SAMPLE PAPER - 3

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. In intrinsic semiconductor at room temperature, number of electrons and holes are: **[1]**

a) unequal b) equal

c) infinite d) zero

2. In which one of the following substances, the resistance decreases with increase of temperature? **[1]**

a) Copper b) Silver

c) Carbon d) Gold

3. The position of the object in front of a concave mirror of focal length 20 cm, producing a real image four times the size of the object is: **[1]**

a) -22.5 cm b) -27.5 cm

c) -20 cm d) -25 cm

4. Choose the only false statement from the following: **[1]**

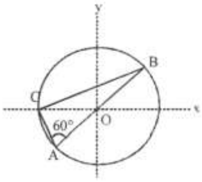
A. In conductors the valence and conduction bands overlap
B. Substances with energy gap of the order of 10eV are insulators
C. The resistivity of a semiconductor increases with increase in temperature
D. The conductivity of a semiconductor increases with increase in temperature

a) Option A b) Option B

c) Option D d) Option C

5. Consider a system of three charges $\frac{q}{3}$, $\frac{q}{3}$ and $\frac{-2q}{3}$ placed at points A, B and C, respectively, as shown in the **[1]**

figure. Take O to be the centre of the circle of radius R and angle CAB = 60°



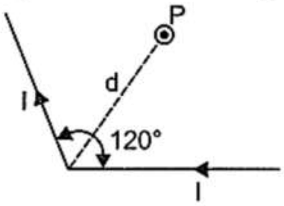
a) The magnitude of the force between the charges at C and B is $\frac{q^2}{54\pi\varepsilon_0 R^2}$

b) The electric field at point O is $\frac{q}{8\pi\varepsilon_0 R^2}$ directed along the negative x-axis

c) The potential at point O is $\frac{q}{12\pi\varepsilon_0 R}$

d) The potential energy of the system is zero

6. A long conducting wire carrying a current I is bent at 120° (see figure). The magnetic field B at a point P on the right bisector of bending angle at a distance d from the bend is : (μ_0 is the permeability of free space). **[1]**



a) $\frac{3\mu_0 I}{2\pi d}$

b) $\frac{\mu_0 I}{2\pi d}$

c) $\frac{\sqrt{3}\mu_0 I}{2\pi d}$

d) $\frac{\mu_0 I}{\sqrt{3}\pi d}$

7. An aeroplane is moving towards north horizontally with a speed of 200 ms^{-1} at a place where the vertical component of the earth's magnetic field is 0.5×10^{-4} tesla. Then, the induced emf set-up between the tips of the wings of the plane, if they are 10 m apart, is: **[1]**

a) 0.01 volt

b) 1 volt

c) 10 volt

d) 0.1 volt

8. The energy levels of a certain atom for 1st, 2nd and 3rd levels are E, $\frac{4E}{3}$ and 2E respectively. A photon of wavelength λ is emitted for a transition $3 \rightarrow 1$. What will be the wavelength of emission for transition $2 \rightarrow 1$? **[1]**

a) $\frac{4\lambda}{3}$

b) $\frac{\lambda}{3}$

c) 3λ

d) $\frac{3\lambda}{4}$

9. In Young's double slit experiment the wavelength of light $\lambda = 4 \times 10^{-7}$ m and separation between the slit is d = 0.1 mm. If the fringe width is 4 mm, then the separation between the slits and screen will be: **[1]**

a) 100 mm

b) 10 $\mathring{A}$

c) 10^6 cm

d) 1 m

10. Consider a neutral conducting sphere. A positive point charge is placed outside the sphere. Then the net charge on the sphere is - **[1]**

a) Negative and distributed uniformly over the surface of the sphere

b) Negative and distributed non–uniformly over the entire surface of the sphere

c) Negative and appears only at the point on the sphere closest to the point charge

d) Zero

11. In a semiconducting material, the mobilities of electrons and holes are μ_e and μ_h respectively. Which of the following is true? **[1]**

a) $\mu_e < 0; \mu_h > 0$

b) $\mu_e < \mu_h$

c) $\mu_e > \mu_h$

d) $\mu_e = \mu_h$

12. A lamp is placed 6.0 m from a wall. On putting a lens between the lamp and the wall at a distance of 1.2 m from the lamp, a real image of the lamp is formed on the wall. The magnification of the image is: **[1]**

a) 6

b) 3

c) 5

d) 4

13. A proton has kinetic energy E = 100 keV which is equal to that of a photon. The wavelength of photon is λ_2 and that of proton is λ_1. The ration of $\frac{\lambda_2}{\lambda_1}$ is proportional to: **[1]**

a) E^{-1}

b) $E^{-1/2}$

c) E^2

d) $E^{1/2}$

14. Two small identical spheres having charges +10μC and -90 μC attract each other with a force of F newton. If they are kept in contact and then separated by the same distance, the new force between them is: **[1]**

a) $\frac{16F}{9}$

b) $\frac{F}{6}$

c) 16 F

d) 9F

15. In an interference experiment, the third bright fringe is obtained on the screen with a light of 700 nm. What should be the wavelength of the light source in order to obtain the 5th bright fringe at the same point? **[1]**

a) 630 nm

b) 500 nm

c) 420 nm

d) 750 nm

16. **Assertion (A):** Forces acting between proton-proton (f_{pp}) proton-neutron (f_{pn}) and neutron-neutron (f_{nn}) are such that $f_{pp} < f_{pn} = f_{nm}$. **[1]**

Reason (R): Electrostatic force of repulsion between two protons reduces net nuclear forces between them.

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:** Soft and hard X-rays differ in frequency as well as velocity. **[1]**

Reason: The penetrating power of hard X-rays is more than the penetrating power of soft X-rays.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

18. **Assertion (A):** An ammeter is connected in series in the circuit. **[1]**

Reason (R): An ammeter is a high resistance galvanometer.

