{CI_1}=\frac{n_2-n_1}{CC_1}+\frac{n_2-n_1}{CC_2}$$

------ (3)

or we have

$$\frac{n_1}{CO}+\frac{n_1}{CI}=(n_2-n_1)\left(\frac{1}{CC_1}+\frac{1}{CC_2}\right) \quad \text{--- (4)}$$

Using sign conventions i.e.

CO = - u , CI = + v , CC_1 = + R_1 and CC_2 = - R_2

The above equation becomes

$$\frac{n_1}{-u}+\frac{n_1}{+v}=(n_2-n_1)\left(\frac{1}{+R_1}+\frac{1}{-R_2}\right) \quad \text{------ (5)}$$

or $$\frac{1}{-u}+\frac{1}{+v}=\left(\frac{n_2}{n_1}-1\right)\left(\frac{1}{+R_1}+\frac{1}{-R_2}\right) \quad \text{-- (6)}$$

But n_2 / n_1 = n , the absolute refractive index of the material of the lens, therefore the above equation takes the form

$$\frac{1}{v}-\frac{1}{u}= (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

But by lens formula we have $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Therefore, from the above two equations we have

$$\frac{1}{f}= (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{------ (7)}$$

This is the Lens maker's equation or formula.

(ii) $$\frac{1}{f_a}=(1.6-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad \text{----(i)}$$

$$\frac{1}{f_l}=\left(\frac{1.6}{1.3}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad \text{----- (ii)}$$

From (i) and (ii) we have

$$\frac{f_l}{f_a}=\left(\frac{0.6}{0.3}\times 1.3\right) \Rightarrow f_l = 2.6\times 10 = 26 \text{ cm}$$

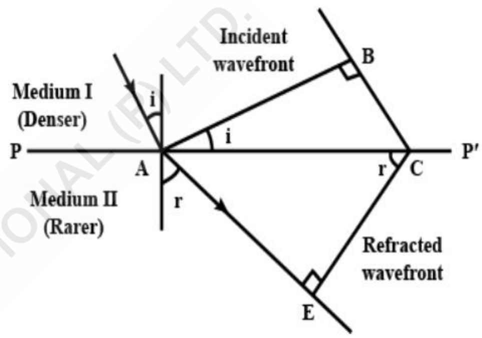
OR

(i) (i) A wavefront is defined as a surface of constant phase.

(a) The ray indicates the direction of propagation of wave while the wavefront is the surface of constant phase.

(b) The ray at each point of a wavefront is normal to the wavefront at that point.

(ii) AB: Incident Plane Wave Front and CE is the refracted Wave front .



From the diagram we have

sin i =BC/AC and sin r = AE /AC

sin i / sin r = BC /AE = v_1 /v_2 = constant

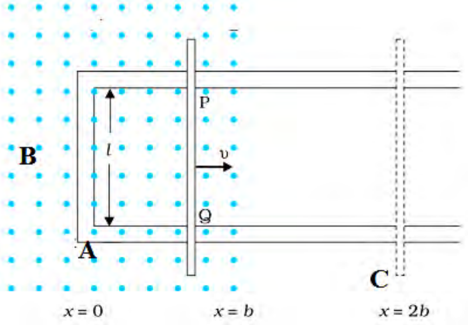
(iii) $$\theta=\frac{\lambda}{a} \Rightarrow a=\frac{\lambda}{\theta}=\frac{6\times 10^{-7}}{0.1\times \pi/180}=3.4\times 10^{-4} \text{ m}$$

(iv)

S.#	INTERFERENCE	DIFFRACTION
1	All the bright fringes have same intensity i.e., are equally bright.	All the bright fringes are not of the same intensity. i.e., are not equally bright.
2	There is a good contrast between the bright and the dark fringes.	There is a poor contrast between the dark and the bright fringes.
3	The width of the interference fringes may or may not be same.	The width of the diffraction fringes is never same.

Q:33. (a) When a bar magnet is pushed towards (or away) from the coil connected to a galvanometer, the pointer in the galvanometer deflects. Identify the phenomenon causing this deflection and write the factors on which the amount and direction of the deflection depends. State the laws describing this phenomenon.

(b) Sketch the change in flux, emf and force when a conducting rod PQ of resistance R and length *l* moves freely to and fro between A and C with speed v on a rectangular conductor placed in uniform magnetic field as shown in the figure.



OR

In a series LCR circuit connected to an ac source of voltage $v = v_m \sin \omega t$, use phasor diagram to derive an expression for the current in the circuit. Hence obtain the expression for the power dissipated in the circuit. Show that power dissipated at resonance is maximum.

