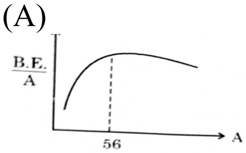
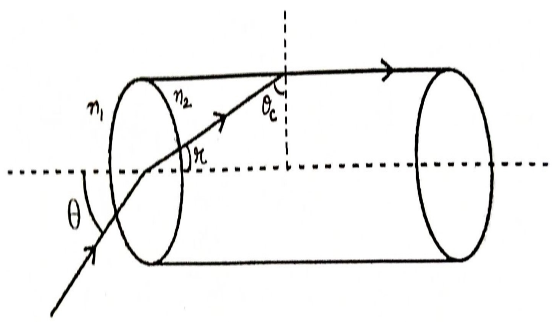
SOLUTIONS PHYSICS(042)

Code: 55/1/1

Q.No	VALUE POINTS/EXPECTED ANSWERS	Marks	Total Marks
	SECTION A		
1	(A) $q_2 < q_3 < q_1$	1	1
2	(C) $\frac{R}{8}$	1	1
3	(B) $\left(-3\hat{j}+2\hat{k}\right)\mu N$	1	1
4	(B) 0.30 C	1	1
5	(B) 2866	1	1
6	(D) $\frac{i_0 v_0}{2}\cos\phi$	1	1
7	(A) X- rays , Micro waves , UV radiation	1	1
8	(B) $\frac{3H}{4}$	1	1
9	(C) $\frac{h}{m}$	1	1
10	(B) $\lambda_e > \lambda_p > \lambda_d$	1	1
11	(A)  	1	1
12	(C) The barrier height and the depletion layer width both decrease.	1	1
13	(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion(A).	1	1
14	(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion(A).	1	1
15	(C) Assertion (A) is true but Reason (R) is false.	1	1
16	(D) Assertion (A) is false and Reason (R) is also false.	1	1
	SECTION - B		
17	Calculating the value of E 1 Calculating the value of r 1 $E = V + Ir$ In first case E = 5 + 2r In second case E = 4 + 4r After solving	 ½ ½	

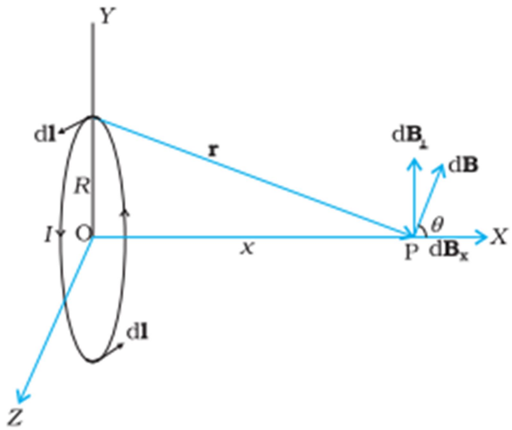
	E= 6 V r = 0.5 Ω	½ ½	2
18	(a) **Calculating the width of the slit 2** Condition for Minima $a \sin\theta = n\lambda$ For First Minima n=1 $a \sin 30^\circ = 600 \times 10^{-9}$ m $a \times \frac{1}{2} = 600 \times 10^{-9}$ m $a = 1200 \times 10^{-9}$ m $= 1.2 \times 10^{-6}$ m OR (b) **Finding the Intensity 2** Phase difference = $\frac{2\pi}{\lambda} \times$ path difference $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$ $\because \Delta x = \frac{\lambda}{8}\ (given)$ $\Delta\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{8}$ $\Delta\phi = \frac{\pi}{4}$ $I = I_\circ + I_\circ + 2\sqrt{I_\circ I_\circ}\cos\frac{\pi}{4}$ $= 2I_\circ + 2I_\circ \times \frac{1}{\sqrt{2}}$ $I = 2I_\circ\left(1 + \frac{1}{\sqrt{2}}\right)$ $= I_\circ(2 + \sqrt{2})$ $I = 3.414\, I_\circ$ **Alternatively** Phase difference = $\frac{2\pi}{\lambda} \times$ path difference	 1 ½ ½ ½ ½ ½ ½ ½	