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

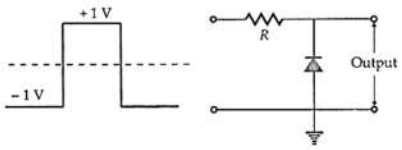
b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

Section B

19. A square wave (-1V to 1V) is applied to the p-n junction diode as shown below. Draw the output waveform. **[2]**



20. The ground state energy of hydrogen atom is -13.6 eV. If an electron makes a transition from an energy level -1.51 eV to - 3.4 eV, then calculate the wavelength of the spectral line emitted and name the series of hydrogen spectrum to which it belongs. **[2]**

21. The oscillating electric field of an electromagnetic wave is given by: $E_y = 30\sin\left[2\times 10^{11}t + 300\pi x\right] Vm^{-1}$ **[2]**

a. Obtain the value of the wavelength of the electromagnetic wave.

b. Write down the expression for the oscillating magnetic field.

OR

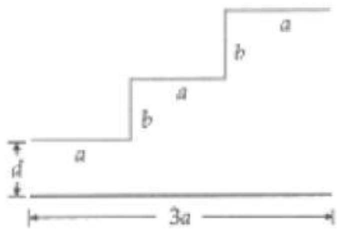
How does Ampere-Maxwell law explain the flow of current through a capacitor when it is being charged by a battery? Write the expression for the displacement current in terms of the rate of change of electric flux.

22. Explain, how a depletion region is formed in a junction diode? **[2]**

23. Show that work done in moving a unit charge along a closed path is zero? **[2]**

OR

A capacitor is made of a flat plate of area A and a second plate having a stair-like structure, as shown in Fig. The width of each stair is **a** and the height is **b**. Find the capacitance of the assembly.



24. Show the variation of photoelectric current with collector plate potential for different intensities but same frequency of incident radiation. **[2]**

25. Explain the role of control rods in a reactor? Why are they made of cadmium? **[2]**

Section C

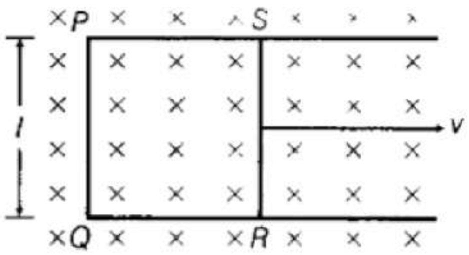
26. Show that the electron revolving around the nucleus in an orbit of radius r with speed v has magnetic moment $\frac{evr}{2}$. Hence Using Bohr's postulate of angular momentum, obtain the expression for the magnetic moment of hydrogen atom in its ground state. **[3]**

27. A beam of light consisting of two wavelengths, 650 nm and 520 nm, are used to obtain interference fringes in a Young's double slit experiment. **[3]**

a. Find the distance of the third bright fringe on the screen from the central maximum for wavelength 650 nm.

b. What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?

28. Figure shows a rectangular conducting loop PQRS in which arm RS of length I is movable. The loop is kept in a uniform magnetic field B directed downward perpendicular to the plane of the loop. The arm RS is moved with a uniform speed v. **[3]**

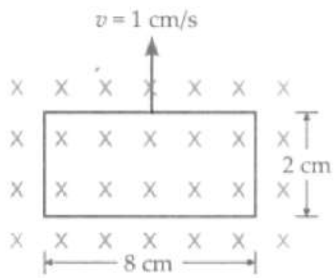


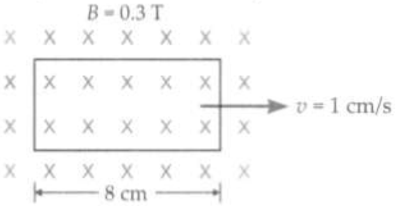
Deduce an expression for

i. the emf induced across the arm RS
ii. the external force required to move the arm and
iii. the power dissipated as heat.

OR

A rectangular loop of sides 8 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of magnitude 0.3 tesla directed normal to the loop. What is the voltage developed across the cut if velocity of loop is 1 cms^{-1} in a direction normal to the (i) longer side (ii) shorter side of the loop? For how long does the induced voltage last in each case?





29. Calculate the electric and magnetic fields produced by the radiation coming from a 100 W bulb at a distance of 3 m. Assume that the efficiency of the bulb is 2.5% and it is a point source. **[3]**

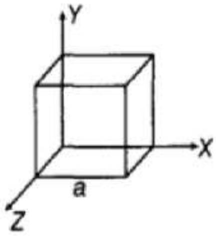
OR

i. Name the e.m. waves which are used for the treatment of certain forms of cancer. Write their frequency range.
ii. Thin ozone layer on top of the stratosphere is crucial for human survival. Why?
iii. An e.m. wave exerts pressure on the surface on which it is incident. Justify.

30. A small compass needle of magnetic moment M and moment of inertia I is free to oscillate in a magnetic field B. It is slightly disturbed from its equilibrium position and then released. Show that it executes simple harmonic motion. Write the expression for its time period. **[3]**

Section D

31. i. An electric dipole of dipole moment p consists of point charges +q and -q separated by a distance 2d apart. Deduce the expression for the electric field E due to the dipole at a distance r from the centre of the dipole on its axial line in terms of the dipole moment p. Hence, show that in the limit $r >> d, \mathbf{E} \longrightarrow 2p/\left(4\pi\varepsilon_0 r^3\right)$. **[5]**
ii. Given the electric field in the region $E = 2x\hat{\mathbf{i}}$, find the net electric flux through the cube and the charge enclosed by it.



OR

a. State the principle of superposition and use it to obtain the expression for the total electric force exerted at a point charge due to an assembly of n discrete point charges.

b. Three charges 10 μC, 5 μC and -5μC are placed in air at the three corners A, B and C of an equilateral triangle of side 0.1m. Find the resultant force experienced by charge placed at corner A.

32. i. An object is placed in front of a concave mirror. It is observed that a virtual image is formed. Draw the ray diagram to show the image formation and hence derive the mirror equation $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$. **[5]**

ii. An object is placed 30 cm in front of a plano-convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed.

