SAMPLE PAPER - 7

Class 12 - Physics

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

General Instructions:

1. There are 35 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

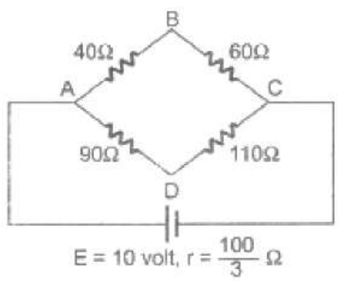
Section A

1. Barrier potential of a p-n junction diode does not depend upon: **[1]**

a) doping density b) temperature

c) diode design d) forward bias

2. In a Wheatstone bridge shown in the following figure the conventional current between the points B and D: **[1]**



a) is from D to B b) is zero

c) is from B to D d) is indeterminate

3. An achromatic combination of lenses produces: **[1]**

a) highly enlarged image b) images unaffected by variation of refractive index with wavelength

c) images in black and white d) coloured images

4. In an intrinsic semiconductor: **[1]**

a) only holes are responsible for flow of b) both holes and electrons carry current

current

c) both holes and electrons carry current with electrons being majority carriers

d) only electrons are responsible for flow of current

5. A $10 \mu\mathrm{F}$ capacitor is charged to a potential difference of 1000 V. The terminals of the charged capacitor are disconnected from the power supply and connected to the terminals of an uncharged $6 \mu\mathrm{F}$ capacitor. What is the final potential difference across each capacitor? **[1]**

a) 100 V

b) 167 V

c) 250 V

d) 625 V

6. An infinite sheet carrying a uniform Surface charge density σ lies on the .xy-plane. The work done to carry a charge q from the point $\vec{A} = a(\hat{i} + 2\hat{j} + 3\hat{k})$ to the point $\vec{B} = a(\hat{i} - 2\hat{j} + 6\hat{k})$ (where a is a constant with the dimension of length and ε_0 is the permittivity of free space) is : **[1]**

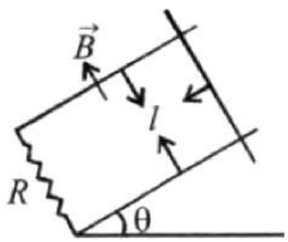
a) $\frac{5\sigma a q}{2\varepsilon_0}$

b) $\frac{2\sigma a q}{\varepsilon_0}$

c) $\frac{3\sigma a q}{\varepsilon_0}$

d) $\frac{3\sigma a q}{2\varepsilon_0}$

7. A copper rod of mass m slides under gravity on two smooth parallel rails, with separation 1 and set at an angle of θ with the horizontal. At the bottom, rails are joined by a resistance R.There is a uniform magnetic field B normal to the plane of the rails, as shown in the figure. The terminal speed of the copper rod is: **[1]**



a) $\frac{\mathrm{mgR} \tan\theta}{B^2 l^2}$

b) $\frac{mgR \cos\theta}{B^2 l^2}$

c) $\frac{\mathrm{mgR} \sin\theta}{B^2 l^2}$

d) $\frac{\mathrm{mgR} \cot\theta}{\mathrm{B}^2 l^2}$

8. As per Bohr model, the minimum energy (in eV) required to remove an electron from the ground state of double ionized Li atom (Z = 3) is: **[1]**

a) 122.4

b) 40.8

c) 13.6

d) 1.51

9. In Young's experiment, the third bright band for light of wavelength 6000 $\mathring{A}$ coincides with the fourth bright band for another source of light in the same arrangement. Then the wavelength of second source is: **[1]**

a) 3600 $\mathring{A}$

b) 4000 $\mathring{A}$

c) 5000 $\mathring{A}$

d) 4500 $\mathring{A}$

10. Match Column I with Column II with appropriate matching. **[1]**

Column I	Column II
a. $\vec{E}$	i. electric field lines
b. $\vec{p}$	ii. $\frac{q}{4\pi\varepsilon_0 r^3}\vec{r}$
c. Two lines of force do not intersect each other	iii. dipole field

d. Field produced by a dipole	iv. $q \times 2a\hat{p}$

a) (a) - (iv), (b) - (i), (c) - (ii), (d) - (iii)

b) (a) - (iv), (b) - (iii), (c) - (i), (d) - (ii)

c) (a) - (ii), (b) - (iv), (c) - (i), (d) - (iii)

d) (a) - (iii), (b) - (i), (c) - (iv), (d) - (ii)

11. A donor impurity results in **[1]**

a) increase of resistance of the semiconductor

b) production of n-semiconductor

c) energy bands just above the filled valency

d) production of p-semiconductor

12. A convex lens of refractive index n_2 is surrounded by a medium of refraciive index n_1. In order that the lens has least power, the correct choice is: (R_1 and R_2 are the magnitudes of the radii of curvature of the two surfaces) **[1]**

a) $R_1 = 2R_2$; $n_2 = 2\ n_1$

b) $R_1 = R_2$; $n_2 = 2n_1$

c) $R_1 = R_2$; $n_2 = 1.1n_1$

d) $R_2 = 2R_1$; $n_2 = 1.5n_1$

13. What is the momentum of a photon having frequency 1.5×10^{13} Hz? **[1]**

a) 3.3×10^{-29} kg-m/s

b) 6.6×10^{-34} kg-m/s

c) 6.6×10^{-30} kg-m/s

d) 3.3×10^{-34} kg-m/s

14. Equipotentials at a great distance from a collection of charges whose total sum is not zero are approximately **[1]**

a) planes

b) ellipsoids

c) spheres

d) paraboloids

15. In a double-slit experiment, green light (5303 $\overset{o}{A}$) falls on a double slit having a separation of 19.44 μ-m and a width of 4.05 μ-m. The number of bright fringes between the first and the second diffraction minima is **[1]**

a) 5

b) 10

c) 4

d) 9

16. **Assertion (A):** Mass is not conserved, but mass and energy are conserved as a single entity called mass-energy. **[1]**
Reason (R): Mass and energy are inter-convertible in accordance with Einstein's relation.

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

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

17. **Assertion (A):** It is necessary to use satellites for long distance T.V. transmission. **[1]**
Reason (R): The television signals are low frequency signals.

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

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

18. **Assertion (A):** Iron behaves as magnet. **[1]**
Reason (R): In magnet, the molecular magnets are aligned in same direction.

