SAMPLE PAPER - 2

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. The manifestation of band structure in solids is due to: **[1]**

a) Boltzmann's law

b) Pauli's exclusion principle

c) Bohr's correspondence principle

d) Heisenberg's uncertainly principle

2. The internal resistance of a cell: **[1]**

a) always acts in the cell in open circuit

b) acts only in closed circuit and it reduces the EMF

c) acts only in closed circuit and it reduces the current

d) none of these

3. To obtain a parallel reflected beam from a torch, the reflector of the torch should be: **[1]**

a) All of these

b) parabolic mirror

c) spherical mirror

d) plane mirror

4. When germanium is doped with phosphorus, the doped material has: **[1]**

a) excess positive charge

b) more positive current carriers

c) more negative current carriers

d) excess negative charge

5. Positive and negative point charges of equal magnitude are kept at $\left(0, 0, \frac{a}{2}\right)$ and $\left(0, 0, \frac{-a}{2}\right)$, respectively. The work done by the electric field when another positive point charge is moved from (-a, 0, 0) to (0, a, 0) is: **[1]**

a) positive

b) negative

c) zero

d) depends on the path connecting the initial and final positions

6. Uniform electric and magnetic fields are produced pointing in the same direction. An electron is projected pointing in the same direction, then **[1]**

a) the velocity of electron decreases

b) the velocity of electron increases

c) the electron turns to left

d) the electron turns to right

7. A copper disc is rotated rapidly below a freely suspended magnetic needle. The magnetic needle starts rotating with: **[1]**

i. speed equal to that of disc but in opposite direction
ii. speed equal to that of disc and in the same direction
iii. speed less than that of disc but in same direction
iv. speed less than that of disc but in opposite direction

a) ii and iii

b) iv and i

c) only iii

d) i and ii

8. In Geiger-Marsden scattering experiment, the trajectory traced by an α-particle depends on: **[1]**

a) none of these

b) number of collisions

c) number of scattered α-particles

d) impact parameter

9. In Young's double-slit experiment using a monochromatic light of wavelength λ the path difference (in terms of an integer n) corresponding to any point having half the peak intensity is **[1]**

a) $(2n + 1)\frac{\lambda}{16}$

b) $(2n + 1)\frac{\lambda}{4}$

c) $(2n + 1)\frac{\lambda}{2}$

d) $(2n + 1)\frac{\lambda}{8}$

10. Electric lines of force: **[1]**

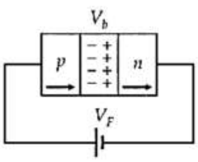
a) are imaginary

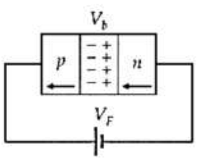
b) exist everywhere

c) exist only when both positive and negative charges are near one another

d) exist only in the immediate vicinity of electric charges

11. In the case of forward biasing of p-n junction, which one of the following figures correctly depicts the direction of flow of carriers? **[1]**

a)


b)


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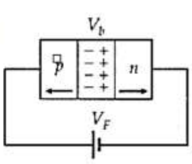

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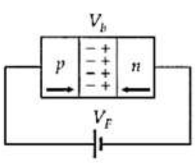


12. Match the corresponding entries of column I with column II [Where m is the magnification produced by the mirror] **[1]**

Column I	Column II
(A) m = - 2	(i) Convex mirror

(B) m = $-\frac{1}{2}$	(ii) Concave mirror
(C) m = +2	(iii) Real image
(D) m = $+\frac{1}{2}$	(iv) Virtual image

a) A-(iv), B-(i), C-(ii), D-(iii)

b) A -(iii), (ii), B-(i), C-(iv), (ii), D-(ii)

c) A-(i), (ii), B-(ii), (iii), C-(ii), (iv), D-(i), (iv)

d) A-(iv), B-(iii), C-(i), D-(ii)

13. In an electron gun, the control grid is given a negative potential relative to the cathode in order to: [1]

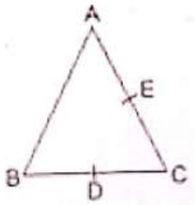
a) to decrease the kinetic energy of electrons

b) decelerate electrons

c) repel electrons and thus control the number of electrons passing through it

d) to select electrons of same velocity and to converge them along the axis

14. Three charges, each +q, are placed at the comers of an isosceles triangle ABC of sides BC and AC, 2a. D and E are the midpoints of BC and CA. The work done in taking a charge Q from D to E, is: [1]