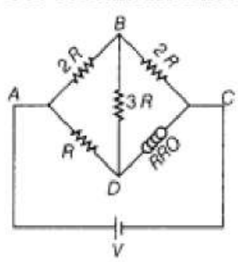
OR

i. Draw a ray diagram showing the image formation by a compound microscope. Obtain the expression for total magnification when the image is formed at infinity.

ii. How does the resolving power of a compound microscope get affected, when

1. focal length of the objective is decreased.
2. the wavelength of light is increased ? Give reasons to justify your answer.

33. i. Use Kirchhoffs rules to obtain the balance condition in a Wheatstone bridge. **[5]**



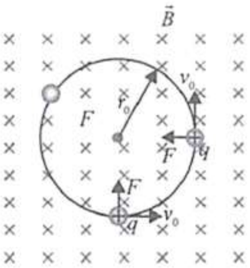
ii. Calculate the value of R in the balance condition of the Wheatstone bridge, if the carbon resistor connected across the arm CD has the colour sequence red, red and orange, as shown in the figure.

iii. If now the resistance of the arms BC and CD are interchanged, to obtain the balance condition, another carbon resistor is connected in place or R. What would now be sequence of colour bands of the carbon resistor?

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?

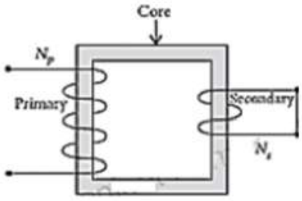
(iii) A charged particles is projected in a magnetic field $\vec{B} = (2\hat{i} + 4\hat{j}) \times 10^2$ T. The acceleration of the particle is found to be $\vec{a} = (x\hat{i} + 2\hat{j})\text{ms}^{-2}$. Find the value of x

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]**

Step-down transformers are used to decrease or step-down voltages. These are used when voltages need to be lowered for use in homes and factories. A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wireline carrying power is 0.5 Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.



(i) What will be the value of the total resistance of the wires?

(ii) What will be the value of line power loss in the form of heat?

(iii) How much power must the plant supply, assuming there is negligible power loss due to leakage?

OR

What will be the voltage drop in the power line?

Solution

SAMPLE PAPER - 3

Class 12 - Physics

Section A

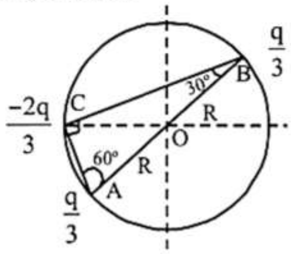
1. **(b)** equal
   Explanation: equal

2. **(c)** Carbon
   Explanation: Carbon

3. **(d)** -25 cm
   Explanation: As we know that,
   m = -4 = $-\frac{v}{u}$
   $\therefore$ v = 4u ...(i)
   $\because \frac{1}{v} + \frac{1}{u} = \frac{1}{f}$
   $\therefore \frac{1}{u} + \frac{1}{4u} = \frac{1}{-20}$ ...(By using (i))
   $\therefore \frac{5}{4u} = -\frac{1}{20}$
   $\therefore u = -\frac{20 \times 5}{4}$ = -25 cm

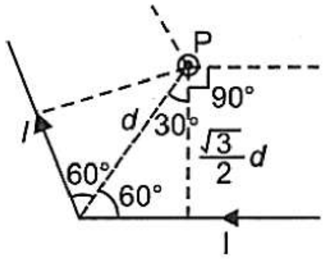
4. **(d)** Option C
   Explanation: The resistivity of a semiconductor decreases with the increase in temperature.

5. **(a)** The magnitude of the force between the charges at C and B is $\frac{q^2}{54\pi\varepsilon_0 R^2}$
   Explanation:



   i. The electric field due to charge $\frac{q}{3}$ at A and charge $\frac{q}{3}$ at B at O will get cancelled. The electric field at O due to charge $(\frac{-2q}{3})$
   E = $\frac{1}{4\pi\epsilon_0}\frac{\frac{2q}{3}}{R^2} = \frac{q}{6\pi\epsilon_0 R^2}$
   In $\Delta ABC \frac{AC}{AB}$ = sin 30°
   $\Rightarrow AC = \frac{AB}{2}$ = R
   Also $\frac{BC}{AB}$ = sin 60° ⇒ BC = $\frac{\sqrt{3}AB}{2} = \sqrt{3}R$
   ii. Potential energy of the system K
   $\left[\frac{(\frac{q}{3})(\frac{2}{3})}{2R}\right] + K\left[\frac{(\frac{q}{3})(\frac{-2q}{3})}{R}\right] + K\left[\frac{(\frac{q}{3})(\frac{-2q}{3})}{\sqrt{3}R}\right]$
   $= \frac{kq^2}{9R}\left[\frac{1}{2} - 2 - \frac{2}{\sqrt{3}}\right] \neq 0$
   iii. Magnitude of force between B and C
   F = $\frac{1}{4\pi\epsilon_0}\frac{(\frac{2q}{3})(\frac{q}{3})}{(\sqrt{3}R)^2} = \frac{q^2}{54\pi\epsilon_0 R^2}$
   iv. Potential V_O = K $\left[\frac{\frac{+q}{3}}{R}\right] + K\left[\frac{\frac{+q}{3}}{R}\right] + K\left[\frac{\frac{-2q}{3}}{R}\right]$ = 0

6. **(c)** $\frac{\sqrt{3}\mu_0 I}{2\pi d}$
   Explanation:



Magnetic field at P due to current through the bent wire is

$$B=2\left[\frac{\mu_0}{4\pi}\frac{I}{\left(\frac{\sqrt{3}}{2}d\right)}(\sin 90^\circ+\sin 30^\circ)\right]$$

$$=2\left[\frac{\mu_0}{4\pi}\frac{1}{\left(\frac{\sqrt{3}}{2}d\right)}\left(1+\frac{1}{2}\right)\right]=\frac{\sqrt{3}\mu_0 I}{2\pi d}$$

