CBSE
Class XII – Physics
Sample Paper 4–Solution

Section B

1. The proton A and the electron B will experience electrostatic force of equal magnitude but in the opposite direction.

2. The human eye is the most sensitive for $5.405 \times 10^{14}\,Hz$.

3. Since $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Taking $R_1 = R,\ R_2 = -R,\ \frac{1}{f} = \frac{2(n-1)}{R}$ .... (1)

When the lens is cut, $R_1 = R, R_2 = \infty,\ \frac{1}{f'} = \frac{n-1}{R}$ .....(2)

From equations (1) and (2), we get

$f' = 2f = 60\,cm$

4. No, matter waves are not electromagnetic waves.

The de Broglie wave equation is $\lambda = \frac{h}{mv}$

OR

The negative energy of the electron orbiting around the nucleus keeps it bounded with the nucleus. If the energy of the electron becomes positive, then the electron will no longer be bounded with the nucleus.

5. Electric current is a vector or scalar quantity, because it does not follow the laws of vector addition, i.e. the angles between the wires carrying current does not affect the total current in the circuit.

OR

$R = 3 \times 10^{-6}\ \Omega$

We know,

$$G = \frac{1}{R}$$

$$\therefore\ G = \frac{1}{3 \times 10^{-6}} = 0.33 \times 10^{5}\ S$$

6.

(i) water (H_2O)

(ii) oxygen (O_2)

OR

Here, $q_1 = q_2 = 100\mu C$, $r = 10cm$, $r_2 = 20cm$

Work done is

$$W = \frac{q_1 q_2}{4\pi\varepsilon_0}\left[\frac{r_2 - r_1}{r_1 r_2}\right]$$

$$= \left(100 \times 10^{-6}\right)^2 \times 9 \times 10^9 \left[\frac{10}{200}\right] \times \frac{1}{10^{-2}}$$

$$= 450\ J$$

7. de Broglie wavelength associated with a body of mass m moving with a velocity v is given by $\lambda = \frac{h}{mv}$ Since the mass of objects used in our daily lives is large, the de Broglie wavelength associated with these objects is small and is not visible. Hence, the wave nature of matter is not more apparent to our daily observations.

8. When light is put off, a large emf is produced to oppose the decay of current in the circuit. This large induced emf across the gap causes sparking in the switch.

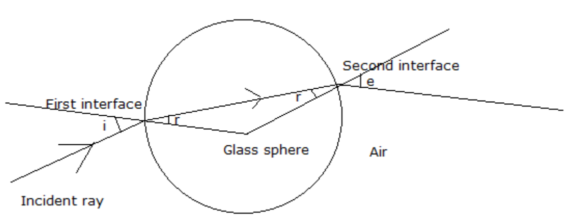
OR

An iron bar experiences a retarding force. It indicates the presence of eddy currents, which are produced whenever there is a change in magnetic flux. So, we conclude that the iron bar is a magnet.

9. A communication satellite is a satellite which can provide a communication link between two stations on the Earth which are separated by a large distance. A geostationary satellite having electronic equipment by which the signals may be received, amplified and transmitted back to the Earth can act as a communication satellite. The communication satellites of India are INSAT 2 B and INSAT 2 C.

10. A stationary charge produces only an electric field around it. When a charge moves with a constant velocity, it produces a constant magnetic field in addition to the electric field. As the charge is accelerated, both electric and magnetic fields change with time and space. One becomes the source of the other, thus giving electromagnetic waves.

11. C) From symmetry, the ray shall not suffer TIR at second interface, because the angle of incidence at first interface equals to angle of emergence at second interface. hence assertion is true but reason is false.



12. C) Assertion is true but Reason is false.

Layman Series: Its energy is in the ultraviolet region. Balmer series: Its energy in visible region. Now frequency of energy of ultraviolet photon is much greater than frequency of visible region.

$$\Delta E = \frac{hc}{\lambda}$$

13. c) Assertion is true reason is false. As can be seen from the expression of f, it depends upon the refractive index of the medium in which the lens is submerged.