	$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$ $\because \Delta x = \frac{\lambda}{8}\ (given)$ $\Delta\phi = \frac{2\pi}{\lambda}\times\frac{\lambda}{8}$ $\Delta\phi = \frac{\pi}{4}$ $I = 4I_{\circ}\cos^2\left(\frac{\phi}{2}\right)$ $I = 4I_{\circ}\cos^2\left(\frac{\pi}{8}\right)$	½ ½ ½	2
19	Calculating angle θ 2  For critical Angle $\frac{n_2}{n_1} = \frac{1}{\sin\theta_c}$ $n_1=1$ $n_2=\frac{2}{\sqrt{3}}$ (given) $\frac{2}{\sqrt{3}} = \frac{1}{\sin\theta_c}$ $\sin\theta_c = \frac{\sqrt{3}}{2}$ $\theta_c = 60^\circ$ $r = 90 - \theta_c$ $= 30^\circ$ From Snell's law at air rod interface $n_1 \sin i = n_2 \sin r$	½ ½ ½	

	$n_2 = \frac{\sin\theta}{\sin r}$ $\frac{2}{\sqrt{3}} = \frac{\sin\theta}{\sin 30^0}$ $\frac{2}{\sqrt{3}} \times \frac{1}{2} = \sin\theta$ $\frac{1}{\sqrt{3}} = \sin\theta$ $\theta = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$	½	2
20	Proving Time period of Revolution ,T α n^3 2 $T = \frac{2\pi r}{v}$ ---------- (1) From Bohr's quantization condition $mvr = \frac{nh}{2\pi}$ $v = \frac{nh}{2\pi mr}$ ---------- (2) From (1) and (2) $T = \frac{2\pi r}{\left(nh/2\pi mr\right)}$ $T = \frac{2\pi r(2\pi mr)}{nh}$ $T = \frac{4\pi^2 mr^2}{nh}$ From $r = \frac{n^2h^2}{4\pi^2 mke^2}$ $T = \frac{4\pi^2 m}{nh}\left(\frac{n^2h^2}{4\pi^2 mke^2}\right)^2$ $T = \frac{n^3h^3}{4\pi^2 mk^2e^4}$ $\Rightarrow T \,\alpha\, n^3$ **Alternatively ---**	½ ½ ½ ½	

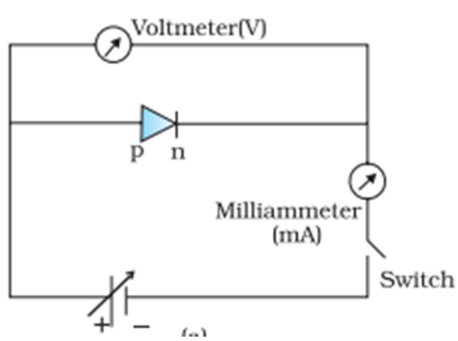
	$T=\frac{2\pi r}{v}$ $\because r \,\alpha\, n^2$ and $v \alpha \frac{1}{n}$ $\therefore T \,\alpha\, n^3$	½ ½ ½ ½	2
21	Finding the number of holes 1 One example 1 1 dopant atom for 5×10^7 Si atoms and number density of Si atoms = $5\times10^{28}\ \frac{\text{atoms}}{\text{m}^3}$ (*given*) No. of holes created per m^3 = $\frac{5\times10^{28}}{5\times10^{7}} = 10^{21}$ Number of holes created per cubic centimeter $= \frac{10^{21}}{10^{6}} = 10^{15}$ Any one example of dopant - Aluminium / Indium / Gallium	1 1	2
	SECTION - C		
22	(a) Finding (i) Equivalent emf of combination 1 (ii) Equivalent internal resistance of combination 1 (iii) Current drawn from combination 1 (i) Because $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ $E_{eq} = \frac{3\times0.4 + 6\times0.2}{0.6} = 4\text{ V}$ (ii) $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$ $r_{eq} = \frac{0.2\times0.4}{0.2+0.4} = 0.133\Omega$ (iii) $I = \frac{E}{R + r_{eq}}$ $I = \frac{4}{4+0.13} = \frac{4}{4.13}A$ $I = 0.9A$	½ ½ ½ ½ ½ ½	