7. **(d)** 0.1 volt

   Explanation: EMF = Blv = $5\times10^{-4}\times10\times200$ = 0.1 V

8. **(c)** 3λ

   Explanation: Concept involved

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

   According to question $E_3 - E_1=\frac{hc}{\lambda}$ i.e., 2E - E = $\frac{hc}{\lambda}$ ...(1)

   $E_2 - E_1=\frac{hc}{\lambda}$, or $\frac{4E}{3}$ - E= $\frac{hc}{\lambda'}$; $\frac{E}{3}=\frac{hc}{\lambda'}$ ...(2)

   Put the value of E in eq 2 we get

   $\frac{hc}{3\lambda}=\frac{hc}{\lambda'}$ or $\lambda'=3\lambda$

9. **(d)** 1 m

   Explanation: Fringe width, $\beta=\frac{\lambda D}{d}$

   $\therefore\quad D=\frac{\beta d}{\lambda}=\frac{4\times10^{-3}\times0.1\times10^{-3}}{4\times10^{-7}}=1\text{m}$

10. **(d)** Zero

    Explanation: If a charge +q is placed outside, then the electric field lines incident on the conducting sphere induces -q charge on one surface whereas the opposite surface becomes oppositely charged (i.e. +q) and the total charge becomes zero.

11. **(c)** $\mu_e>\mu_h$

    Explanation: $\mu_e>\mu_h$, because the electron is lighter than hole.

12. **(a)** 6

    Explanation: 6

13. **(b)** $E^{-1/2}$

    Explanation: For photon, $\lambda_2=\frac{hc}{E}$ ... (i)

    For proton, $\lambda_1=\frac{h}{p}=\frac{h}{\sqrt{2mE}}\because p=\sqrt{2mE}$ ...(ii)

    $\therefore\frac{\lambda_2}{\lambda_1}=\frac{hc}{E\times\frac{h}{\sqrt{2mE}}}\propto E^{-1/2}$

14. **(a)** $\frac{16F}{9}$

    Explanation: $\frac{16F}{9}$

15. **(c)** 420 nm

    Explanation: 3rd Bright fringe × 700 nm = 5th Bright fringe × λ

    $\therefore\quad\lambda=\frac{3\times700}{5}$ = 420 nm

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. **(d)** Assertion is wrong statement but reason is correct statement.

    Explanation: Assertion is wrong statement but reason is correct statement.

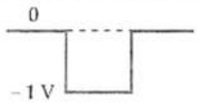
    Soft and hard X-rays differ only in frequency. Soft X-rays have low frequency as compared to hard X - rays. But both types of X-rays travel with speed of light.

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

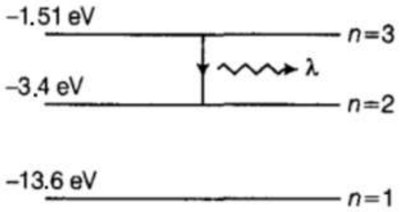
Explanation: An ammeter is a low resistance galvanometer. It is used to measure the current in amperes. To measure the current of a circuit, the ammeter is connected in series in the circuit so that the current to be measured must pass through it. Since, the resistance of ammeter is low, so its inclusion in series in the circuit does not change the resistance and hence the main current in the circuit.

Section B

19. The p-side of the diode is earthed, it is at zero potential. So the diode conducts current when the input level is - 1V and does not conduct when the input level is +1V. As the diode is ideal, the output across it will be either 0 or - 1V, as shown in the figure.



20. Energy levels of H-atom are ,



We know that, the wavelength of spectral line emitted

$\lambda = hc/\Delta E$

Taking, hc = 1240 eV-nm

We have, ΔE = 1.51 - (-3.4) = 1.89 eV

$\therefore \quad \lambda = \frac{1240}{1.89} \approx 656\text{nm}$

This belongs to Balmer series.

21. $E_y = 30 \sin\left[2 \times 10^{11} t + 300\pi x\right] Vm^{-1}$

a. On comparing the given equation with $E_y = E_0 \sin(\omega t + kx)$, we get

$k = 300\pi = \frac{2\pi}{\lambda}$

$\Rightarrow \lambda = \frac{1}{150} = 6.7 \times 10^{-3} m$

b. The wave is propagating along X-axis, electric field is oscillating along Y-axis, so according to right hand system of (vector E, vector B, vector K), the magnetic field must oscillate along Z-axis.

On comparing the given equation with $E = E_0 \sin(\omega t + kx)$, we get,

$E_0 = 30$ V/m

Now, $B_0 = \frac{E_o}{c} = \frac{30}{3 \times 10^8} = 10^{-7}$ T

Thus, equation of oscillating magnetic field is

$B_z = B_0 \sin(\omega t + kx)$

$\Rightarrow B_z = (10^{-7}) \sin\left[2 \times 10^{11} t + 300\pi x\right] T$

OR

When we charge a capacitor with the help of a cell, current flows all through the circuit except the part of a circuit which lies between two plates of the capacitor. There is no current found in that gap. But it was found that an electric field exists inside the plates, therefore, indicating the existence of a magnetic field which leads to inconsistency in the Ampere's circuital law.

When a battery is attached to a capacitor, conduction current flow in wire outside the capacitor, then through the capacitor the Electric flux $\phi_E = EA$.

when $E = \frac{Q}{\epsilon_0 A}$ and $Q = \epsilon_0 EA$

so $I = \frac{dQ}{dt} = \frac{\epsilon_0 d\phi}{dt}$

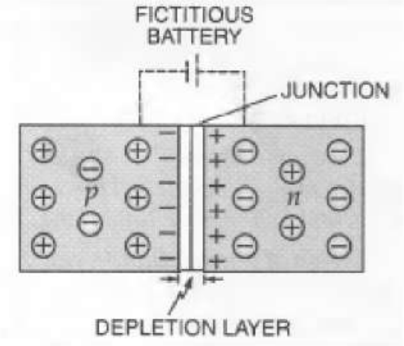
This maintains the current in the capacitor.

During charging, the electric flux between the plates of the capacitor keeps on changing, this results in the production of a displacement current between the plates.