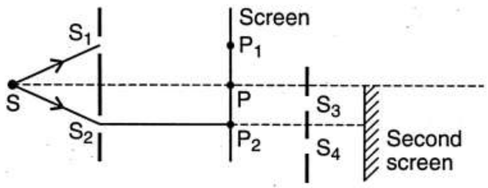
a) $\frac{qQ}{4\pi\varepsilon_0 a}$

b) zero

c) $\frac{3qQ}{4\pi\varepsilon_0 a}$

d) $\frac{3qQ}{8\pi\varepsilon_0 a}$

15. Figure shows a standard two slit arrangement with slits S_1, S_2, P_1, P_2 are the two minima points on either side of P. At point P2 on the screen, there is a hole and behind P_2 is a second two-slit arrangement with slits S_3, S_4 and a second screen behind them. Which of the following statements correct? [1]



a) There would be a single bright point on the second screen.

b) The second screen would be totally dark.

c) There would be a regular two slit pattern on the second screen.

d) There would be no interference pattern on the second screen but it would be lighted.

16. **Assertion (A):** Unlike electric forces and gravitational forces, nuclear force has limited range. [1]
Reason (R): Nuclear force do not obey inverse square law.

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):** Light is a transverse wave but not an electromagnetic wave. [1]
Reason (R): Maxwell showed that speed of electromagnetic waves is related to the permeability and the permittivity of the medium through which it travels.

a) Both A and R are true and R is the correct

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

c) A is true but R is false. d) A is false but R is true.

18. **Assertion (A):** A galvanometer can be used as an ammeter only. **[1]**

Reason (R): A galvanometer can be used in electric circuit to detect the electric current.

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. Draw a circuit diagram for the reverse-biased p-n junction diode. Sketch the voltage-current graph for the same. **[2]**

20. The wavelength of the second line of the Balmer series in the hydrogen spectrum is 4861 $\overset{o}{A}$. Calculate the wavelength of the first line. **[2]**

21. Professor C.V Raman surprised his students by suspending freely a tiny light ball in a transparent vacuum chamber by shining a laser beam on it. Which property of EM waves was he exhibiting? Give one more example of this property. **[2]**

OR

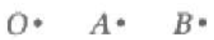
An e.m. wave is travelling in a medium with a velocity $v = v\hat{i}$. The electric field oscillations, of this e.m. wave, are along the y-axis.

a. Identify the direction in which the magnetic field oscillations are taking place, of the e.m. wave.
b. How are the magnitudes of the electric field and magnetic fields in the electromagnetic wave related to each other?

22. Draw the circuit to forward bias a diode. (The supply is 3 V and 100 mA battery). If the diode is made of silicon and knee voltage is 0.7 V, and a current of 20 mA passes through the diode, find the wattage of the resistor and the diode. **[2]**

23. A point charge Q is placed at point **O** as shown in the figure. Is the potential at point A, i.e., V_A, greater, smaller or equal to potential, V_B at point B, when Q is **[2]**

a. positive, and
b. negative charge?



OR

What do you mean by a potential difference of 1 volt?

24. i. The work function for the surface of aluminium is 4.2 eV. How much potential difference will be required to stop the emission of maximum energy electrons emitted by light of 2000 $\overset{o}{A}$ wavelength? **[2]**

ii. What will be the wavelength of that incident light for which stopping potential will be zero? Given h = 6.6 × 10^{-34} Js, c = 3 × 10^8ms^{-1}.

25. How long can an electric lamp of 100W be kept glowing by fusion of 2.0 kg of deuterium? Take the fusion reaction as: ${}^2_1H + {}^2_1H \rightarrow {}^3_2 He + n + 3.2MeV$ **[2]**

Section C

26. Using Bohr's total postulates, derive the expression for the total energy of the electron in the stationary states of hydrogen atom. **[3]**

27. For a single slit of width a the first minimum of the interference pattern of a monochromatic light of wavelength **[3]**

λ occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance a. Explain.

28. Define self-inductance of a coil. Obtain the expression for the energy stored in an inductor L connected across a source of emf. **[3]**

OR

Two different coils have self inductances, L_1 = 8mH and L_2 = 2mH. At a certain instant, the current in the two coils is increasing at the same constant rate and the power supplied to the two coil is the same.