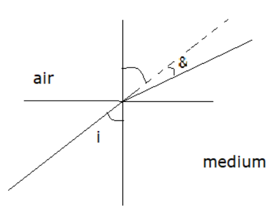
14. A) Both A and R are true and R is the correct explanation of A.

In case of the electric field of an electric dipole, the electric lines of force originate from positive charge and end at negative charge. Since isolated magnetic lines are closed continuous loops extending throughout the body of the magnet.

Section B

15.

1. **(c)**Maximum angle of refraction from denser medium to rarer medium is the critical angle Hence,
   $1.5 \sin C = 1 \times \sin 90^0$
   $\sin C = 2/3$
   $C = \sin^{-1} 2/3$
2. **(d)**Dispersion produced by thin prism. This phenomenon arise due to the fact that refractive index varies with wavelength. It has been observed for a prism that μ decreases with increase in the wavelength $\mu_{blue} > \mu_{red}$
3. **(d)** Both a and b. The necessary condition for the Phenomenon of Total Internal Reflection: Light must incident on the interface from denser medium. Angle of incidence must be greater than critical angle.
4. **(a)** $i = i_c$ The rays become parallel to the surface when angle of incidence is equal to the critical angle for that given pair of media.
5. **(a)** $i = i_c$ .The figure shows the deviation of light travelling from denser medium to rarer medium. As the angle of incidence increases the deviation δ would increase and it reaches it maxia at $i = i_c$.



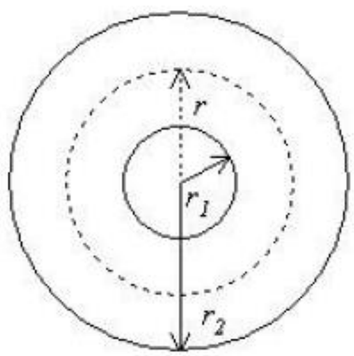
16.

1. **(d)**_In n-type semiconductor $n_p < n_e$ whereas in p-type semiconductor $n_p > n_e$. Hence for extrinsic semiconductor $n_p \neq n_e$
2. **(a)** Increases
3. **(d)** All of these
4. **(d)** Both a and c
5. **(a)** The hole concentration decreases

Section C

17. Resistance = $\rho \dfrac{\ell}{A}$

$$dR = \frac{\rho\, dr}{4\pi r^2}$$



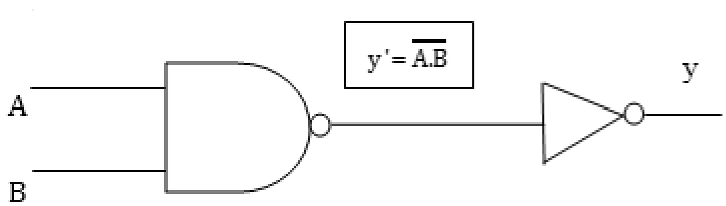
$\therefore$ Total resistance $= \displaystyle\int_{r_1}^{r_2} \frac{\rho\, dr}{4\pi r^2} = \frac{\rho}{4\pi}\left[-\frac{1}{r}\right]_{r_1}^{r_2}$

$$R = \frac{\rho}{4\pi}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

18. If the output y' of a two-input NAND gate is used as input of the NOT gate:
Here, the Boolean expression for output y is

$$y = \overline{A.B}$$

$$y = \overline{\overline{A.B}} = A.B$$



A	B	y’	y
0	0	1	0
1	0	1	0
0	1	1	0
1	1	0	1

19.

(i) Actual depth t =12.5 cm

Apparent depth a = 9.4 cm

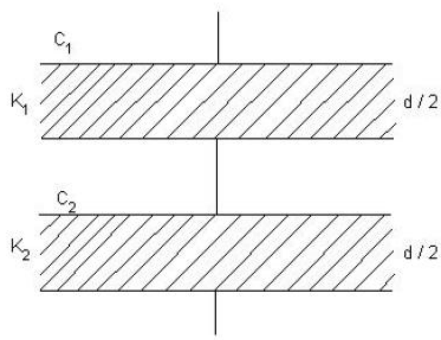
$$ {}_{a}\mu_{w} = \frac{t}{a} = \frac{12.5}{9.4} = 1.33 $$