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

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

Section B

19. In a full-wave junction diode rectifier, the input a.c. has an rms value of 10 V. The transformer used is a step-up transformer having a transformation ratio 1 : 2. Calculate the d.c. and a.c. voltages in the rectified output. **[2]**

20. Using the relevant Bohr's postulates, derive the expressions for the **[2]**
    i. speed of the electron in the nth orbit
    ii. radius of the nth orbit of the electron in hydrogen atom.

21. Two students A and B prepare the following table about the electromagnetic waves. Rewrite this table in its corrected form : **[2]**

Student	Direction of			Peak Value of	
	Electric field	**Magnetic field**	**Propagation**	**Electric field**	**Magnetic field**
A	Along X-axis	Along X-axis	Along Y-axis	E	E = cB
B	Along Y-axis	Along Z-axis	Along X-axis	E = cB	B

OR

Name the electromagnetic radiations used for
    i. water purification, and
    ii. eye surgery.

22. What happens when a forward bias is applied to the p-n junction? **[2]**

23. An uncharged capacitor is connected to a battery. Show that half the energy supplied by the battery is lost as heat while charging the capacitor. **[2]**

OR

Two point charges 20×10^{-6}C and - 4×10^{-6}C are separated by a distance of 50 cm in air.
    i. Find the point on the line joining the charges, where the electric potential is zero.
    ii. Also, find the electrostatic potential energy of the system.

24. Calculate the ratio of the accelerating potential required to accelerate a proton and an α-particle to have the same de-Broglie wavelength associated with them. **[2]**

25. Define the terms: nucleons, atomic number, mass number, nuclear mass and nuclide, in relation to a nucleus. **[2]**

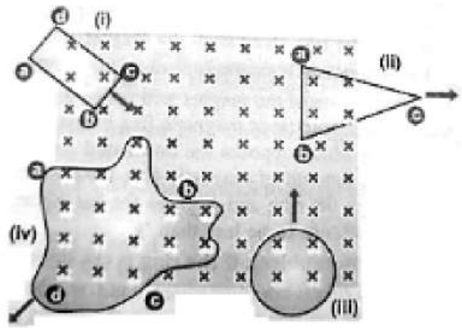
Section C

26. In a Geiger-Marsden experiment, what is the distance of closest approach to the nucleus of a 7.7 MeV $\alpha-$particle before it comes momentarily to rest and reverses its direction? **[3]**

27. White light is incident on a soap film at an angle of $\sin^{-1} \frac{4}{5}$ and the reflected light on examination by the spectroscope shows dark bands. The consecutive dark bands correspond to wavelengths 6100 $\mathring{A}$ and 6000 $\mathring{A}$. If the refractive index of the film is $\frac{4}{3}$, calculate its thickness. **[3]**

28. The figure below shows planer loops of different shapes moving out of or into a region of the magnetic field which is directed normal to the plane of the loops away from the reader. Determine the direction of induced current in each loop using Lenz's law. Check if you would obtain the same answers by considering the magnetic **[3]**

force on the charge inside the moving loops.



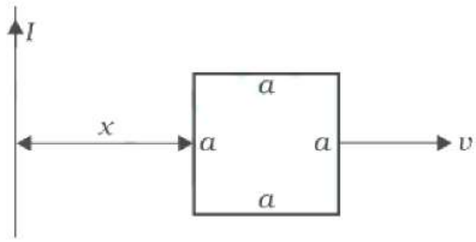
OR

a. Obtain an expression for the mutual inductance between a long straight wire and a square loop of side a as shown in Figure.

b. Now assume that the straight wire carries a current of 50 A and the loop is moved to the right with a constant velocity, v = 10 m/s.

Calculate the induced emf in the loop at the instant when x = 0.2 m.

Take a = 0.1 m and assume that the loop has a large resistance.



29. Name the type of EM waves having a wavelength range 10^{-7} m to 10^{-9} m. How are these waves generated? Write their two uses. **[3]**

OR

Answer the following questions.

i. Name the waves which are produced during radioactive decay of a nucleus. Write their frequency range.

ii. Welders wear special glass goggles while working. Why? Explain.

iii. Why are infrared waves often called as heatwaves? Give their one application.

30. Calculate the force acting between two magnets of length 15 cm each and pole strength 80 Am each when the separation between their north poles is 10 cm and that between south poles is 40 cm. **[3]**

Section D

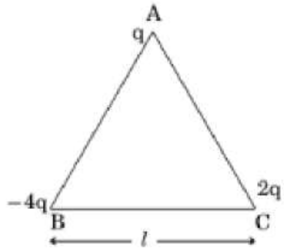
31. **[5]**

i. Use Gauss's law to show that due to a uniformly charged spherical shell of radius R, the electric field at any point situated outside the shell at a distance r from its center is equal to the electric field at the same point, when the entire charge on the shell was concentrated at its center. Also plot the graph showing the variation of an electric field with r, for $r \leq R$ and $r \geq R$.

ii. Two-point charges of +1 μC and +4 μC is kept 30 cm apart. How far from the +1 μC charge on the line joining the two charges, will the net electric field be zero?

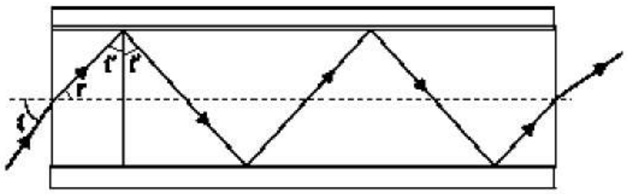
OR

i. Three point charges q, – 4q and 2q are placed at the vertices of an equilateral triangle ABC of side l as shown in the figure. Obtain the expression for the magnitude of the resultant electric force acting on the charge q.



ii. Find out the amount of the work done to separate the charges at infinite distance.

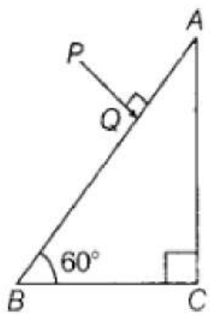
32. i. Figure shows a cross-section of a light pipe made of a glass fibre of refractive index 1.68. The outer covering of the pipe is made of a material of refractive index 1.44. What is the range of the angles of the incident rays with the axis of the pipe for which total reflections inside the pipe take place as shown in the figure. **[5]**



ii. What is the answer, if there is no outer covering of the pipe?