Find the ratio of :

a. induced voltage
b. current and
c. energy stored in the two coils at that instant?

29. **[3]**
   i. How are electromagnetic waves produced? Explain.
   ii. A plane electromagnetic wave is travelling through a medium along the +ve z-direction. Depict the electromagnetic wave showing the directions of the oscillating electric and magnetic fields.

OR

Suppose that the electric field amplitude of an electromagnetic wave E_0 = 120 NC^{-1} and that its frequency is ν = 50.0 MHz.

i. Determine, B_0, ω, k, and λ.
ii. Find expressions for E and B.

30. Define neutral point. Locate the positions of neutral points, when a small bar magnet is placed with its north pole **[3]**
   i. towards the north of the earth and
   ii. towards the south of the earth.

Section D

31. Consider a sphere of radius R with charge density distributed as **[5]**

$\rho(r)$ = kr for r $\leq$ R

= 0 for r > R

a. Find the electric field at all points r.
b. Suppose the total charge on the sphere is 2e where e is the electron charge. Where can two protons be embedded such that the force on each of them is zero? Assume that the introduction of the proton does not alter the negative charge distribution?

OR

In 1959 Lyttleton and Bondi suggested that the expansion of the Universe could be explained if matter carried a net charge. Suppose that the Universe is made up of hydrogen atoms with a number density N, which is maintained a constant. Let the charge on the proton be: e_p = – (1 + y)e where e is the electronic charge.

a. Find the critical value of y such that expansion may start.
b. Show that the velocity of expansion is proportional to the distance from the centre.

32. Determine the 'effective focal length' of the combination of the two lenses having focal lengths 30 cm and -20cm if they are placed 8.0 cm apart with their principal axes coincident. Does the answer depend on which side of the combination a beam of parallel light is incident? Is the notion of effective focal length of this system useful at all? **[5]**

OR

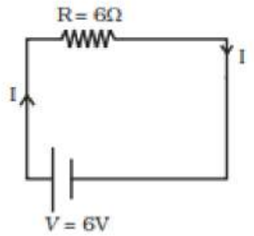
With the help of ray diagram, show the formation of image of a point object by refraction of light at a spherical surface separating two media of refractive indices n_1 and n_2 ($n_2 > n_1$) respectively. Using this diagram, derive the relation $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$. Write the sign conventions used.

What happens to the focal length of convex lens when it is immersed in water?

33. a. Consider circuit in Fig. How much energy is absorbed by electrons from the initial state of no current (ignore thermal motion) to the state of drift velocity? **[5]**

b. Electrons give up energy at the rate of RI^2 per second to the thermal energy. What time scale would one associate with energy in problem (a)?

n = no. of electron/volume = $10^{29}/m^3$, length of circuit = 10 cm, cross-section = A = $(1mm)^2$



Section E

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

A charged particle moving in a magnetic field experiences a force that is proportional to the strength of the magnetic field, the component of the velocity that is perpendicular to the magnetic field and the charge of the particle.

This force is given by $\vec{F} = q(\vec{v} \times \vec{B})$ where q is the electric charge of the particle, v is the instantaneous velocity of the particle, and B is the magnetic field (in tesla). The direction of force is determined by the rules of cross product of two vectors. Force is perpendicular to both velocity and magnetic field. Its direction is given as $\vec{v} \times \vec{B}$ if q is positive and opposite of $\vec{v} \times \vec{B}$ if q is negative.

The force is always perpendicular to both the velocity of the particle and the magnetic field that created it. Because the magnetic force is always perpendicular to the motion, the magnetic field can do no work on an isolated charge. It can only do work indirectly, via the electric field generated by a changing magnetic field.

(i) What kind of magnetic field is produced by an infinitely long current carrying conductor?

(ii) What happens to a stationary electron placed in magnetic field ?

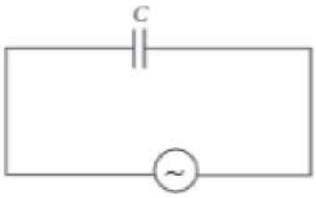
(iii) What happens to the velocity of a proton projected with a uniform velocity v along the axis of a current-carrying solenoid?

OR

What are the conditions under which a charged particle experiences magnetic force in a magnetic field?