(ii) ${}_{a}\mu_{l} = 1.63$

$$ a^{l} = \frac{t}{{}_{a}\mu_{l}} = \frac{12.5}{1.63} = 7.7\,cm $$

Therefore, the microscope has to be moved by $(9.4 - 7.7)\,cm$, i.e. 1.7 cm

20. The capacitor can be considered split into two capacitors in series as shown below



Here, $c_1 = \dfrac{2K_1\varepsilon_o A}{d}$ and $c_2 = \dfrac{2k_2\varepsilon_0 A}{d}$

The capacitance of capacitors in series is

$$ \frac{1}{c} = \frac{1}{c_1} + \frac{1}{c_2} $$

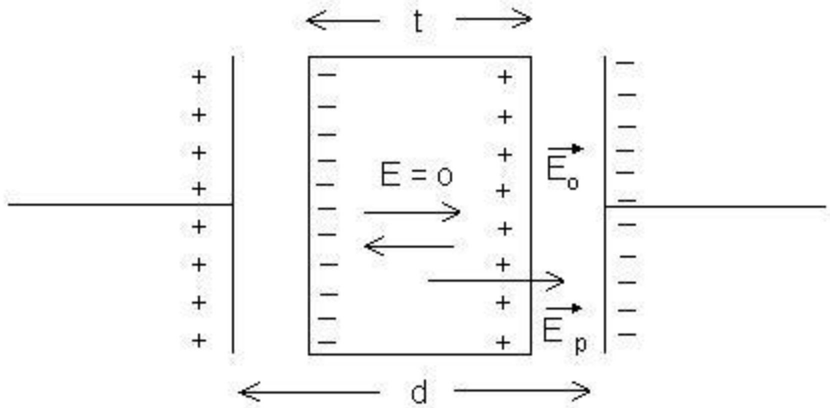
$$ \Rightarrow \qquad c = \frac{c_1 c_2}{c_1 + c_2} $$

$$ c = \frac{2\varepsilon_o A}{d}\left(\frac{k_1 k_2}{k_1 + k_2}\right) $$

OR

Let σ be the surface charge density of capacitor plates of area A. The electric field between the plates in the air space is

$$ E_o = \frac{\sigma}{\varepsilon_o} $$



As in the case of a conducting slab $E_p = E_o$,the net electric field inside the conducting slab is zero.

Now potential difference between the plates of capacitor is

$$V = E_o(d - t) = \frac{\sigma}{\varepsilon_o}(d - t)$$

$$Q = \sigma A$$

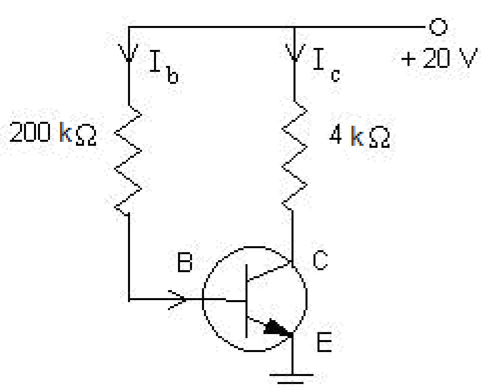
$$C = \frac{Q}{V} = \frac{\varepsilon_o A}{d - t} = \frac{C_o}{1 - t/d}$$