OR

A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism. From B which face will the ray emerge? Justify your answer.



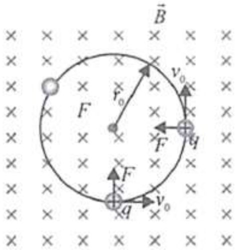
33. i. Derive the relation between current density J and potential difference V across a current carrying conductor of length l, area of cross-section A and the number density n of free electrons. **[5]**

ii. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. [Assume that the number density of conduction electrons is 9×10^{28} m^{-3}]

Section E

34. **Read the text carefully and answer the questions:** **[4]**

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 magnetic field is perpendicular to the velocity of the electron. A force acts on the particle perpendicular to both $\vec{v}_0$ and q. 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 doubled to $2v_0$ What will be the radius of the circle if the initial radius is r_0?

(ii) If the speed of particle gets doubled, what will be the new time period of particle?

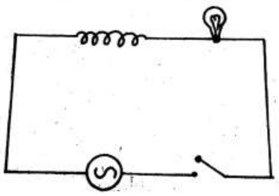
(iii) A charged particles is projected in a magnetic field $\vec{B} = (2\hat{i} + 4\hat{j}) \times 10^2$ T. The acceleration of the particle is found to be $\vec{a} = (x\hat{i} + 2\hat{j})\text{ms}^{-2}$. Find the value of x

OR

What will be the trajectory of electron If the direction of velocity of the electron makes an acute angle with the direction of magnetic field?

35. **Read the text carefully and answer the questions:** **[4]**

A light bulb and an open coil inductor are connected to an ac source through a key as shown in the figure. The switch is closed and after some time, an iron rod is inserted into the interior of the inductor. The glow of the light bulb (a) increases, (b) decreases, (c) is unchanged, as the iron rod is inserted.



(i) A bulb and a capacitor are connected in series to an a.c. source of variable frequency. How will the brightness of the bulb change on increasing the frequency of the a.c. source? Give reason.

(ii) Define capacitor reactance. Write its SI units.

(iii) A capacitor behaves like a perfect conductor for high frequency a.c. Explain, why?

OR

Why does it happen? Give your answer with reasons.

Solution

SAMPLE PAPER - 7

Class 12 - Physics

Section A

1. **(c)** diode design

   Explanation: We know that in p-n junction diode, the barrier potential is produced due to the concentration of holes and electrons near the junction. As a result of this, barrier potential depends upon doping density, temperature and forward biasing. But the barrier potential does not depend on diode design.

2. **(c)** is from B to D

   Explanation: $R_{ABC} = 100\Omega$, $R_{ADC} = 200\Omega$

   $R_{\text{Total}} = \frac{100\times200}{100+200} = \frac{200}{3}\Omega$

   $\therefore I = \frac{E}{R_{\text{Toal}}+r} = \frac{10}{\frac{200}{3}+\frac{100}{3}} = \frac{1}{10}\text{amp}$

   $I_{ABC} = \frac{2}{10}$ amp , $I_{ADC} = \frac{1}{10}\text{amp}$

   $V_A - V_B = 40 \times \frac{2}{10}$ =8 Volt

   $V_A - V_D = 90 \times \frac{2}{10}$ =18 Volt

   $\therefore V_B > V_D$ Hence current will flow from B to D

3. **(b)** images unaffected by variation of refractive index with wavelength

   Explanation: The image of an object in white light formed by a lens is usually coloured and blurred. This defect of image is called chromatic aberration and arises due to the fact that focal length of a lens is different for different colours. In case of two thin lenses in contact, the combination will be free from chromatic aberration. The lens combination which satisfies this condition are called achromatic lenses.

4. **(b)** both holes and electrons carry current

   Explanation: both holes and electrons carry current

5. **(d)** 625 V

   Explanation: After charging, total charge on the capacitor:

   Q = CV (where C = $10\mu F$)

   $\therefore \quad Q = 10 \times 10^{-6} \times 1000 = 10^{-2}\text{C}$

   When this charged capacitor is connected to uncharged capacitor, then total charge remains same.

   $\therefore Q = Q_1 + Q_2$

   $10^{-2} = (C_1 + C_2)V$

   $\therefore \quad V = \frac{10^{-2}}{16\times10^{-6}}$ = 625 volt

6. **(d)** $\frac{3\sigma aq}{2\varepsilon_0}$

   Explanation: Here, $\overrightarrow{r_A} = a(\hat{i} + 2\hat{j} + 3\hat{k}), \quad \overrightarrow{r_B} = a(\hat{i} - 2\hat{j} + 6\hat{k})$

   Displacement vector $\vec{r}$ from point A to B is $\vec{r} = \vec{r}_B - r_A$

   $= a(\hat{i} + 2\hat{j} + 6\hat{k}) - a(\hat{i} + 2\hat{j} + 3\hat{k})$

   $= a(-4\hat{j} + 3\hat{k})$

   Electric field due to an infinite plane sheet of uniform surface charge density σ is $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

   where $\hat{n}$ is a unit vector normal to the plane.

   Here $\hat{n} = \hat{k}$

   $\therefore \vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{k}$

   Work done in moving a charge q from A to B is

   $W = \vec{F}\cdot\vec{r} = q\vec{E}\cdot\vec{r} \quad (\because \vec{F} = q\vec{E})$

   $= q\left(\frac{\sigma}{2\varepsilon_0}\hat{k}\right)a(-4\hat{j} + 3\hat{k}) = \frac{3\sigma aq}{2\varepsilon_0}$.