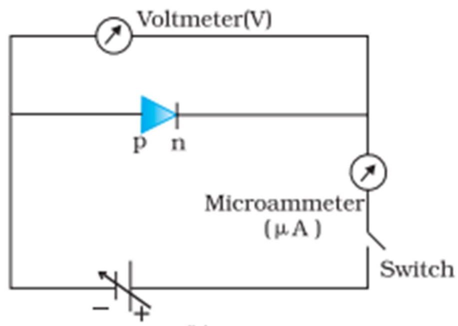
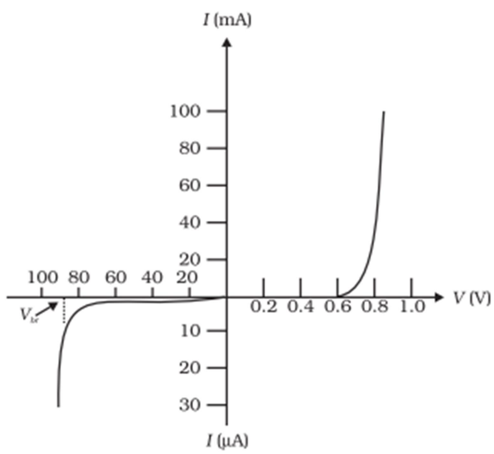
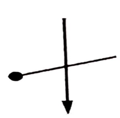
	OR		
	(b) (i) Finding the relation (i) between R' and R 1 (ii) between v_d' and v_d 1 (ii) To identify whether all free electrons are moving in the same direction. 1		
	(i) $l' = 2l$		
	$Al = A'l'$ = volume of the wire		
	$Al = A'(2l)$		
	$\frac{A}{2} = A'$		
	$R = \frac{\rho l}{A}$	½	
	$R' = \frac{\rho l'}{A'}$		
	$R' = \frac{\rho(2l)}{A/2}$		
	$\frac{R'}{R} = 4$	½	
	Alternatively		
	$R' = n^2 R$	½	
	n= 2		
	$R' = 4R$	½	
	(ii) $v_d = \frac{eE}{m}\tau$	½	
	$v_d = \frac{eV}{ml}\tau$		
	$v_d' = \frac{eV}{ml'}\tau$		
	$\frac{v_d'}{v_d} = \frac{l}{l'} = \frac{1}{2}$	½	
	(ii) No	1	3
23	Derivation for Magnetic field on the axis 2 ½ Magnetic field at the centre ½		

	 	½	
	From Biot Savart' s Law $\left\|d\vec{B}\right\| = \frac{\mu_\circ}{4\pi}\frac{I\left\|d\vec{l}\times\vec{r}\right\|}{r^3}$ Now $r^2 = x^2 + R^2$ Because $\left\|d\vec{l}\times\vec{r}\right\| = rdl$	½	
	$\therefore dB = \frac{\mu_\circ}{4\pi}\frac{idl}{(x^2+R^2)}$ $d\vec{B}$ has two components. All the components perpendicular to x- axis are summed over and we obtain a null result. Only x- components contribute. The net contribution along x- direction	½	
	$dB_x = dB\cos\theta$ $\cos\theta = \frac{R}{\left(R^2+x^2\right)^{\frac{1}{2}}}$ Thus : $dB_x = \frac{\mu_\circ i}{4\pi}dl\frac{R}{\left(R^2+x^2\right)^{\frac{3}{2}}}$ Summing dB_x over the entire loop $\oint dl = 2\pi R$	½	
	$\vec{B} = B_x\hat{i} = \frac{\mu_\circ iR^2}{2(x^2+R^2)^{\frac{3}{2}}}\hat{i}$ Magnetic field at the centre of the loop- Here x= 0	½	
	$\therefore \vec{B} = \frac{\mu_\circ i}{2R}\hat{i}$	½	3