where $C_o = \frac{E_o A}{d}$

21. Since $\beta = 100$

$I_c = 2 \times 10^{-3}$ A

$V_{CE} = ?; V_{BE} = ?; V_{BC} = ?$



$$V_{CE} = V'_{BE} - I_C \times 4 \times 10^3$$

$$= 20 - 2 \times 10^{-3} \times 4 \times 10^{+3} = 20 - 8$$

$$V_{CE} = 12 \text{ volt}$$

$$\beta = \frac{I_c}{I_b}$$

$$I_b = \frac{I_c}{\beta} = 2 \times 10^{-5}\ A$$

$$V_{BE} = V_{EE} - I_b \times 2 \times 10^{-5}\ A$$

$$V_{BE} = 20 - 4 = 16\ volt$$

and

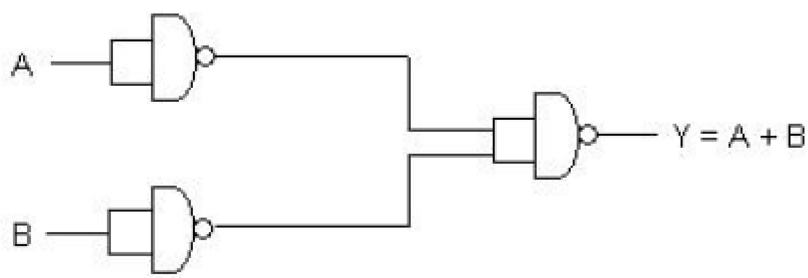
$$V_{BC} = V_{BE} - V_{CE}$$

$$= 16 - 12$$

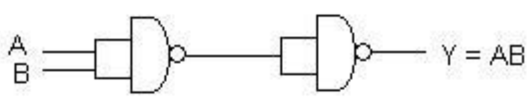
$$V_{BC} = 4\ volt$$

OR

(i) Realisation of the OR gate using the NAND gate



(ii) Realisation of the AND gate using the NAND gate



22.

$$\text{Since } \lambda = \frac{h}{p}$$

(i) Momentum, $p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{10^{-9}}$

$$p = 6.63 \times 10^{-25}\ kg\ m/s$$

The momentum of electron and photon will be the same.

(ii) Kinetic energy of the electron $= \frac{h^2}{2\lambda^2 me}$

$$= \frac{\left(6.63 \times 10^{-34}\right)^2}{2 \times \left(10^{-9}\right)^2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19}}$$

$$= 1.51\ eV$$

23. **Effect on electric field:**

(i) $E = \frac{V}{L}$

When V is halved,

$$E' = \frac{V}{2L} = \frac{E}{2}$$

Electric field gets halved.

(ii) When L is doubled,

$$E' = \frac{V}{2L} = \frac{E}{2}$$

Electric field gets halved.

Effect on resistance:

When potential is halved, the current also reduces in the same proportion. Thus, resistance does not change.

i.e. $\frac{V}{I} = R = \text{constant}$

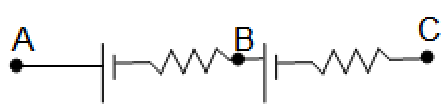
(i) $R = \frac{\rho l}{A}$

(ii) As length is doubled, resistance also doubles.

OR

Consider first two cells in series, where one terminal of the two cells is joined leaving the other terminal in either cell free.

Let *V* (A), *V* (B), *V* (C) be the potentials at points A, B and C as shown below.



Then *V* (A) – *V* (B) is the potential difference between the positive and negative terminals of the first cell.

We know that

$V(A) - V(B) = E_1 - Ir_1$, where E_1 is the emf of the 1st cell.

Similarly,

$V(B) - V(C) = E_2 - Ir_2$, where E_2 is the emf of the 2nd cell.

Hence, the potential difference between the terminals A and C of the combination is

$$V_{AC} = [V(A) - V(B)] + [V(B) - V(C)]$$

$$= E_1 + E_2 - I(r_1 + r_2)$$

If we wish to replace the combination by a single cell between A and C of emfE_{eq} and internal resistance r_{eq}, then we would have

$V_{AC} = E_{eq} - I\, r_{eq}$

Comparing the last two equations, we get
$E_{eq} = E_1 + E_2$
and $r_{eq} = r_1 + r_2$

The rule for a series combination can be clearly extended to n number of cells:
(i) Equivalentemf of a series combination of n cells is just the sum of their individual emfs, and
(ii) Equivalent internal resistance of a series combination of n cells is just the sum of their internal resistances.

24. As the magnet falls with greater and greater velocity, stronger and stronger current is induced in the copper tube which opposes the motion of the magnet.
When the opposing force due to the induced current equals the weight of the magnet, it acquires a constant terminal velocity.
No, because flux Φ which is equal to NBA is constant.