7. **(c)** $\frac{\text{mgR}\sin\theta}{B^2l^2}$

   Explanation:

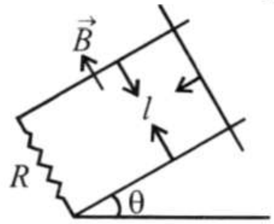
From Faraday's law of electomagnetic induction,

e = $\frac{d\phi}{dt} = \frac{d(BA)}{lt} = \frac{d(Bll)}{dt} = \frac{Bdl \times l}{dt}$ = BVl

Also, F = ilB = $\left(\frac{BV}{R}\right)(l^2B)$ = $\frac{B^2l^2V}{R}$

At equilibrium

mg sin θ = $\frac{B^2lV}{R}$ $\Rightarrow$ V = $\frac{mgR\sin\theta}{B^2l^2}$



8. **(a)** 122.4

Explanation: According to Bohr's theory,

E_n = $\frac{RhcZ^2}{n^2}$ = $\frac{13.6z^2}{n^2}$eV

Here z = 3, n = 1

Required energy = $|E_n|$ = 13.6 × 9

= 122.4 eV

9. **(d)** 4500 Å

Explanation: $x = \frac{mD\lambda_1}{d} = \frac{(m+1)D\lambda_2}{d}$

or $3 \times 6000 = 4\lambda_2$

or $\lambda_2 = \frac{3 \times 6000}{4} = 4500\text{Å}$

10. **(c)** (a) - (ii), (b) - (iv), (c) - (i), (d) - (iii)

Explanation: As we know that,

$\vec{E} = \frac{q}{4\pi\varepsilon_0 r^3}\vec{r}, \vec{p}$ = q × 2a$\hat{p}$

Field produced by a dipole is known as dipole field.

Electric field lines do not intersect each other.

11. **(b)** production of n-semiconductor

Explanation: A donor impurity produces n-type semiconductor.

12. **(c)** $R_1 = R_2$; $n_2 = 1.1n_1$

Explanation: We know that

P = $\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

By sign convention, R_1 is +ve and R_2 is -ve.

$\therefore$ P = $\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

We know that, $n_{21} = \frac{n_2}{n_1}$

Case (a): $P_1 = (2 - 1)\left(\frac{1}{2R_2} + \frac{1}{R_2}\right) = \frac{3}{2R_2}$

Case (b) : $P_2 = (1.5 - 1)\left[\frac{1}{(R_2/2)} + \frac{1}{R_2}\right] = \frac{3}{2R_2}$

Case (c): $P_3 = (1.1 - 1)\left(\frac{1}{R_2} + \frac{1}{R_2}\right) = \frac{0.2}{R_2}$

Case (d): $P_4 = (2 - 1)\left(\frac{1}{R_2} + \frac{1}{R_2}\right) = \frac{2}{R_2}$

So, $P_{\min} = \frac{0.2}{R_2}$

13. **(a)** 3.3×10^{-29} kg-m/s

Explanation: Momentum = (Energy/c)

$\therefore p = \frac{hv}{c} = \frac{(6.62\times10^{-34})(1.5\times10^{13})}{3\times10^{8}}$

= 3.3×10^{-29} kg-m/s

14. **(c)** spheres

Explanation: Here we have to find out the shape of the equipotential surface. These surfaces are perpendicular to the field lines. So there must be an electric field which cannot be without charge. So the algebraic sum of all charges must not be zero. Equipotential surface at a great distance means that the space of charge is negligible as compared to distance. So the collection of charges is considered as a point charge. The electric potential due to point charge is given by V=1/4$\pi \in_0$r. It means that potential due to a point charge is same for all equidistant points, which are at the same potential form spherical shape. The lines of the field from point charges are radial. So the equipotential surface (perpendicular to the field lines) form a sphere.

15. **(a)** 5

Explanation: Here, the wavelength of light used (λ) = 5303$\overset{\circ}{A}$

Distance between two-slit (d) = 19.44 μm

Width of single slit (a) = 4.05μm

Here, the angular width between the first and second diffraction minima

$\theta = \frac{\lambda}{a}$

and angular width of a fringe due to double slit is

$\theta' = \frac{\lambda}{d}$

$\therefore$ Number of fringes between first and second diffraction minima, n = $\frac{\theta}{\theta'}$ = $\frac{\frac{\lambda}{a}}{\frac{\lambda}{d}}$ = $\frac{d}{a} = \frac{19.44}{4.05}$ = 4.81 or n $\simeq$ 5

$\therefore$ 5 interfering bright fringes lie between the first and second diffraction minima.

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

Explanation: Both A and R are true and R is the correct explanation of A.

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

Explanation: The television signals being of high frequency are not reflected by the ionosphere. So the T.V. signals are broadcasted by tall antenna to get large coverage, but for transmission over large distance satellites are needed. That is why, satellites are used for long distance T.V. transmission.

18. **(d)** A is false but R is true.

Explanation: In an ordinary piece of iron, the molecular magnets are randomly oriented and form closed chains. Since the molecular magnets cancel the effect of each other, thus ordinary iron piece does not behave as a magnet.

Section B

19. rms value of input a.c., V_{rms} = 10 V

Peak value of input a.c.,

$V_0 = \sqrt{2}V_{rms} = \sqrt{2} \times 10$ = 14.14 V

As the step-up transformer has a transformation ratio 1 : 2, the maximum value of the output voltage of the transformer applied to the diodes is

$V_0' = 2 \times V_0 = 2\times$ 14.14 = 28.28 V

d.c. voltage in the rectified output = $\frac{2V_0'}{\pi}$

= 0.637 $\times$ 28.28 = 18.01 V

a.c. voltage in the rectified output

= 0.305 $V_0^{'}$ = 0.305 $\times$ 28.28 = 8.62 V

20. a. From Bohr's first postulate,

$\frac{mv^2}{r} = \frac{kZe^2}{r^2}$

where k = $\frac{1}{4\pi\varepsilon_o}$

Thus, r = $\frac{kZe^2}{mv^2}$

From Bohr's postulate of angular momentum,

r = $\frac{nh}{2\pi mv}$

$\therefore \frac{kZe^2}{mv^2} = \frac{nh}{2\pi mv}$ or v = $\frac{2\pi kZe^2}{nh}$

This is the velocity of electron in Bohr's stationary orbit.

b. Now, mvr = $\frac{nh}{2\pi}$ or v = $\frac{nh}{2\pi mr}$

Also, $\frac{mv^2}{r} = \frac{kZe^2}{r^2}$

Putting the value of v, we get

$\frac{m}{r}\frac{n^2h^2}{4\pi^2m^2r^2} = \frac{kZe^2}{r^2}$ or r $= \frac{n^2h^2}{4\pi^2mkZe^2}$

This is the radii of Bohr's stationary orbit.