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

Let a source of alternating e.m.f. $E = E_0 \sin \omega t$ be connected to a capacitor of capacitance C. If P is the instantaneous value of current in the circuit at instant t, then $I = \frac{E_0}{1/\omega C} \sin\left(\omega t + \frac{\pi}{2}\right)$. The capacitive reactance limits the amplitude of current in a purely capacitive circuit and it is given by $X_C = \frac{1}{\omega C}$.



(i) What is the unit of capacitive reactance?

(ii) What will be the capacitive reactance of a 5 μ F capacitor for a frequency of 10^6 Hz?

(iii) In a capacitive circuit, by what value of phase angle does alternating current leads the e.m.f?

OR

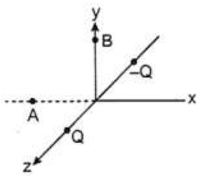
One microfarad capacitor is joined to a 200 V, 50 Hz alternator. What will be the rms current through the capacitor?

Solution

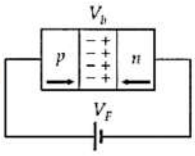
SAMPLE PAPER - 2

Class 12 - Physics

Section A

1. **(b)** Pauli's exclusion principle
   Explanation: Pauli's exclusion principle
2. **(c)** acts only in closed circuit and it reduces the current
   Explanation: The internal resistance of a cell acts only in a closed circuit and it reduces the current.
3. **(b)** parabolic mirror
   Explanation: parabolic mirror
4. **(c)** more negative current carriers
   Explanation: Ge(32) = 2, 8, 18, 4
   P(15) = 2, 8, 5
   therefore, 5+ 4 = 9 - 8 = 1(extra)
5. **(c)** zero
   Explanation: 

   A = (-a, 0, 0)
   B = (0, a, 0)
   Point charge is moved from A to B.
   $V_A - V_B = 0$
   $\therefore W_{AB} = q(V_A - V_B) = 0$
6. **(a)** the velocity of electron decreases
   Explanation: Electron will not experience any force due to magnetic field as direction of velocity is parallel to direction of magnetic field since magnetic force = qvBsinθ.
   Due to electric field, force on electron will be in direction opposite to that of electric field, hence opposite to direction of motion of electron. Hence it will deaccelerate and its velocity will decrease.
7. **(c)** only iii
   Explanation: speed less than that of disc but in same direction
8. **(d)** impact parameter
   Explanation: The trajectory of an α-particle depends on the impact parameter which is the perpendicular distance of the initial velocity vector of the α-particle from the centre of the nucleus. For small impact parameter α-particle close to the nucleus suffers larger scattering.
9. **(b)** (2n + 1)$\frac{\lambda}{4}$
   Explanation: $I = I_{\max} \cos^2 \frac{\phi}{2}$ ....(i)
   Given $I = \frac{I_{\max}}{2}$ ...(ii)
   $\therefore$ From Eqs. (i) and (ii), we have
   $\phi = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}$
   Or path difference, $\Delta x = \left(\frac{\lambda}{2\pi}\right) \cdot \phi$
   $\therefore \Delta x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4} ..., \left(\frac{2n+1}{4}\right) \lambda$
10. **(a)** are imaginary
    Explanation: An electric line of force is an imaginary continuous line or curve drawn in an electric field.

11. **(d)** 

Explanation: Due to forward biasing, the holes of p-region move towards n-side and electrons of n-side move towards the p-side.

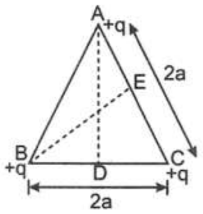
12. **(c)** A-(i), (ii), B-(ii), (iii), C-(ii), (iv), D-(i), (iv)

Explanation: In the case of mirrors, convex mirrors always produce diminished and virtual images. Hence, the convex mirror cannot have magnification, m > 1. Also, in mirrors, the virtual image always forms on right-hand side. Hence magnification produced is always positive, (i.e. m for virtual image, m = $+\frac{1}{2}$ or m = +2).

13. **(c)** repel electrons and thus control the number of electrons passing through it

Explanation: The electron gun consists of a heater and cathode to generate electrons, a control grid to control brightness by controlling electron flow, and two anodes. In an electron gun, the control grid is given a negative potential relative to the cathode to repel electrons and to control the number of electrons passing through it.

14. **(b)** zero

Explanation: 

Here, AC = BC = 2a

D and E are the mid-points of BC and AC.