24	a) Deriving the expression for energy stored in an inductor. 1 ½ b) Deriving the energy density of magnetic field. 1 ½ a) Induced emf in an inductor $\lvert\varepsilon\rvert = L\dfrac{dI}{dt}$ Rate of work done at any instant $\dfrac{dW}{dt} = \lvert\varepsilon\rvert I$ Total Amount of work done in establishing current I $W = \int dW = \int_0^I LIdI$ Energy required to build up current I is $W = \frac{1}{2} L I^2$ b) The Magnetic Energy is $W = U_B = \frac{1}{2} LI^2$ $= \frac{1}{2} L \left(\dfrac{B}{n\mu_0}\right)^2$ as $B = n\mu_0 I$ Using $L = \mu_0 n^2 Al$ $U_B = \dfrac{1}{2}\left(\mu_0 n^2 Al\right)\left(\dfrac{B^2}{\mu_0^2 n^2}\right)$ Energy density $= \dfrac{U_B}{\text{volume}}$ $\dfrac{U_B}{\text{volume}} = \dfrac{1}{2} \times \mu_0 n^2 Al \times \dfrac{B^2}{\mu_0^2 n^2} \times \dfrac{1}{Al}$ $= \dfrac{1}{2}\dfrac{B^2}{\mu_0}$	 ½ ½ ½ ½ ½ ½	3
25	a) Showing that ($I_c + I_d$) has the same value. 2 b) Explanation of Kirchhoff's first rule at each plate of capacitor. 1 a) ∵ Total current $I = I_c + I_d$ outside the capacitor $I_d = 0$ $\therefore I = I_c$ Inside the capacitor $I_c = 0$	 ½ ½	

	$\therefore\ I = I_d = \varepsilon_0 \frac{d\phi_E}{dt}$ $= \varepsilon_0 \frac{d}{dt}[EA]$ $= \varepsilon_0 \frac{d}{dt}\left[\frac{\sigma}{\varepsilon_0} A\right]$ $= \frac{\varepsilon_0}{\varepsilon_0} A \frac{d}{dt}\left[\frac{Q}{A}\right]$ $I = \frac{dQ}{dt} = I_c$ **Alternatively** $\because$ Total current $I = I_c + I_d$ outside the capacitor $I_d = 0$ $\therefore I = I_c$ Inside the capacitor $I_c = 0$ $I = I_d = \varepsilon_0 \frac{d\phi_E}{dt}$ $= \varepsilon_0 \frac{d}{dt}\left[\frac{Q}{\varepsilon_0}\right]$ $I = \frac{dQ}{dt} = I_c$ hence $I_c + I_d$ has the same value at all points of the circuit. b) Yes Current entering the capacitor is (I_c) and between the plates capacitor is (I_d) $I_c = I_d$ which validates Kirchhoff's junction rule.	½ ½ ½ ½ ½ ½ 1	3
26	Reason for a) All photoelectrons not having same Kinetic Energy. 1 b) Having different saturation current for different intensity. 1 c) Stopping of emission of photoelectrons at a certain wavelength. 1 a) When monochromatic light is incident on a metal surface then more/less tightly bound electrons will emerge with less/more kinetic energy. So all the photoelectrons do not eject with same kinetic energy. b) Maximum number of photoelectrons ejected per second (saturation current) is directly proportional to the Intensity of incident radiation Hence saturation current is different for different intensities.	 1 1	

	c) when λ increases , ν decreases and energy of incident photon ($h\nu$) also decreases. When $\lambda > \lambda_0$, $\nu < \nu_0$ (threshold frequency) , no photoelectron is ejected. Emission of photoelectrons stop at $\lambda > \lambda_0$.	1	3
27	a) Defining Mass Defect ½ Defining Binding Energy ½ Describing Fission Process ½ b) Calculation of Mass Defect 1 Calculation of Energy ½ a) Difference in the mass of the nucleus and its constituents is defined as mass defect. Binding Energy is the energy required to separate the nucleons from the nucleus. In Fission process a heavy nucleus splits into lighter nuclei and energy is released. As a result the Binding Energy per nucleon increases. b) $\Delta m = (m_p + m_n) - m_d$ $\Delta m = (1.007277 + 1.008665) - 2.013553$ $\Delta m = 0.002389$ u Energy released = $\Delta m \times c^2$ Energy released = 0.002389×931.5 $= 2.2253$ MeV ≈ 2.22 MeV	½ ½ ½ ½ ½ ½	3
28	a) Circuit Arrangement for studying V–I characteristics. 1 b) Showing the shape of characteristic curves. 1 c) Two informations from the characteristics ½ + ½ a)  Circuit diagram for forward characteristics	½	