21. Correction for student 'A'

Electric field	Magnetic field	Peak Value of	
		Electric Field	Magnetic Field
Along X-axis or Along Z-axis	Along Z-axis or Along X-axis	E	$B = \frac{E}{c}$

No correction for student B.

OR

i. Ultraviolet Radiations with the wavelength shorter than visible light is used for Water Purification
ii. Ultraviolet rays/Laser

22. When a p-n junction is forward biased:
   i. the potential barrier across decreases
   ii. the width of the depletion layer decreases
   iii. the effective resistance across the junction decreases
   iv. the junction conducts current

23. Let capacitance of the capacitor = C

$\therefore$ emf of the battery = V

Charge given to the capacitor, q = CV

Energy supplied by the battery = Work done by the battery = qV

Energy stored in the capacitor $= \frac{1}{2}CV^2 = \frac{1}{2}qV$

Thus, half the energy supplied by the battery is lost as heat while charging the capacitor.

OR

i. Suppose the point of zero potential is located at a distance x metre from the charge of 20 $\times$ 10^{-6} C.

Then, $V = \frac{1}{4\pi\varepsilon_0}\left[\frac{20\times10^{-6}}{x} - \frac{4\times10^{-6}}{0.50-x}\right]$ = 0

This gives x = 0.41 m = 41 cm

ii. $U = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{r}$

$= \frac{9\times10^9\times20\times10^{-6}\times(-4)\times10^{-6}}{0.50}$ = -1.44 J

24. de-Broglie matter wave equation for accelerating charged particle is given by

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

where, h = Planck's constant

m = mass of charged particle

q = charge of charged particle

V = potential difference

Ratio of wavelengths of proton and α-particle

$\Rightarrow \quad \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\left(\frac{m_\alpha}{m_p}\right)\left(\frac{q_\alpha}{q_p}\right)\left(\frac{V_\alpha}{V_p}\right)}$

$\because \quad \frac{\lambda_p}{\lambda_\alpha} = 1, \frac{m_\alpha}{m_p} = 4, \frac{q_\alpha}{q_p} = 2, \frac{V_\alpha}{V_p} = ?$

1 = $\sqrt{4 \times 2 \times (V_\alpha/V_p)}$

$\Rightarrow \quad 1 = 8 \times V_\alpha/V_p \Rightarrow V_p/V_\alpha = 8$

$\Rightarrow \quad V_p : V_\alpha = 8:1$

25.
   i. **Nucleons:** Protons and neutrons which are present in the nuclei of atoms are collectively known as nucleons.
   ii. **Atomic number:** The number of protons in the nucleus is called the atomic number of the element. It is denoted by Z.
   iii. **Mass number:** The total number of protons and neutrons present in a nucleus is called the mass number of the element. It is denoted by A.
   iv. **Nuclear mass:** The total mass of the protons and neutrons present in a nucleus is called the nuclear mass.
   v. **Nuclide:** When an atom is talked of with particular reference to its nuclear composition, it is called a nuclide. Thus a nuclide is a specific nucleus of an atom characterised by its atomic number Z and mass number A.

Section C

26. The key idea here is that throughout the scattering process, the total mechanical energy of the system consisting of an α-particle and a gold nucleus is conserved. The system's initial mechanical energy is E_i, before the particle and nucleus interact, and it is equal to its mechanical energy E_f when the α-particle momentarily stops. The initial energy E_i is just the kinetic energy K of the incoming α-particle. The final energy E_f is just the electric potential energy U of the system. The potential energy U can be calculated from Eq. Let d be the centre-to-centre distance between the α-particle and the gold nucleus when the α-particle is at its stopping point. Then we can write the conservation of energy $E_i = E_f$ as

$$K = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{d} = \frac{2Ze^2}{4\pi\varepsilon_0 d}$$

Thus the distance of closest approach d is given by:-

$$d = \frac{2Ze^2}{4\pi\varepsilon_0 K}$$

The maximum kinetic energy found in α-particles of natural origin is 7.7 MeV or 1.2×10^{-12} J. Since $\frac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9$ N m^2/C^2.

Therefore with e = 1.6×10^{-19} C, Z = 79 we have,

$$d = \frac{(2)\left(9.0\times10^9 \mathrm{Nm^2/C^2}\right)\left(1.6\times10^{-19}\mathrm{C}\right)^2 79}{1.2\times10^{-12}\mathrm{J}}$$

d (Au) = 3.0×10^{-14} m = 30 fm. (1 fm (i.e. fermi) = 10^{-15} m.)

The radius of gold nucleus is, therefore, less than 3.0×10^{-14} m. This is not in very good agreement with the observed result as the actual radius of gold nucleus is 6 fm. The cause of discrepancy is that the
distance of closest approach is considerably larger than the sum of the radii of the gold nucleus and the α-particle. Thus, the α-particle reverses its motion without ever actually touching the gold nucleus.

27. Here i = $\sin^{-1}\frac{4}{5}$

$\therefore$ sin i = $\frac{4}{5}$

As $\mu = \frac{\sin i}{\sin r}$

$\therefore$ sin r = $\frac{\sin i}{\mu} = \frac{4/5}{4/3} = \frac{3}{5}$ = 0.6

cos r = $\sqrt{1-\sin^2 r} = \sqrt{1-(0.6)^2}$ = 0.8

For a dark fringe in the reflected light,

2 μt cos r = $n\lambda$n = 0, 1, 2, 3, ...

Suppose nth and (n + 1)th dark bands correspond to wavelengths 6100 $\mathring{A}$ and 6000 $\mathring{A}$ respectively. Then

In first case,

$2 \times \frac{4}{3} \times t \times 0.8 = n \times 6100 \times 10^{-10}$ ...(i)

In second case,

$2 \times \frac{4}{3} \times t \times 0.8 = (n + 1) \times 6000 \times 10^{-10}$

$\therefore n \times 6100 \times 10^{-10} = (n + 1) \times 6000 \times 10^{-10}$

or n = 60

Putting the value of n in equation (i), we get

$2 \times \frac{4}{3} \times t \times 0.8 = 60 \times 6100 \times 10^{-10}$

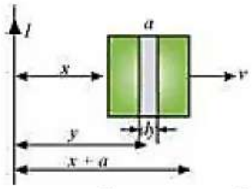
or t = 1.716×10^{-5} m

28. i. Due to motion, the magnetic flux linked with the loop abcd increases. According to Lenz's law, this increase in flux is opposed by the induced current. Therefore, the induced current must flow along bcdab.
 ii. Due to motion, magnetic flux linked with abc decreases. The induced current is along bacb.
 iii. The magnetic flux increases in this case. Therefore, the induced current is anticlockwise.
 iv. As magnetic flux decreases due to motion, the induced current is along cdabc.