AE - EC = a

and BD = DC = a

In ΔADC, $(AD)^2 = (AC)^2 - (DC)^2$

$= (2a)^2 - (a)^2$

$= 4a^2 - a^2 = 3a^2$

AD = $a\sqrt{3}$

Similarly, BE = $a\sqrt{3}$

Potential at point D due to the given charge configuration is,

$V_D = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{BD} + \frac{q}{DC} + \frac{q}{AD}\right]$

$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{a} + \frac{1}{a} + \frac{1}{\sqrt{3}a}\right]$

$= \frac{q}{4\pi\varepsilon_0 a}\left[2 + \frac{1}{\sqrt{3}}\right]$ ...(i)

Potential at point E due to the given charge configuration is,

$V_E = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AE} + \frac{q}{EC} + \frac{q}{BE}\right]$

$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{a} + \frac{1}{a} + \frac{1}{a\sqrt{3}}\right]$

$= \frac{q}{4\pi\varepsilon_0 a}\left[2 + \frac{1}{\sqrt{3}}\right]$ ...(ii)

From eqns. (i) and (ii), it is clear that,

$V_D = V_E$

The work done in taking a charge Q from D to E is,

$W = Q(V_E - V_D) = 0$ $(V_D = V_E)$

15. **(c)** There would be a regular two slit pattern on the second screen.

Explanation: According to the figure given in the problem, there is a hole at minima point P_2. This hole will act as a source of fresh light for slits S_3 and S_4. Hence, there will be a regular two slit pattern on the second screen.

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

Explanation: Both A and R are true but R is not the correct explanation of A.

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

Explanation: The speed of em waves in free space is given by

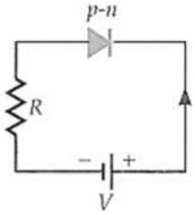
$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

where $\mu_0 = 4\pi \times 10^{-7}$ Ns^2/C^2 is permeability constant of vacuum and $\varepsilon_0 = 8.85419 \times 10^{-12}$ C^2/Nm^2 is the permittivity of free space. After substituting these value, the value of c (= 2.99792×10^8 m/s) which is same as the speed of light in vacuum. From this it is concluded that light is an electromagnetic wave.

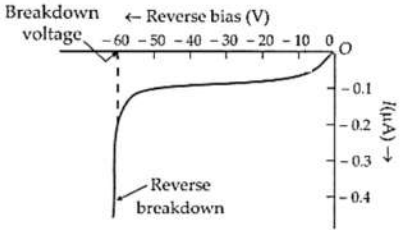
18. **(d)** A is false but R is true.

Explanation: A galvanometer can be used both as ammeter and voltmeter, It can be used as an ammeter by joining a low resistance in parallel with it and as a voltmeter by joining a high resistance in series with it.

Section B

19. 

The figure shows a reverse-biased p-n junction diode in which the p-side is connected to the -ve terminal and the n-side is connected to the +ve terminal of the battery and shows its voltage-current graph.



20. The wavelengths λ_1 and λ_1 of the first and second lines of the Balmer series are given by

$\frac{1}{\lambda_1} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5}{36}R$ and $\frac{1}{\lambda_2} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = \frac{3}{16}R$

$\therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{3}{16} \times \frac{36}{5} = \frac{27}{20}$

or $\lambda_1 = \frac{27}{20} \times \lambda_2 = \frac{27}{20} \times 4861 = 6562\text{Å}$

21. The properties of an electromagnetic wave are the same as other waves. Like other waves, an electromagnetic wave also carries energy and momentum. We know the dual nature of radiation and matter.

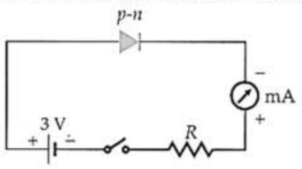
since it carries momentum, an electromagnetic wave also exerts pressure called radiation pressure. This property of electromagnetic waves helped professor CV Raman surprised his students by suspending freely a tiny light ball in a transparent vacuum chamber by shining a laser beam on it.

OR

a. Here e.m. wave travels in x-direction and electric field oscillates along y-direction. But the e.m. wave propagates in the direction of $\vec{E} \times \vec{B}$. Hence magnetic field must oscillate along z-direction because $(+\hat{j}) \times (+\hat{k}) = +\hat{i}$

b. $\frac{E_0}{B_0} = c$, the speed of light.