$I_d = \varepsilon_0 \frac{d\phi_E}{dt} \left(I_d = \varepsilon_0 A \frac{dE}{dt}\right)$

22. When a p-type crystal is placed in contact with n-type crystal so as to form one piece, the assembly so obtained is called p-n junction or junction diode or crystal diode. The surface of contact of p and n-type crystals is called junction. In the p-section, holes are the majority carriers; while in n-section, the majority carriers are electrons. Due to the high concentration of different types of

charge carriers in the two sections, holes from p-region diffuse into n-region and electrons from n-region diffuse into p-region. In both cases, when an electron meets a hole, the two cancel the effect of each other and as a result, a thin layer at the junction becomes devoid of charge carriers. This is called the **depletion layer or depletion region** as shown in Fig.



23. Work = Force × displacement

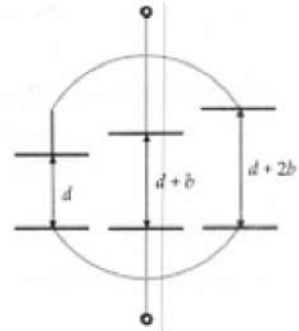
In a closed-loop, the charge always ends up from where it began its journey rendering displacement as Null.

So, using the above formula we get

Work done = Force × 0 = 0

OR

As shown in Fig. the given arrangement is equivalent to a parallel combination of three capacitors of capacitances C_1, C_2 and C_3



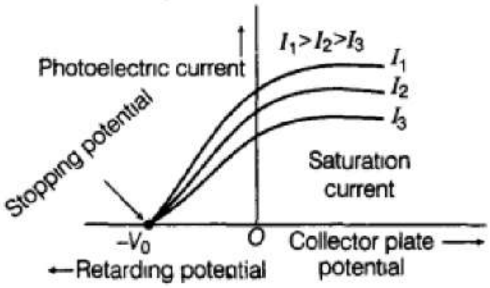
Here $C_1 = \frac{\varepsilon_0 A/3}{d}, C_2 = \frac{\varepsilon_0 A/3}{d+b}, C_3 = \frac{\varepsilon_0 A/3}{d+2b}$

$\therefore C = C_1 + C_2 + C_3 = \frac{\varepsilon_0 A}{3}\left[\frac{1}{d} + \frac{1}{d+b} + \frac{1}{d+2b}\right]$

$= \frac{\varepsilon_0 A}{3}\left[\frac{(d+b)(d+2b)+d(d+2b)+d(d+b)}{d(d+b)(d+2b)}\right]$

$= \frac{\varepsilon_0 A\left(3d^2+6bd+2b^2\right)}{3d(d+b)(d+2b)}$

24. The variation of photoelectric current with collector plate potential for different intensities at constant frequency is shown below:



Graph shows that more electrons are being emitted per second, proportional to the intensity of incident radiation. But the stopping potential remains the same as that for the incident radiation of intensity I_1, as shown graphically in Fig. Thus, for a given frequency of the incident radiation, the stopping potential is independent of its intensity. In other words, the maximum kinetic energy of photoelectrons depends on the light source and the emitter plate material, but is independent of intensity of incident radiation.

25. For a controlled nuclear chain reaction (which is the basis of nuclear reactor), number of available neutrons should never exceed one per fission. The excess neutrons over this critical limit must be absorbed. This is the role of control rods.

As cadmium has a high cross section for neutron absorption, therefore control rods are of cadmium.

Section C

26. Magnetic momentum,

$\mu = -\left(\frac{e}{2m}\right) L$

where (-) indicates μ direction is opposite to L.

As Bohr's atomic model

L = mvr

$\therefore \mu=-\left(\frac{e}{2m}\right) \times mvr$

$\mu=\frac{evr}{2}$

Energy levels of hydrogen atom

$E_n=-\frac{2\pi^2 m K^2 e^4}{n^2 h^2}$

For lowest energy level, n = 1

$E_1=-\frac{2\pi^2 m K^2 e^4}{n^2 h^2}$

$E_1=-\frac{2\pi^2 m K^2 e^4}{h^2}$

$E_1=-\left(\frac{4\pi^2 m Ke^2}{h^2}\right)\frac{Ke^2}{2}$

while $r=-\frac{h^2}{4\pi^2 Kme^2}$

$E_n=-\frac{Ke^2}{2r}=\frac{-13.6}{n^2} eV$

$\because \mu=\frac{evr}{2}$

$E_1=-\frac{Kev.er}{2vr^2}$ = -13.6

$\frac{K\mu}{vr^2}$ = -13.6

$\mu=13.6\left(\frac{vr^2}{Ke}\right)$

27. Here, $\lambda_1=650\ nm=650 \times 10^{-9} m$

$\lambda_2=520\ nm=520 \times 10^{-9} m$

Suppose, d = distance between two slits

D = Distance of screen from the slits

a. For third bright fringe, n = 3

$x=n\ \lambda_1 \cdot \frac{D}{d}$

$=3 \times 650 \times \frac{D}{d}=1950 \frac{D}{d}$

b. Let nth bright fringe due to wavelength 650 nm coincide with (n -1)th due to wavelength 520 nm.

Therefore, $n\ \lambda_2=(n-1)\lambda_1$

or, $n \times 520=(n-1) \times 650 \Rightarrow n=5$

Hence, the least distance from the central maximum can be obtained by the relation:

$x=n\lambda_2 \frac{D}{d}=5 \times 520 \frac{D}{d}=2600 \frac{D}{d}\ nm$

Note: The value of d and D are not given in the question.

28. i. Let RS moves with speed v rightward and also RS is at distances x_1 and x_2 from PQ at instants t_1 and t_2, respectively.