	 Circuit diagram for Reverse characteristics	½	
	b) 	1	
	Note : Please do not deduct marks for not writing values.	½ + ½	
	c) Any two informations Knee voltage / reverse saturation current / Breakdown voltage / very low resistance in forward biasing / very high resistance in Reverse biasing.		3
	SECTION - D		
29	i) (B) 5mC	1	
	ii) (A) zero	1	
	iii) (D) [$M^0L^0TA^0$]	1	
	iv) (A) $\frac{1}{2\sqrt{e}} mA$ **Note: 1 mark for this part may be given to all the students who have attempted other parts of the question.** OR (B) 0.5 mA	1	4
30	i) (C) 	1	
	ii) (A) For a convex mirror magnification is always negative	1	
	iii) (B) 2f	1	

	OR (B) 12 cm iv) (C) $\sqrt{X_1 X_2}$	1	4
	SECTION - E		
31	a) i) Calculating the change in electrostatic energy of the system 2 ii) (1) Finding the capacitance. 1 (2) Finding the potential difference. 1 (3) Answering and Reason ½ + ½ (i) $\vec{E} = \frac{3\times10^5}{r^2}\hat{r}$ (Given) $dV = -\vec{E}.d\vec{r}$ V = 3 × 10⁵ / r Electrostatic energy of the system in the absence of the field $U_i = \frac{Kq_1q_2}{r_{12}}$ Electrostatic energy in the presence of the field $U_f = \frac{Kq_1q_2}{r_{12}} + q_1V(\vec{r}_1) + q_2V(\vec{r}_2)$ $\Delta U = U_f - U_i = q_1V(\vec{r}_1) + q_2V(\vec{r}_2)$ $\Delta U = \frac{5\times10^{-6}\times3\times10^5}{3\times10^{-2}} - \frac{1\times10^{-6}\times3\times10^5}{3\times10^{-2}}$ = 40 J ii) 1) $C = \frac{Q}{V} = \frac{80}{16} = 5\mu F$ 2) $C' = KC$ $= 3\times5\mu F = 15\ \mu F$ $V' = \frac{Q}{C'} = \frac{80\mu C}{15\mu F} = 5.33V$ 3) No, The capacitance of the system depends on its geometry. OR b) i) Comparing the magnitude of the Electric fields 2 ii) Calculating the work done on the charge 3 Total charge for A = Total charge for B = Total charge for C = +4q As , $E = \frac{kQ}{r^2}$	 ½ ½ ½ ½ 1 ½ ½ ½ ½ 1	

Since Q = 4q and r = 3R

$$E = \frac{k(4q)}{9R^2} = \frac{4kq}{9R^2}$$ ½

$\therefore$ $E_A = E_B = E_c$ ½

ii) $$V_c = \left[\frac{k \times 6 \times 10^{-6}}{5 \times 10^{-2}} - \frac{k \times 6 \times 10^{-6}}{5 \times 10^{-2}}\right]$$ 1

$$= 0$$

$$V_A = \left[\frac{k \times 6 \times 10^{-6}}{15 \times 10^{-2}} - \frac{k \times 6 \times 10^{-6}}{5 \times 10^{-2}}\right]$$ ½

$$= \frac{k \times 6 \times 10^{-6}}{10^{-2}}\left[\frac{1-3}{15}\right]$$

$$= -\frac{9 \times 10^{9} \times 6 \times 10^{-6} \times 2}{15 \times 10^{-2}}$$

$= -7.2 \times 10^5$ V ½

$W = q\left[V_A - V_c\right]$ ½

$= 5 \times 10^{-6}\left[-7.2 \times 10^5 - 0\right]$

W = - 3.6 J ½

5

32 a)

i) Finding the direction of magnetic field near points P,Q and R	½ + ½ + ½
Conclusion about the relative magnitude of magnetic field.	½ + ½ + ½
ii) Showing the given expression of magnetic moment.	2

i) <u>Near point P</u>

Magnetic field is acting into the plane of the paper as Force is acting upwards. ½