22. The circuit for forward biased diode is shown in figure.



Here emf of battery = 3 V

Knee voltage, V_k = 0.7 V

$\therefore$ Voltage drop across R = 3 - 0.7 = 2.3 V

Current in the circuit, I = 20 mA = 20×10^{-3} A

Wattage of R = Voltage drop across R $\times$ Current

= $2.3 \times 20 \times 10^{-3}$ = 0.046 W

Wattage of diode

= Voltage drop across diode × current

= $0.7 \times 20 \times 10^{-3} = 0.014$ W

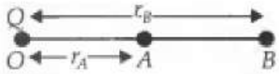
23. a. $V_A > V_B$

b. $V_A < V_B$

Detailed Answer:

Let r_A is the distance of point A from point charge Q

and r_B is the distance of point B from point charge Q.



Potential at point A :

$V(r_A) = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r_A}$

Potential at point B :

$V(r_B) = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r_B}$

Since $r_A < r_B$, so when :

charge Q is positive; $V_A > V_B$ so that $v_A - v_B > 0$

charge Q is negative; $V_A < V_B$

OR

Potential difference is the difference in the amount of energy that charge carriers have between two points in a circuit. A potential difference of one volt is equal to one Joule of energy being used by one Coulomb of charge when it flows between two points in a circuit.

24. i. Here $W_0 = 4.2$ eV $= 4.2 \times 1.6 \times 10^{-19}$ J,

$\lambda = 2000$ Å $= 2000 \times 10^{-10}$m, $V_0 = ?$

The maximum K.E. of the emitted photoelectron,

$K_{\max} = \frac{hc}{\lambda} - W_0$

$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2000 \times 10^{-10}} - 4.2 \times 1.6 \times 10^{-19}$

$= 3.18 \times 10^{-19}$J

Stopping potential,

$V_0 = \frac{K_{\max}}{e}$

$= \frac{3.18 \times 10^{-19}}{1.6 \times 10^{-19}} = 1.9875$ V.

ii. For threshold wavelength λ_0, $K_{max} = 0$. Hence

$\lambda_0 = \frac{hc}{W_0} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4.2 \times 1.6 \times 10^{-19}}$

$= 2.946 \times 10^{-7}$ m = 2946 Å.

25. When two nuclei of deuterium fuse together,

Energy released = 3.2 MeV

Number of deuterium atoms in 2 kg

$= \frac{6.023 \times 10^{23}}{2} \times 2000 = 6.023 \times 10^{26}$

When 6.023×10^{26} nuclei of deuterium fuse together, energy released

$= \frac{3.2}{2} \times 6.023 \times 10^{26} MeV$

$= \frac{3.2}{2} \times 6.023 \times 10^{26} \times 1.6 \times 10^{-13} J$

$= 1.54 \times 10^{14} J$ or Ws

Power of electric lamp = 100 W

If the lamp glows for time t, then the electrical energy consumed by the lamp is 100 t.

$\therefore 100t = 1.54 \times 10^{14}$ or $t = 1.54 \times 10^{12} s$

$= \frac{1.54 \times 10^{12}}{3.154 \times 10^7} years$

$= 4.88 \times 10^4 years$

Section C

26. According to Bohr's postulates, in a hydrogen atom, a single electron revolves around a nucleus of charge +e. For an electron moving with a uniform speed in a circular orbit of a given radius, the centripetal force is provided by Coulomb force of attraction between the electron and the nucleus. The gravitational attraction may be neglected as the mass of electron and proton is very small. So,

$mv^2/r = ke^2/r^2$ (where, $k = 1/4\pi\varepsilon_0$)

or $mv^2 = ke^2/r$.............(i)

where, m = mass of electron, r = radius of electronic orbit, v = velocity of electron

Again, by Bohr's second postulates

$mvr = nh/2\pi$

where, n = 1, 2, 3, ... or $v = nh/2\pi mr$

Putting the value of v in Eq. (i)

$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{ke^2}{r} \Rightarrow r = \frac{n^2h^2}{4\pi^2kme^2}$ ....(ii)

Kinetic energy of electron ,

$E_K = \frac{1}{2}mv^2 = \frac{ke^2}{2r}\left(\because \frac{mv^2}{r} = \frac{ke^2}{r^2}\right)$