25. **Pulse–amplitude modulation (PAM)**
Here, the carrier wave is in the form of pulses and the information signal is a continuous wave.
(i) Amplitude of the pulse varies in accordance with the modulating signal. It could be single polarity or double polarity PAM.
(ii) **Pulse–code modulation (PCM)**

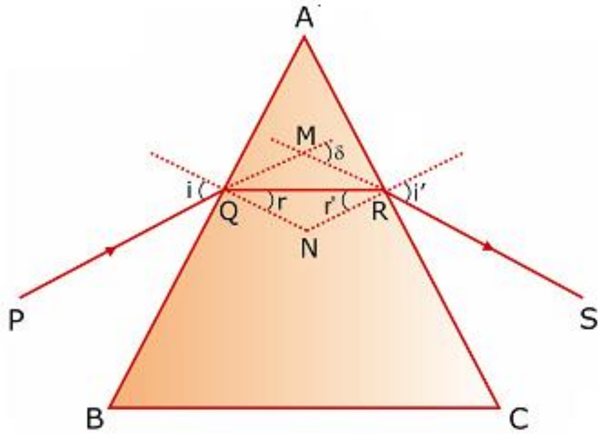
It is the modulation technique employed in digital communication. In PCM, the carrier wave is a continuous wave and the information signal is in the form of a coded pulse.

Common modulating techniques are
i) Amplitude shift keying (ASK)
ii) Frequency shift keying (FSK)
iii) Phase shift keying (PSK)

Since PCM is more error and noise free than PAM for communication, it is preferred.

Section D

26. Consider light passing through a prism ABC as shown.



The angle between the emergent ray RS and the incident ray direction PQ is called the angle of deviation δ .

In the quadrilateral AQNR,

$\angle A + \angle QNR = \angle 180^0$

From the triangle QNR,

$r + r' + \angle QNR = 180^0$

Comparing, we get

$r + r' = A$

The total deviation is the sum of deviations at the two faces:

$\delta = (i - r) + (i' - r')$

$\Rightarrow \delta = i + i' - A$

At the minimum deviation $\delta = D_m$, $i = i'$ which implies that r = r'.

We get from $r + r' = A$

$2r = A$

$\Rightarrow r = \frac{A}{2}$

Similarly, the equation $\delta = i + i' - A$ gives

$D_m = 2i - A$

$\Rightarrow i = \frac{A + D_m}{2}$

The refractive index of the prism with respect to the medium outside is

$$n_{21} = \frac{n_2}{n_1} = \frac{\sin\left[(A + D_m)/2\right]}{\sin\left[A/2\right]}$$

This is the prism formula.

27. It is referring to the rms value. V_{rms}= 220 V.

So, the peak value for voltage is $V_0 = \sqrt{2}V_{rms} = 311\ V$.

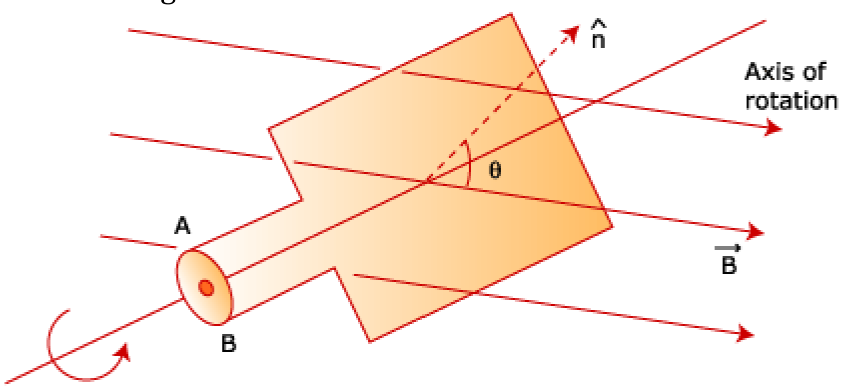
The instantaneous power is always $P(t)=V(t)I(t)$, and in this case, it is

$$P(t)=\frac{V_0^{\ 2}}{X_c}\cos(\omega t+\phi)\cos(\omega t+\phi+\pi/2)$$

Thus, the average power is

$$\overline{P_c} = \frac{V_0^{\ 2}}{2X_c}\cos\left(\frac{\pi}{2}\right) = 0$$

28. A wire loop of area A is free to rotate about an axis which is perpendicular to a uniform magnetic field B.



If the normal to the loop n makes an angle θ with B , then flux through the loop is $\Phi = BA\cos\theta$.