<u>Near point Q</u>

Magnetic field is into the plane of paper as force is acting upwards. ½

<u>Near point R</u>

Magnetic field is acting out of the plane of the paper as $\vec{F}$ is acting downwards. ½

<u>Relative Magnitude of the Magnetic field.</u>

As $B \ \alpha \ \frac{1}{r}$

Therefore,

Near point P, magnitude of B is small. ½

Near point Q, B is relatively smaller than point P. ½

Near point R, B is relatively larger than point P. ½

$(B_Q < B_P < B_R)$

ii) Let r be the radius of the circular coil and I is the current in the coil then

$B = \frac{\mu_0 I}{2r}$ or $I = \frac{2Br}{\mu_0}$ ½

$A = \pi r^2$ $r = \sqrt{\frac{A}{\pi}}$ ½

$M = IA$ ½

$= \frac{2Br}{\mu_0} A$

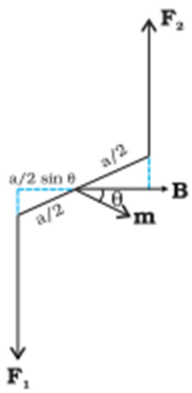
$= \frac{2BA}{\mu_0}\sqrt{\frac{A}{\pi}}$ ½

OR

b)

i) Deriving the expression for the torque.	3
ii) 1) Finding the change in radius.	1
2) Finding the change in time period of Revolution.	1

i)



½

$\vec{F_1}$ and $\vec{F_2}$ are the forces acting on two arms of the rectangular coil having sides a and b.

$\left|\vec{F_1}\right| = \left|\vec{F_2}\right| = I\,b\,B$ (b = length of the arm) 1

Forces constitute a couple. The magnitude of Torque on the loop is –

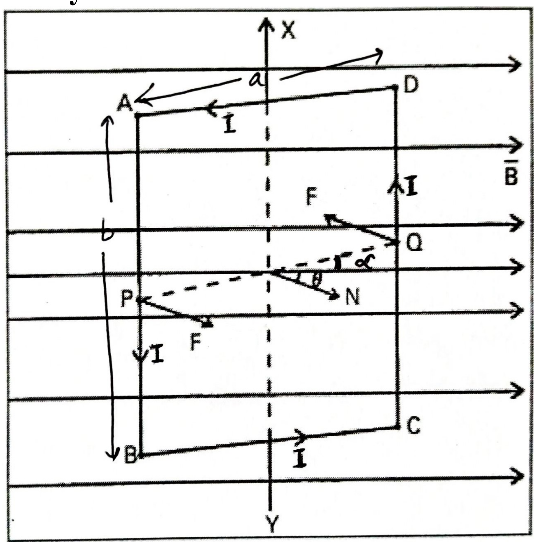
$\tau = F_1 \frac{a}{2}\sin\theta + F_2 \frac{a}{2}\sin\theta$

$= I\ a\ b B \sin\theta$ ½

$= IA B \sin\theta$ ½

$\vec{\tau} = I\vec{A} \times \vec{B}$ ½

Alternatively



½

If the plane of the current carrying coil marks an angle ∝ with the magnetic field

$\vec{F}_{DA} = -\vec{F}_{Bc}$ (cancel each other) . ½

Force on the arm DC is into the plane of the paper

$|F_{DC}| = IbB$. ½

Force on the arm AB is out of the plane of the paper.

$|F_{AB}| = IbB$ ½

Both of them form a couple and Torque acting on the coil is

τ=either force ×perpendicular distance between the two forces.

$\tau = IbB \times a\cos\alpha$

$= IabB\cos\alpha$

$\tau = IAB\cos\alpha$ ½

Let $\hat{n}$ =outward drawn normal to the plane of the coil.