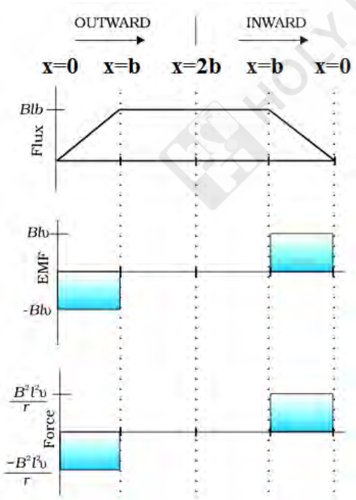
Ans. (a) Phenomenon: electromagnetic Induction

Factors: (i) Strength of magnetic field of magnet (ii) speed of motion of bar magnet.

Direction depends upon (i) motion of magnet whether inward or outward (ii) direction of north/south pole.

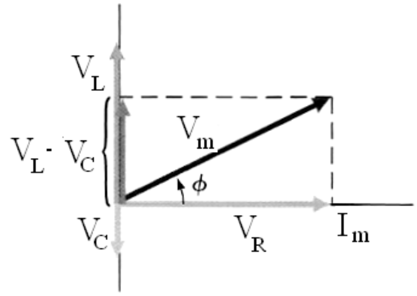
Law: The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

(b) The sketch is as shown below.



OR

The voltages across the various elements are drawn as shown in figure below.



From the diagram we observe that the vector sum of the voltage amplitudes $\mathbf{v_R}$, $\mathbf{v_L}$ and $\mathbf{v_C}$ equals a phasor whose length is the maximum applied voltage v_m , where the 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

$$V_m = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$= \sqrt{(I_m R)^2 + (I_m X_L - I_m X_C)^2} \quad \text{-----} \quad (1)$$

$$\text{or} \quad V_m = I_m \sqrt{R^2 + (X_L - X_C)^2} \quad \text{------} \quad (2)$$

where $X_L = \omega L$ and $X_C = 1/\omega C$, therefore we can express the maximum current as

$$I_m = \frac{V_m}{\sqrt{R^2 + (X_L - X_C)^2}} \quad \text{------} \quad (3)$$

Let the instantaneous value of voltage and current in the ac circuit be

$V = V_m \sin \omega t$ and $I = I_m \sin(\omega t - \phi)$ ----(1)

where ϕ is the phase difference between voltage and current. Suppose the voltage and current remain constant for a small time dt. Therefore, electrical energy consumed in the small time dt is

$$dW = V\,I\,dt \quad \text{------} \ (2)$$

The total electrical energy consumed in one time period of ac is given by

$$W = \int_0^T v\,i\,dt = \int_0^T V_m \sin \omega t \; I_m \sin(\omega t - \phi) dt$$

$$= \int_0^T V_m I_m \sin \omega t \{\sin \omega t \cos \phi - \cos \omega t \sin \phi\} dt$$

Or $$W = \int_0^T I_m V_m \{\sin^2 \omega t \cos \phi - \sin \omega t \cos \omega t \operatorname{Sin} \phi\} \, dt$$

Or $$W = I_m V_m \int_0^T \left[\frac{(1 - \cos 2\omega t)}{2} \cos \phi - \frac{\sin 2\omega t}{2} \sin \phi \right] dt$$

or

$$W = \frac{I_m V_m}{2} \int_0^T [\cos \phi - \cos 2\omega t \cos \phi - \sin 2\omega t \sin \phi] \, dt$$

$$\text{or } W = \frac{I_m V_m}{2} \int_0^T [\cos \phi - \cos(2\omega t + \phi)] \, dt \quad \text{or}$$

$$W = \frac{I_m V_m}{2} \int_0^T \cos \phi \, dt - \int_0^T \cos(2\omega t + \phi) \, dt$$

or

$$W = \frac{I_m V_m}{2}\left[t\cos\phi - \frac{\sin(2\omega t+\phi)}{2\omega}\right]_0^T = \frac{I_m V_m}{2}[T\cos\phi - 0]$$

Therefore, the total electrical energy consumed in an ac circuit is $W = \frac{I_m V_m}{2} T\cos\phi$ ------ (3)

Now average power is defined as the ratio of the total electrical energy consumed over the entire cycle to the time period of the cycle, therefore

$$P_{av} = \frac{I_m V_m}{2} T\cos\phi \times \frac{1}{T} = \frac{I_m V_m}{2}\cos\phi = \frac{I_m}{\sqrt{2}}\frac{V_m}{\sqrt{2}}\cos\phi$$
------ (4)

Hence, the average power consumed in an ac circuit is

$$P_{av} = I_{rms} V_{rms} \cos\phi \qquad \text{----- (5)}$$

At resonance $\phi = 0^0$

Therefore $P_{av} = I_{rms} V_{rms}$ =maximum