If this loop rotates with a constant angular velocity $\omega = \frac{d\theta}{dt}$, the flux through it changes at the rate

$$\frac{d\Phi}{dt} = -BA\sin\theta\frac{d\theta}{dt} = -BA\omega\sin(\omega t + C_0)$$

where C_0 is a constant

$\therefore$ emf is induced between ends A and B given by

$$\varepsilon = BA\omega\sin(\omega t + Co)$$

$$\varepsilon = V_m\sin(\omega t + Co)$$

$V_m = BA\omega$ = Peak value of emf generated.

OR

Here, the current gain is 75, i.e. >1.

Besides, there is a phase difference of π between the signal at the input and the output.

Both these factors indicate that the amplifier is connected in the common emitter mode.

29. For a α particle, Z_1=2 and Z_2=79 for gold.

Also given that kinetic energy of α particle is K = 12.5 MeV =$12.5\times1.6\times10^{-13}$ J.

The distance of the closest approach is given by

$$r_0 = \frac{1}{4\Pi \in_0}\frac{Z_1 Z_2 e^2}{K}$$

$$r_0 = \frac{9\times10^9 \times 2\times 79\times\left(1.6\times10^{-19}\right)^2}{12.5\times1.6\times10^{-13}}$$

$$= 1.8\times10^{-14}\ \text{m}$$

OR

Energy of a photon of wavelength λ is $E = \frac{hc}{\lambda}$

For $\lambda = 620\text{nm}$

$$E = \frac{6.62\times10^{-34}\times3\times10^8}{620\times10^{-9}\times1.6\times10^{-19}} = 2.0\text{eV}$$

Thus, transition D for which E is 2.0 eV will take place.

30. 1 amu = 931.5 MeV

$$\Delta m = 2(2.015) - (3.017 + 1.009) = 0.004\ \text{amu}$$

Hence, energy released per deuteron = (0.004 x 931.5)/2 = 1.863 MeV

The number of deuterons in 1kg =$N_A/2$ =$6.023\times10^{26}/2$

Energy released = $(3.01\times10^{26})(1.863\times10^6)(1.6\times10^{-19})$ J = 9.0×10^{13} J

Section E

31. (a) We know that $I = V_d\, n e A$

$$V_d = \frac{I}{enA} \qquad (1)$$

Given that $I = 1.5\ A$, $A = 1.0\times10^{-7}\ m^2$

$e = 1.6\times10^{-19} C$

Density of copper $= 9.0\times10^3 kg/m^3$

Atomic mass of copper = 63.59u

Therefore, the number of atoms or number of free electrons per unit volume of copper is

$$(n) = \frac{6.0\times10^{23}}{63.59}\times9.0\times10^6$$

$$n = 8.5\times10^{28}\ m^{-3}$$

Thus, from equation (1), we get

drift velocity $V_d = \dfrac{1.5}{8.5\times10^{28}\times1.6\times10^{-19}\times1.0\times10^{-7}}$

$V_d = 1.1\times10^{-3}\ m\ /\ s = 1.1 m\ s^{-1}$

(b)

(i) Thermal speed of copper atoms at temperature T is obtained from the formula

$\dfrac{1}{2}MV^2 = \dfrac{3}{2}K_BT \Rightarrow V = \sqrt{\dfrac{3K_BT}{M}}$

at $T = 300k$,

$V = 2\times10^2\ m/s$

Thus, drift speed of electrons is much smaller; about 10^{-5} times the typical thermal speed at ordinary temperatures.

(ii) Electric field travels along a conductor with a speed of electromagnetic wave $(3.0\times10^8\ m/s)$. Drift speed in comparison is 10^{-11} times the speed of electric field.