$\theta + \alpha = 90^0$

$\alpha = 90^0 - \theta$

$\tau = IAB\cos(90-\theta)$

$= IAB\sin\theta$

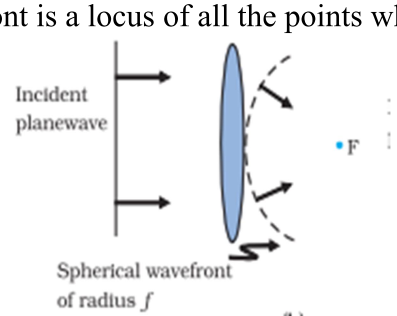
$\vec{\tau} = I\vec{A}\times\vec{B}$ ½

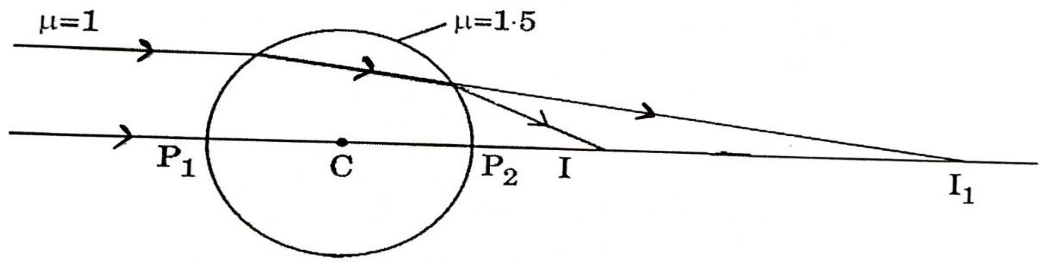
ii) 1) $r=\frac{mv}{qB}=\frac{\sqrt{2mK}}{qB}$ ½

$r \;\alpha\; \sqrt{K}$

$\frac{r'}{r}=\frac{\sqrt{K/2}}{\sqrt{K}}=\frac{1}{\sqrt{2}}$

$r'=\frac{r}{\sqrt{2}}$ ½

	2) $T=\frac{2\pi m}{qB}$ Time period does not depend on Kinetic Energy ∴ Time period will not change.	½ ½	5
33	a) i) 1) Definition of coherent sources. 1 Necessity of coherent sources for sustained interference pattern 1 2) Explanation 1 ii) 1) Finding distance between adjacent bright fringes. 1 2) Finding angular width 1 i) 1) If the phase difference between the displacement produced by each of the wave from two sources does not change with time then two sources are said to be coherent. **Alternatively** Two sources are said to be coherent if they emit light continuously of same frequency / wavelength and having zero or constant phase difference. Coherent sources are required to get constant phase difference. 2) Two independent sources will never be coherent because phase difference between them will not be constant. ii) 1) Distance between adjacent bright fringe = fringe width $\beta = \frac{\lambda D}{d}$ $= \frac{600\times 10^{-9}\times 1.2}{0.1\times 10^{-3}} = 7.2\,\text{mm}$ 2) $\theta = \frac{\lambda}{d}$ $= \frac{600\times 10^{-9}}{0.1\times 10^{-3}} = 6\times 10^{-3}$ rad= 0.34° Give full marks if the student writes the answer in radians only. OR b) i) Definition of wave front. 1 Drawing the incident and refracted wave front ½ + ½ ii) Drawing the ray diagram 1 Obtaining the position of final image 2 i) A wavefront is a locus of all the points which oscillate in phase. 	1 1 1 ½ ½ ½ ½ 1 ½ + ½	

	ii)		
		1	
	From Ist surface , Refraction is from rarer to denser medium and object is at ∞		
	$n_1 = 1$, $n_2 = 1.5$, R = 15 cm , u= ∞		
	$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$	½	
	$\frac{1.5}{v} - \frac{1}{\infty} = \frac{1.5-1}{15}$	½	
	v= 45 cm		
	From 2nd surface , Refraction is from denser to rarer medium and object is at 15 cm		
	$n_1 = 1$, $n_2 = 1.5$, R = -15 cm , u= 15cm		
	$\frac{n_1}{v} - \frac{n_2}{u} = \frac{n_1 - n_2}{R}$	½	
	$\frac{1}{v} - \frac{1.5}{15} = \frac{1-1.5}{-15}$		
	v= 7.5 cm	½	5