Yes, we would obtain the same answers by considering the magnetic force on the charges inside the loop.

OR

a. Take a small element dy in the loop at a distance y from the long straight wire (as shown in the given figure).



Magnetic flux associated with element day, $d\phi = BdA$

Where,

dA = Area of element dy = a dy

B = Magnetic field at distance y

$= \frac{\mu_0 I}{2\pi y}$

I = current in the wire

$\mu_0 =$ Permeability of free space = $4\pi \times 10^{-7}$ T mA^{-1}

$\therefore d\phi = \frac{\mu_0 Ia}{2\pi}\frac{dy}{y}$

$\phi = \frac{\mu_0 Ia}{2\pi}\int\frac{dy}{y}$

y tends from x to a + x

$\therefore \phi = \frac{\mu_0 Ia}{2\pi}\int_x^{a+x}\frac{dy}{y}$

$= \frac{\mu_0 Ia}{2\pi}[\log_e y]_x^{a+x}$

$= \frac{\mu_0 \text{Ia}}{2\pi}\log_e\left(\frac{a+x}{x}\right)$

For mutual inductance M, the flux is given as:

$\phi = MI$

$\therefore MI = \frac{\mu_0 Ia}{2\pi}\log_e\left(\frac{a}{x}+1\right)$ thus by compairing the equations we get,

$M = \frac{\mu_0 a}{2\pi}\log_e\left(\frac{a}{x}+1\right)$

b. Emf induced in the loop, e = B'av $= \left(\frac{\mu_0 I}{2\pi x}\right)av$

Given,

I = 50 A

x = 0.2 m

a = 0.1 m

v = 10 m/s

$e = \frac{4\pi\times10^{-7}\times50\times0.1\times10}{2\pi\times0.2}$

$e = 5\times10^{-5}\text{V}$

29. EM waves: ultraviolet

Sun is an important source of UV rays. Some special lamps and very hot bodies also produce UV rays.

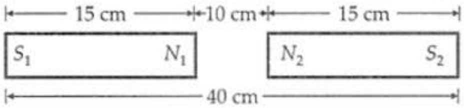
Uses:

i. In LASIK eye surgery.
ii. UV lamps are used to kill germs in water purifiers. Also, UV radiation is widely used in industrial processes and in medical and dental practices for a variety of purposes, such as killing bacteria.

OR

i. γ-rays are produced during radioactive decay of a nucleus. Its frequency range is from $3\text{x}10^{18}$ Hz to $5\text{x}10^{22}$ Hz.
ii. Welders wear special glass goggles while working to protect their eyes from radiation hazards of ultraviolet rays(UV rays). The range of UV rays is 10^{15} Hz to 10^{17} Hz.
iii. Infrared waves are called heat waves because they cause the atoms and molecules to vibrate when they encounter a substance. This increases the velocity and hence internal energy of atoms and molecules. Thereby, increasing the temperature of the substance as the heat produced in the matter is directly proportional to the internal energy of atoms and molecules. They are used in physical therapy and weather forecasting.

30. The situation is shown in the figure. Here $q_{m_1} = q_{m_2}$ = 80 Am



Force of repulsion between poles N_1 and N_2 is

$F_1 = \frac{\mu_0}{4\pi} \cdot \frac{q_{m_1} q_{m_2}}{r^2} = \frac{10^{-7} \times 80 \times 80}{(0.10)^2}$ = 0.064 N

Force of repulsion between poles S_1 and S_2 is

$F_2 = \frac{10^{-7} \times 80 \times 80}{(0.40)^2}$ = 0.004 N

Force of attraction between N_1 and S_2 is

$F_3 = \frac{10^{-7} \times 80 \times 80}{(0.25)^2}$ = 0.010 N

Force of attraction between N_2 and S_1 is

$F_4 = F_3$ = 0.010 N

Resultant force between the two magnets is

$F = F_1 + F_2 - F_3 - F_4$

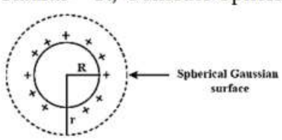
= 0.064 + 0.004 - 0.010 - 0.010

= 0.048 N (repulsive)

Section D

31. i. Let Surface charge density of spherical shell = λ

Radius = R, Consider Spherical Gaussian surface of radius = r



from Gauss Law

$\phi = \frac{q_{in}}{\epsilon_0}$

$= \frac{\lambda \times 4\pi r^2}{\epsilon_0}$

$\phi = \frac{4\pi\lambda R^2}{\epsilon_0}$ ...(i)

Also, $\phi = \vec{E} \cdot \vec{A} = E\left(4\pi r^2\right)$ ...(ii)

From equation (i) and (ii)

$E\left(4\pi r^2\right) = \frac{4\pi\lambda R^2}{\epsilon_0}$

$E = \frac{\lambda R^2}{\epsilon_0 r^2}$ ...(iii)

$\therefore \lambda = \frac{\theta}{4\pi R^2}$ or $\lambda R^2 = \frac{\theta}{4\pi}$

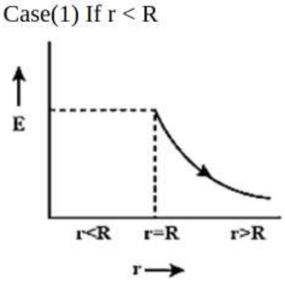
$E = \frac{\theta}{4\pi\epsilon_0 r^2}$ ......(iv) hence, From equation (iv)

Electric field only depend on charge enclosed and location of point.

Therefore charge with either on canter or surface enclose charge by Gaussian surface (r > R) will not change

$\therefore$ Hence it is proved.

Case(1) If r < R



this graph shows the variation of electric field with radius r

Charge enclose, $q_{in} = 0$

E = 0

Case(2) If r > R

$E = \frac{\theta}{4\pi\epsilon_o r^2}$

ii. Given that,

First point charge = +1 μC

Second point charge = +4 μC

Distance = 30 cm

Let us consider the net electric field zero at x distance from first charge.