OR

We take a closed loop ADCA and apply Kirchhoff's second rule

$-4(I,-I_2)+2(I_2+I_3-I_1)-I_1+10=0$

$7I_1-6I_2-2I_3=10$ (1)

For the closed loop ABCA, we get

$-4I_2-2(I_2+I_3)-I_1+10=0$

$I_1-6I_2-2I_3=10$ (2)

For the closed loop BCDEB, we get

$-2(I_2,+I_3)-2(I_2+I_3-I_1)+5=0$

$2I_1-4I_2-4I_3=-5$ (3)

On solving equations (1), (2) and (3), we get

$I_1 = 2.5A$

$I_2 = 0.63A$

$I_3 = 1.88A$

Thus, the currents in various branches of the network are

$AB = I_2 = 0.63A$

$AD = I_1 - I_2 = 1.87A$

$CA = I_1 = 2.5A$

$CD = I_2 + I_3 - I_1 = 0.01A$

$DEB = I_3 = 1.88\ A$

$BC = I_2 + I_3 = 2.51A$

32.

(a) Radius of the circular path in a magnetic field

$$r = \frac{mv}{qB}$$

Since $m_p > m_e$

Therefore, the radius of the proton's circle will be larger.

$$\frac{r_p}{r_e} = \frac{m_p}{m_e} = \frac{1.67 x 10^{-37}}{9.1 x 10^{-31}} = 1835$$

(b) Lorentz force on moving a charged particle in the magnetic field is always perpendicular to the velocity of the particle.

The work done by the magnetic force

$$dW = \vec{F}.d\vec{\ell}$$

$$dW = Fd\ell\cos\theta$$

$$\text{but } \theta = 90^{o}$$

$$dW = 0$$

Thus, on moving the charged particle in a uniform magnetic field, no work is performed. Hence, the kinetic energy of the charged particle will remain constant.

(c)

(i) the field is reduced to half

(ii) the field will be halved

(iii) the field will be perpendicular to the plane of the page, pointing downwards

OR

Bio–Savart's Law: The magnetic field induction at a point P due to a current element is

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

Magnetic field at the centre of a circular coil carrying current:

According to Biot–Savart's law, magnetic field at the centre of the coil carrying I due to current element Idl is

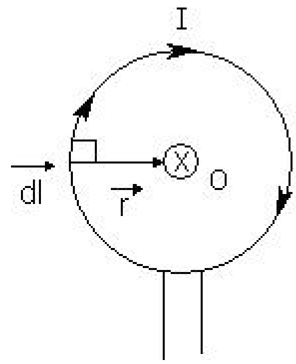
$$dB = \frac{\mu_o}{4\pi}\frac{Idl}{r^2} \qquad (\because \theta = 90^{o})$$

Magnetic field due to the whole loop is

$$B = \int dB = \frac{\mu_o}{4\pi}\frac{I}{r^2}\int dl$$

$$B = \frac{\mu_o}{4\pi}\frac{I}{r^2} \times 2\pi r$$

$$B = \frac{\mu_o I}{2r}$$



When there are N turns, we have

$$B = \frac{\mu_o N I}{2r}$$

Magnetic field at the centre of the semicircular arc of radius ‘r’ carrying current I is

$$B = \frac{\mu_o I}{4r}$$

Given $r = 20cm = 0.2m$

$I = 10A$

$\mu_o = 4\pi \times 10^{-7}\ Tm\ A^{-1}$

$$B = \frac{4\pi \times 10^{-7} \times 10}{4 \times 0.2}$$

$B = 1.57 \times 10^{-5}$ tesla.

It is perpendicular to the plane of the paper directed inwards.

33. Total Internal Reflection:

Total internal reflection is the phenomenon of the reflection of light rays back to the denser medium when they are incident on the boundary of a denser and rarer medium at an angle of incidence greater than the critical angle.

Conditions for total internal reflection:

(a) Light rays should go from the denser medium to the rarer medium.