Change in flux, $d\phi=\phi_2-\phi_1=Bl(x_2-x_1)$ [$\because$ magnetic flux, $\phi=\vec{B}.\vec{A}=BAcos0^0=Blx$]

$\Rightarrow d\phi = Bldx \Rightarrow \quad \frac{d\phi}{dt}=Bl\frac{dx}{dt}=Blv \quad \left[\because v=\frac{dx}{dt}\right]$

If resistance of loop is R, then $I=\frac{vBl}{R}$

ii. Magnetic force = BIl sin 90°

$=\left(\frac{vBl}{R}\right)Bl=\frac{vB^2l^2}{R}$

Now, External force must be equal to magnetic force

$\therefore$ External force $=\frac{vB^2l^2}{R}$

iii. As, $P=I^2R=\left(\frac{vBl}{R}\right)^2 \times R=\frac{v^2B^2l^2}{R^2} \times R$

$\therefore P=\frac{v^2B^2l^2}{R}$

OR

Given,

Length of loop, l = 8 cm $=8 \times 10^{-2}\ m$

Breadth of loop, b = 2 cm $=2 \times 10^{-2}\ m$

Strength of magnetic field, B = 0.3 T

Velocity of loop, v = 1 cm / sec $=10^{-2}\ m/sec$

Let the field be perpendicular to the plane of the paper directed inwards.

i. The magnitude of induced emf,

$\varepsilon = Blv$

$= 0.3 \times 8 \times 10^{-2} \times 10^{-2}$

$= 2.4 \times 10^{-4}\ V$

Time for which induced emf will last is equal to the time taken by the coil to move outside the field is

$I = \frac{distance\ travelled}{velocity} = \frac{2\times10^{-2}}{10^{-2}}$ = 2 sec

ii. The conductor is moving outside the field normal to the shorter side.

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

The magnitude of induced emf is

$\varepsilon = Bbv$

$= 0.3 \times 2 \times 10^{-2} \times 10^{-2}$

$= 0.6 \times 10^{-4}\ V$

Time, $t = \frac{distance\ travelled}{velocity} = \frac{8\times10^{-2}}{10^{-2}} = 8\ sec$

29. The bulb, as a point source, radiates light in all directions uniformly. At a distance of 3 m, the surface area of the surrounding sphere is

$A = 4\pi r^2 = 4\pi(3)^2 = 113\ m^2$

The intensity I at this distance is

$I = \frac{\text{Power}}{\text{Area}} = \frac{100\text{W}\times2.5}{113\text{m}^2}$ %

$= 0.022\ W/m^2$

Half of this intensity is provided by the electric field and half by the magnetic field is given by:

$\frac{1}{2}I = \frac{1}{2}\left(\varepsilon_0 E_{rms}^2 c\right)$

$= \frac{1}{2}$ $(0.022\ W/m^2)$

$E_{rms} = \sqrt{\frac{0.022}{(8.85\times10^{-12})(3\times10^8)}}\text{V/m}$

$= 2.9\ V/m$

The value of E found above is the root mean square value of the electric field. Since the electric field in a light beam is sinusoidal, the peak electric field, E_0 is

$E_0 = \sqrt{2}E_{\text{rms}} = \sqrt{2} \times 2.9\text{V/m}$

$= 4.07\ V/m$

Thus, the electric field strength for reading is fairly large. Compare it with an electric field strength of TV or FM waves, which is of the order of a few microvolts per metre.

Now, let us calculate the strength of the magnetic field.

$B_{rms} = \frac{E_{rms}}{c} = \frac{2.9\text{Vm}^{-1}}{3\times10^8\text{ms}^{-1}} = 9.6 \times 10^{-9}\ T$

Again, since the field in the light beam is sinusoidal, the peak magnetic field is $B_0 = \sqrt{2}\,B_{rms} = 1.4 \times 10^{-8}$ T. Note that although the energy in the magnetic field is equal to the energy in the electric field, the magnetic field strength is evidently very weak.

OR

i. Gamma's rays.

Frequency range > 3×10^{20} Hz.

ii. The small ozone layer on top of the stratosphere is crucial for human survival because it absorbs most of the ultraviolet rays coming from the sun. If the ozone layer had not been there then ultraviolet rays will also enter the earth and cause danger to the survival of the human race.

iii. An e.m. wave carries a linear momentum with it. The linear momentum carried by a portion of a wave having energy U is given $p = \frac{U}{c}$.

Thus, if the wave incident on a material surface is completely absorbed, it delivers energy U and momentum $p = \frac{U}{c}$ to the surface. If the wave is totally reflected, the momentum of the wave changes from p to -p, Therefore, it follows that an e.m. waves incident on a surface exert a force and hence pressure on the surface.

30. When compass needle of magnetic moment M and moment of inertia I is slightly disturbed by an angle θ from the mean position of equilibrium. Then, restoring torque begins to act on the needle which try to bring the needle back to its mean position which is given by

$\vec{\tau} = -\vec{M} \times \vec{B}$

$\Rightarrow \tau = -MB\sin\theta$ (taking only magnitude), B being magnetic field intensity.

Since, θ is small, so, $\sin\theta = \theta$

$\tau = -MB\theta$ ...... (i)

But $\tau = I\alpha$ ...... (ii)

where, α = angular acceleration, I = moment of inertia of the needle and M = magnetic moment of dipole

On comparing Eqs. (i) and (ii),

$\Rightarrow I\alpha = -MB\theta \Rightarrow \alpha = -(MB/I)\theta$ .....(iii)

Thus, angular acceleration α is directly proportional to angular displacement θ. Therefore, the needle will execute SHM.

Comparing equation (iii) with the general form of SHM, $\alpha = -\omega^2\theta$, we get

$\omega = \sqrt{\frac{MB}{I}}$

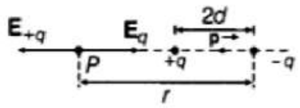
Hence, the time period,

$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{MB/I}}$ or $T = 2\pi\sqrt{\frac{I}{MB}}$

This is the required expression.

Section D

31. i. Let P be a point at distance r from the centre of the dipole on the side of charge -q so its distance from +q will be r+d and from +q its distance will be r-d.



Then, the Electric field at point P due to charge -q of the dipole is given by, $E_{-q} = -\frac{q}{4\pi\varepsilon_0(r+d)^2}\hat{p}$

where, $\hat{p}$ is the unit vector along the dipole axis (from -q to q) as shown in the figure.