Using formula of electric field

$E_x = E_{30-x}$

$\frac{kq_1}{r^2} = \frac{kq_2}{r'^2}$

Put the value into the formula

$\frac{1\times10^{-6}}{x^2} = \frac{4\times10^{-6}}{(30-x)^2}$

$\frac{(30-x)^2}{x^2} = \frac{4\times10^{-6}}{1\times10^{-6}}$

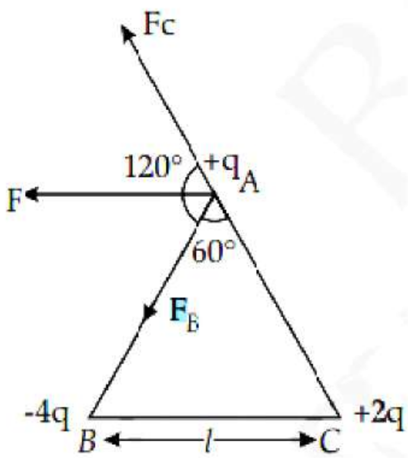
$\frac{30-x}{x} = \sqrt{\frac{4}{1}},$

30 - x = 2x

x = 10 cm

OR

i. Consider the figure shown below. The forces acting on charge q at A due to charges -4q at B and 2q at C are F_1 along AB and F_2 along CA respectively.



$|\vec{F}_1| = \frac{1}{4\pi\varepsilon_0}\frac{(4q)(q)}{l^2} = \frac{1}{4\pi\varepsilon_0}\frac{(4q^2)}{l^2} = \frac{1}{\pi\varepsilon_0}\frac{q^2}{l^2}$

$|\vec{F}_2| = \frac{1}{4\pi\varepsilon_0}\frac{(2q)(q)}{l^2} = \frac{1}{2\pi\varepsilon_0}\frac{q^2}{l^2}$

Thus, $F_1 = 2F_2$

Now angle between $\vec{F}_1$ and $\vec{F}_2$ is 120^o. Thus magnitude of the resultant force F is given by,

F = $\sqrt{F_1^1 + F_2^2 + 2F_1F_2\cos 120^\circ}$

F = $\sqrt{(2F_2)^2 + F_2^2 + 4F_2^2\cos 120^\circ}$

F = $\sqrt{4F_2^2 + F_2^2 - 2F_2^2}$

F = $\sqrt{3F_2^2}$

F = $\frac{\sqrt{3}}{2\pi\varepsilon_0}\frac{q^2}{l^2}$

ii. The amount of work done to separate the charges to infinity will be equal to potential energy of the system of charges.

U = $\frac{1}{4\pi\varepsilon_0 l}$[q $\times$(-4q) + (q $\times$ 2q) + (-4q $\times$ 2q)]

U = $\frac{1}{4\pi\varepsilon_0 l}$[$-4q^2 + 2q^2 - 8q^2$]

U = $\frac{1}{4\pi\varepsilon_0 l}$ [$-10q^2$]

U = $-\frac{1}{4\pi\varepsilon_0 l}$ [$10q^2$]

32. i. The working of an optical fibre is based on the phenomena of total internal reflection.

Given, refractive index of the glass fibre with respect to air,

$\mu_2 = {}^a\mu_g = 1.68$

Refractive index of the outer coating material with respect to air,

$\mu_1 = {}^a\mu_{\text{outer}} = 1.44$

Let the critical angle be i_c

So, $\mu = \frac{\mu_2}{\mu_1} = \frac{1}{\sin i_c}$

$\Rightarrow \sin i_c = \frac{\mu_1}{\mu_2} = \frac{1.44}{1.68} = 0.8571$

$\Rightarrow i_c = \sin^{-1}(0.8571) \approx 59^\circ$

The total internal reflection will take place when the angle of incidence i will be greater than the critical angle i_c, i.e. $i > i_c = 59°$ or when angle of refraction, $r < r_{max}$

where, $r_{max} = 90° - i_c = 90° - 59° = 31°$

So, ${}^a\mu_g = \frac{\sin i_{\max}}{\sin r_{\max}} = 1.68$

or, $\sin i_{max} = 1.68 \sin 31° = 1.68 \times 0.5150 = 0.8652$

or $i_{max} = \sin^{-1} (0.8652) = 60°$

Thus, all the rays which are incident in the range $0 < i < 60°$, will suffer total internal reflection in the pipe (but $i \neq 0$).

ii. If the outer covering of the pipe is not present, then,

Refractive index of the outer pipe, μ_1 = Refractive index of air = 1

For the angle of incidence i = 90°, we can write Snell's law at the air−pipe interface as:

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

where, i = angle of incidence, r = angle of refraction,

$\frac{\sin\ i}{\sin\ r} = 1.68$

$\sin r = \frac{\sin 90}{1.68} = \frac{1}{1.68} = 0.59$

$\Rightarrow r = 36.5°$

Now, i' = 90° - r

$\Rightarrow i' = 90° - 36.5°$

$\Rightarrow i' = 53.5°$

Since i' > r, all incident rays will suffer total internal reflection.

OR

Now here since light is going from one medium to another (air to glass), refraction is taking place. In case of refraction, we use sell's law according to which

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

where μ is the refractive index of the second medium (in which light is incident) with respect to first, i is the angle of incidence and r is the angle of refraction. All angles are measured with a normal drawn to the refracting surface at point of incidence.

Now the light is entered normally to the surface on face AB of the prism, so the angle of incidence will be

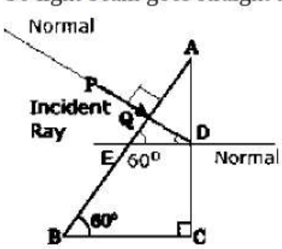
$i = 0^o$

In such a case, light goes undeviated from its path in the second medium as

$\sin r = \frac{\sin i}{\mu} = \frac{0}{\mu} = 0$

So angle of refraction, $r = 0^o$

So light beam goes straight and meet face AC of prism at D as shown in figure.