(b) The angle of incidence should be greater than the critical angle i_c where $\sin i_c = \frac{1}{\mu}$

Then the rays are totally internally reflected.

for angle $i = i_c$

$r = 90^0$

$${}_2\mu_1 = \frac{\sin i}{\sin r} = \frac{\sin i_c}{\sin 90^0}$$

$$\Rightarrow \quad {}_1\mu_2 = \frac{1}{\sin i_c}$$

(i) To deviate ray through 180°. fig (a)

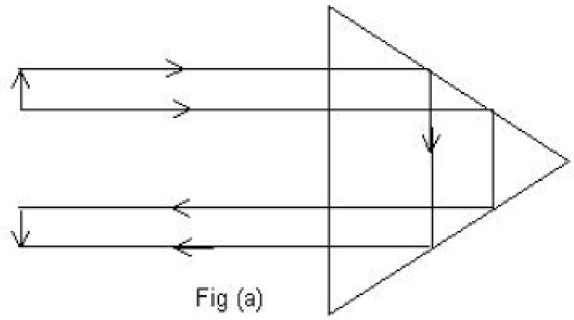


Fig (a)

(ii) To invert object fig (b),

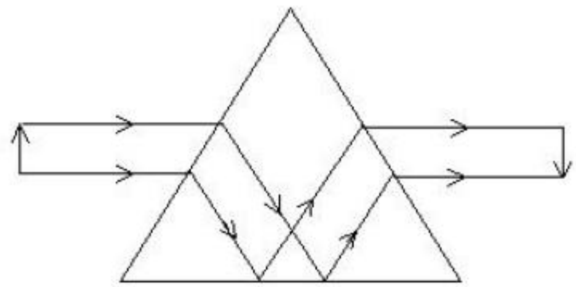


Fig (b)

OR

Let μ_1 be the refracting index of the rarer medium and μ_2 be the refracting index of the spherical convex refracting surface XY of the small aperture.

From A, draw AM such that $AM \perp OI$

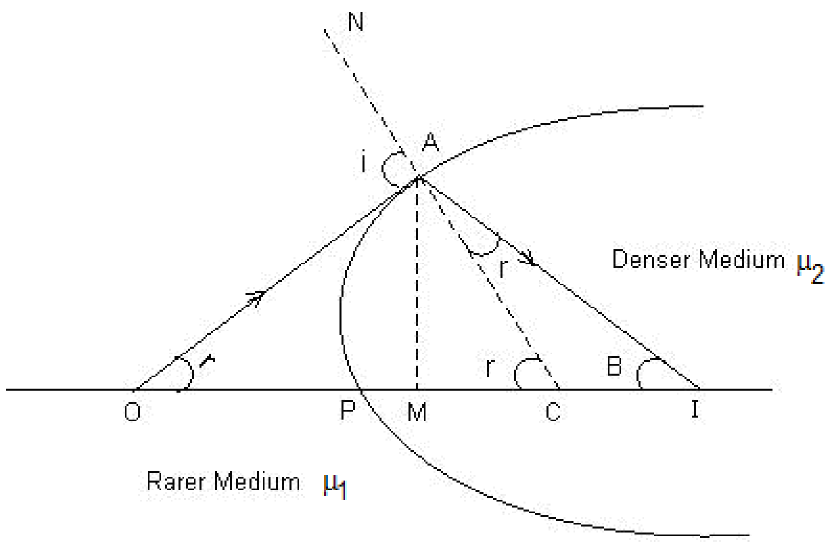
In ΔIAC

$$r + B = \gamma \ (\text{Exterior angle property})$$

$r = \gamma - \beta$

Similarly, in Δ OAC

$i = \alpha + \gamma$



According to Snell's law

$$\frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r} » \frac{i}{r} \Rightarrow \mu_2 r = \mu_1 i$$

So, $\mu_1 (\alpha + \gamma) = \mu_2 (\gamma - \beta)$ (i)

Let $\alpha \approx \tan \alpha = \frac{AM}{OM} = \frac{AM}{PO}$

$$\beta = \tan \beta = \frac{AM}{MI} = \frac{AM}{PC}$$

As the spherical surface has a small aperture, we have

$$y = \tan \beta = \frac{AM}{MC} = \frac{AM}{PC}$$

Substituting the value in eq. (i), we have

$$\frac{\mu_1}{PO} + \frac{\mu_2}{PI} = \frac{\mu_2 - \mu_1}{PC}$$

By sign convention, put $PO = -u,\ PI = +v,\ PC = +R$

We get

$$\frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}$$

which is the required relation.