Also, the electric field at point P due to charge +q of the dipole is given by, $\mathbf{E}_{+q} = \frac{q}{4\pi\varepsilon_0(r-d)^2}\hat{p}$

The total field at point P will be the vector sum of all the electric fields

$\mathbf{E} = \mathbf{E}_{+q} + \mathbf{E}_{-q} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-d)^2} - \frac{1}{(r+d)^2}\right]\hat{p}$

$\Rightarrow \quad \mathbf{E} = \frac{q}{4\pi\varepsilon_0} \cdot \frac{4dr}{\left(r^2-d^2\right)^2}\hat{p}$

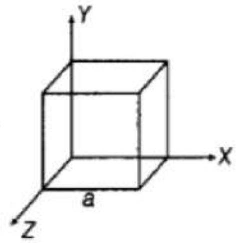
For r >> d, $\mathbf{E} = \frac{4qd}{4\pi\varepsilon_0 r^3}\hat{\mathbf{p}}$

Now, electric dipole moment vector, $\mathbf{p} = q \times 2d\,\hat{p}$

Thus, $\mathbf{E} = \frac{2\mathbf{p}}{4\pi\varepsilon_0 r^3}$

So, electric field due to a dipole decreases as cube of the distance from the centre of the dipole.

ii.



As per the problem, electric field has only x component, for faces normal to X -direction. The magnitude of the electric field at the left face will be

$E_L = 0$ (as, x = 0 at the left face).

The magnitude of the electric field at the right face is E_R = 2a (as, x = a at the right face).

The corresponding fluxes are:

$\phi_L = \mathbf{E}_L \cdot \Delta\mathbf{S} = 0$

$\phi_R = \mathbf{E}_R \cdot \Delta\mathbf{S} = E_R\Delta S\cos\theta = E_R\Delta S \quad (\because \theta = 0^\circ)$

$\Rightarrow \quad \phi_R = E_R a^2$

Net flux (ϕ) through the cube

$= \phi_L + \phi_R = 0 + E_R a^2 = E_R a^2 = 2a(a)^2 = 2a^3 \quad (\text{since } E = 2x\hat{\mathbf{i}})$

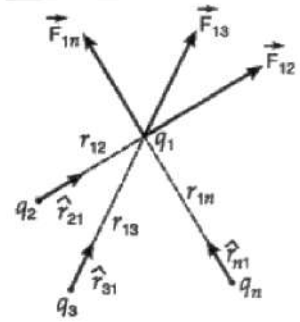
Now,

$\phi = q/\varepsilon_0 \quad \therefore \quad q = \phi\varepsilon_0 = 2a^3\varepsilon_0$

OR

a. The principle of superposition states that when a number of charges are interacting, the total force on a given charge is the vector sum of the individual forces exerted on the given charge by all the other charges.

Consider that n point charges $q_1, q_2, q_3, \dots q_n$ are distributed in space in a discrete manner. The charges are interacting with each other.



According to principle of superposition, the total force on charge q_1 is given by

$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \dots + \vec{F}_{1n}$ .....(i)

If the distance between the charges q_1 and q_2 is denoted as r_{12} and $\hat{r}_{21}$ is unit vector from charge q_2 to q_1 then

$\overrightarrow{F_{12}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r_{12}^2} \hat{r}_{21}$

Similarly, the force on charge q_1 due to other charges is given by

$\overrightarrow{F_{13}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_3}{r_{13}^2} \hat{r}_{31}$

and $\overrightarrow{F_{1n}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_n}{r_{1n}^2} \hat{r}_{n1}$

Hence, in the equation (i), substituting for $\overrightarrow{F_{12}}, \overrightarrow{F_{13}}, \dots \overrightarrow{F_{1n}}$ the total force on the charge q_1 to all other charges is given by

$\vec{F}_1 = \frac{1}{4\pi\varepsilon_0} \left(\frac{q_1 q_2}{r_{12}^2} \hat{r}_{21} + \frac{q_1 q_3}{r_{13}} \hat{r}_{31} + \dots + \frac{q_1 q_n}{r_{1n}^2} \hat{r}_{n1} \right)$

b. Here, $q_A = 10\mu C = 10^{-5}$ C ; $q_B = 5 \times 10^{-6}$ C ; $q_c = -5 \times 10^{-6}$ C and AB = BC = AC = 0.1 m

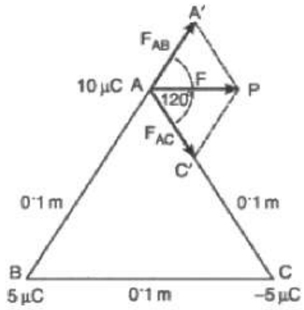
Now, $F_{AB} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_A q_B}{AB^2} = \frac{9\times10^9\times10^{-5}\times5\times10^{-6}}{(0\cdot1)^2}$

or F_{AB} = 45 N (repulsive)

Also, $F_{AC} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_A q_C}{AC^2} = \frac{9\times10^9\times10^{-5}\times5\times10^{-6}}{(0.1)^2}$

or F_{AC} = 45 N (attractive)

The forces F_{AB} and F_{AC} are inclined at an angle of 120° as shown in Fig.



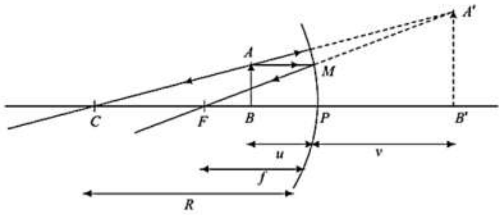
If F is the resultant force on the charge q_A, then

$F = \sqrt{F_{AB}^2 + F_{AC}^2 + 2F_{AB} \cdot F_{AC} \cos 120^\circ}$

$= \sqrt{45^2 + 45^2 + 2 \times 45 \times 45 \times (-0\cdot5)} = 45$ N

The resultant force acts on the charge $10\mu C$ charge along AP i.e. parallel to side BC of the ΔABC.