Now the normal is perpendicular to face AC of the prism, so ED will be parallel to base BC. Thus,

$\angle QED = \angle ABC = 60^\circ$ (alternate angles)

$\angle BQD = 90^\circ$ (as PQ is normal to AB)

Now in ΔEQD we can see,

$\angle QED + \angle EQD + \angle QDE = 180^\circ$ (Sum of all the angles in interior of a triangle is 180^o)

$60^o + 90^o + \angle QDE = 180^o$

$\angle QDE = 180^o - 150^o = 30^o$

So angle of incidence on surface AC of prism is 30^o

Now while refraction of a beam from denser medium to rarer medium (here glass to air), if angle of incidence of light beam is greater than critical angle, then the beam undergoes total Internal reflection and return back to same medium. Critical angle is given as

$i_c = \sin^{-1}\left(\frac{1}{\mu}\right)$

where i_c is the critical angle, μ is the refractive index of denser medium with respect to rarer medium.

Here refractive index of glass is $\mu = 1.5 = \frac{3}{2}$

So critical angle is

$i_c = \sin^{-1}\left(\frac{2}{3}\right) = 41.81^0$

which is greater than angle of incidence which is 30^o, so beam will not reflect back and will emerge from face AC of the prism.

To find the angle of refraction, we will use Snell's law,

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

Here angle of incidence, $i = 30^o$

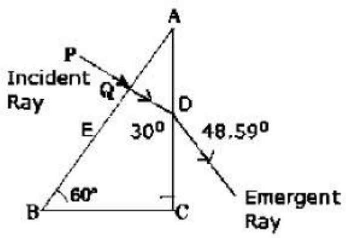
Refractive index of air w.r.t. glass is $\mu = \frac{1}{1.5} = \frac{2}{3}$

i.e. $\sin r = \frac{\sin 30^\circ}{1.5} = \frac{\left(\frac{1}{2}\right)}{\left(\frac{2}{3}\right)} = \frac{3}{4}$

So angle of refraction is

$r = \sin^{-1}\frac{3}{4} = 48.59^o$

So light ray will emerge from face AC of the prism making an angle of 48.59^0 with the normal to AC at point of incidence as shown in the figure.



33. i. Let us consider a conductor of length ' l ' , cross-sectional Area ' A ' and having ' n ' number of electrons per unit volume drifting with drift velocity v_d.

$I = neAv_d \ldots (i)$

When these electrons are moving, they collide with another electrons and in between the two successive collision the time taken is called relaxation time (τ).

Electric field inside the wire is given by

E = V/l ...(ii)

where,E is electric field, l is the length of the conductor and V is potential.

If relaxation time is τ, the drift speed (v_d) is given by,

$v_d = e\tau E/m$

where, m = mass of electron, τ = relaxation charge, e = electronic charge and E = electric field.

Putting the value of V_d in Eq. (i). we get

$\Rightarrow \quad I = \frac{ne^2\tau}{m}AE$ ...(iii)

$I = me^2\tau AV/ml$ [From Eqs. (ii)]

$\Rightarrow J = I/A = ne^2\tau V/ml$

ii. Given, $I = 1.5A, n = 9 \times 10^{28}\mathrm{m}^{-3}$

$A = 1.0 \times 10^{-7}\mathrm{m}^2$

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

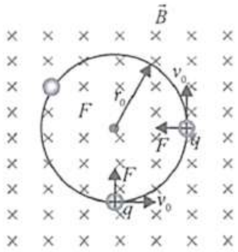
$\Rightarrow v_d = \frac{15}{9\times10^{28}\times1.6\times10^{-19}\times1.0\times10^{-7}}$

$\Rightarrow v_d = 1.04 \times 10^{-3}\mathrm{m/s}$

Section E

34. **Read the text carefully and answer the questions:**

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 magnetic field is perpendicular to the velocity of the electron. A force acts on the particle perpendicular to both $\vec{v}_0$ and q. 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) $2r_0$

As, $r_0 = \frac{mv}{qB} \Rightarrow r' = \frac{m(2v_0)}{qB} = 2r_0$

(ii) T_0

As, $T = \frac{2\pi m}{qB}$

Thus, it remains same as it is independent of velocity.

(iii) As $F \perp B$

Hence, $a \perp B$

$\therefore \vec{a} \cdot \vec{B} = 0$

$\Rightarrow (x\hat{i} + 2\hat{j}) \cdot (2\hat{i} + 4\hat{j}) = 0$

$2x + 8 = 0 \Rightarrow x = -4\ ms^{-2}$

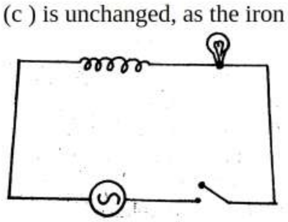
OR

If the charged particle has a velocity not perpendicular to $\vec{B}$, then the component of velocity along $\vec{B}$ remains unchanged as the motion along the $\vec{B}$ will not be affected by $\vec{B}$.

Then, the motion of the particle in a plane perpendicular to $\vec{B}$ is as before circular one. Thereby, producing helical motion.

35. **Read the text carefully and answer the questions:**

A light bulb and an open coil inductor are connected to an ac source through a key as shown in the figure. The switch is closed and after some time, an iron rod is inserted into the interior of the inductor. The glow of the light bulb (a) increases, (b) decreases, (c) is unchanged, as the iron rod is inserted.



(i) As the frequency of the a.c. source increases, the capacitance reactance decreases $\left(X_c \propto \frac{1}{f}\right)$. More current flows through the circuit. So the bulb glows with more brightness.

(ii) Capacitor reactance is the resistance offered by a capacitor, when it is connected to an electric circuit. It is given by

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

where ω is the angular frequency and C is the capacitance of capacitor.

The SI unit of capacitor reactance is Ohm (Ω).

(iii) Now, $X_C = \frac{1}{2\pi fC}$

When frequency of a.c. supply is high, X_C will be approximately zero i.e. capacitor will behave as a conductor.

OR

The glow of the bulb decreases, As the iron rod is inserted, the magnetic field inside the coil magnetizes the iron increasing the magnetic field inside it. Hence, the inductance of the coil increases. Consequently, the inductive reactance of the coil increases. As a result, a larger fraction of the applied ac voltage appears across the inductor, leaving less voltage across the bulb. Therefore, the glow of the light bulb decreases.