32. i.



Here, $\Delta ABC \sim \Delta A'B'C$,

$\frac{AB}{A'B'} = \frac{CB}{CB'} = \frac{CP-BP}{CP+PB'} = \frac{-2f+u}{-2f+v}$ ...(i)

Also, $\Delta MPF \sim \Delta A'B'F$, therefore,

$\frac{MP}{A'B'} = \frac{FP}{FB'} = \frac{FP}{FP+PB'}$

$\therefore \frac{AB}{A'B'} = \frac{-f}{-f+v}$ [$\because$ MP = AB] ...(ii)

From equation (i) and (ii), we get

$\frac{-2f+u}{-2f+v} = \frac{-f}{-f+v}$

$\Rightarrow$ -fv - fu + uv = 0

uv = fv + fu

Dividing both sides by uvf, we get,

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$, this is the required result.

ii. By using the Lens-maker formula, we get

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

$\frac{1}{f} = (1.5 - 1)\left[\frac{1}{20} - \frac{1}{\infty}\right]$

$\frac{1}{f} = \frac{0.5}{20} = \frac{1}{40}$

$\Rightarrow$ f = 40 cm

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

$\frac{1}{40} = \frac{1}{v} - \frac{1}{(-30)}$

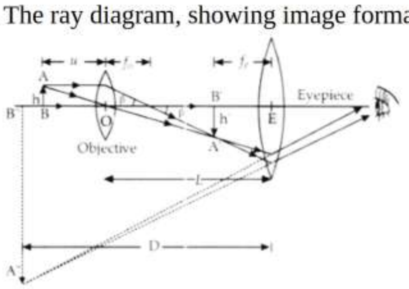
v = $\frac{-40 \times 30}{10}$

v = -120 cm

Image is virtual, and enlarged in front of lens 120 cm away.

OR

i. The ray diagram, showing image formation by a compound microscope, is given below ;-



ii. Linear Magnification due to objective lens is given by $= \frac{\tan\beta}{\tan\alpha}$

$\tan\beta = \frac{h'}{L} = \frac{h}{f_o}$

$\frac{h'}{h} = \frac{L}{f_0}$

(where the distance between the second focal point of the objective and the first focal point of the eyepiece is called the tube length of the compound microscope and is denoted by L) The eyepiece will act as a simple microscope, hence we may use the formula of magnification by a simple microscope for normal adjustment.

$m_e = \frac{D}{f_e}$

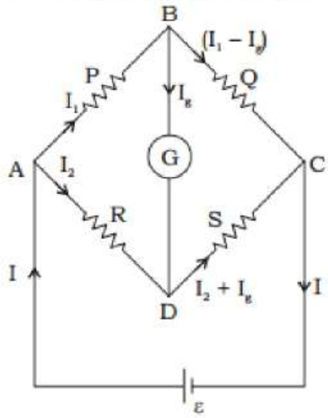
Total magnification, m = $m_o \times m_e$

$= \frac{L}{f_o} \times \frac{D}{f_e} d_{\min}$

a. From the equation, it is clear that resolving power increases when the focal length of the objective is decreased. This is because the minimum separation, $d_{\min}$ decreases when f is decreased.

b. Resolving power decreases when the wavelength of light is increased. This is because the minimum separation, d_{min} increases when λ is increased.

33. i. A Wheatstone bridge arrangement is shown as below:



Using Kirchoff's second law to the loop ABDA we get

$I_1 P - I_g C - I_2 R = 0 : G$ is the galvanometer resistance.

Applying Kirchoff's law to loop BCDB, we get

$(l_1 - l_g) Q - (l_2 + l_g) S - G l_g = 0$

When the bridge is balanced $l_g = 0$

Then, the equations can be written as,

$l_1 P - I_2 R = 0$ or $1_1 P = I_2 R$ ... (1)

$I_1 Q - I_2 S = 0$ or $l_1 Q = I_2 S$ ..... (2)

on dividing equation (1) by (2), we get

$\frac{P}{Q} = \frac{R}{S}$, which is the balanced condition of a Wheatstone bridge.

ii. Let a carbon resistor S is given to the bridge arm CD. Then,

$\Rightarrow \frac{2R}{R} = \frac{2R}{S}$

$\therefore \frac{R}{S} = 1 \Rightarrow R = S = 22 \times 10^3 \ \Omega$

iii. After interchanging the resistances, the balanced bridge would be

$\frac{2R}{X} = \frac{22 \times 10^3}{2 \times 22 \times 10^3} = \frac{1}{2}$

Here X is the resistance of arm AD

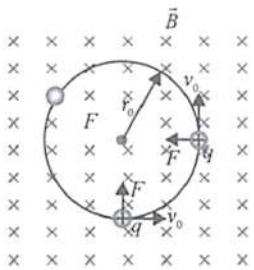
$\Rightarrow X = 4R = 4 \times 22 \times 103 = 88 \text{ k}\Omega$

Hence colour code is Grey orange.

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 ⊥ B

Hence, a ⊥ B

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

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

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

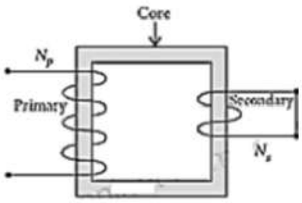
OR

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:**

Step-down transformers are used to decrease or step-down voltages. These are used when voltages need to be lowered for use in homes and factories. A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wireline carrying power is 0.5 Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.



(i) Resistance of the two wire lines carrying power = 0.5 Ω/km

Total resistance = (15 + 15)0.5 = 15 Ω

(ii) Linear power loss = I^2 R

RMS current in the coil, $I = \frac{P}{V_1} = \frac{800 \times 10^3}{4000}$ = 200 A

$\therefore$ Power loss = $(200)^2 \times 15$ = 600 kW

(iii)Assuming that the power loss is negligible due to the leakage of the current.

The total power supplied by the plant = 800 kW + 600 kW = 1400 kW

OR

Voltage drop in the power line = IR = 200 × 15 = 3000 V