Using Eq(ii), we get

$E_K = \frac{ke^2}{2}\frac{4\pi^2kme^2}{n^2h^2} = \frac{2\pi^2k^2me^4}{n^2h^2}$

Potential energy of electron,

$E_P = -\frac{k(e)\times(e)}{r} = -\frac{ke^2}{r}$

Using Eq(ii), we get

$E_P = -ke^2 \times \frac{4\pi^2kme^2}{n^2h^2} = -\frac{4\pi^2k^2me^4}{n^2h^2}$

Hence, total energy of the electron in the n^{th} orbit

$E = E_P + E_K = -\frac{4\pi^2k^2me^4}{n^2h^2} + \frac{2\pi^2k^2me^4}{n^2h^2}$

$= -\frac{2\pi^2k^2me^4}{n^2h^2}$

27. The angle will be $\frac{\lambda}{a}$.

Here, the statement considers interference as a general term to represent both diffraction (and interference phenomenon in single slit) and interference by two slits. In terms of physical point of view diffraction is also an interference of secondary wavelets from a single slit.

From the theory of diffraction we know that minima condition is given by

$n\lambda = a\sin\theta$

for the minima n = 1

$\Rightarrow \lambda = a\sin\theta$

As because is small we have $\sin\theta \approx \theta$

$\Rightarrow \lambda = a\theta$

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

Thus in single slit the first minima occurs at angle.

But when we consider interference of two slits separated by a distance a and distance of screen from the slit = D, the position of the first maxima is given by

$y = \frac{\lambda D}{a}$

Again, y being small compared to D.

$y = D\theta$

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

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

This means in the case of two slits we have a miximum at $\frac{\lambda}{a}$ angle.

28. Self-inductance of a coil is the property of the coil in which it opposes the change of current flowing through it. Inductance is attained by a coil due to the self-induced emf produced in the coil itself by changing the current flowing through it.

Self-induction of the long solenoid of inductance L, (A long solenoid is one which length is very large as compared to its cross-section area.) the magnetic field inside such a solenoid is constant at any point and given by

$B = \frac{\mu_0 NI}{l}$

Magnetic flux through each turn of solenoid

$\phi = B \times$ area of each turn

$\phi = \frac{\mu_0 NI}{l} \times$ A

total flux = flux $\times$ total number of turns

$N\phi = N\left(\frac{\mu_0 NI}{l} \times A\right)$ ... (i)

If L is the coefficient of inductance of solenoid

$N\phi$ = LI ... (ii)

from equation (i) and (ii)

LI = $N\left(\frac{\mu_0 NI}{l} \times A\right)$

L = $\frac{\mu_0 N^2 A}{l}$ ... (iii)

The magnitude of emf is given by

|e| or e = $L\frac{dI}{dt}$ ... (iv)

multiplying I to both sides

eIdt = LIdI

but I = $\frac{dq}{dt}$

Idt = dq

Also work done (dW)= voltage $\times$ Charge(dq)

or dW = e$\times$dq = eIdt

substituting the values in equation (iv)

dW = LIdt

By integrating both sides

$\int_0^w dW = \int_0^{I_0} LIdt$

W = $\frac{1}{2}LI_0^2$

this work done is in increasing the current flow through inductor is stored as potential energy (U) in the magnetic field of inductor

U = $\frac{1}{2}LI_0^2$

OR

a. We know $e = L\frac{dI}{dt}$

   Thus, $\frac{e_1}{e_2} = \frac{L_1}{L_2} = \frac{8}{2} = 4$

b. We know, P = e I

   $P_1 = P_2$

   $e_1 I_1 = e_2 I_2$

   $\therefore \frac{I_1}{I_2} = \frac{e_2}{e_1} = \frac{1}{4}$

c. We know,

   $U = \frac{1}{2}LI^2$

   and $\frac{I_1}{I_2} = \frac{e_2}{e_1}$

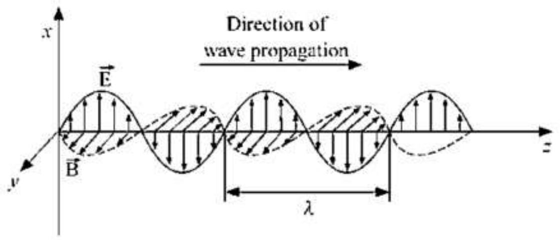
   $\therefore \frac{U_1}{U_2} = \frac{\frac{1}{2}L_1}{\frac{1}{2}L_2}\left(\frac{I_1}{I_2}\right)^2 = \frac{8}{2}\left(\frac{1}{4}\right)^2 = \frac{1}{4}$

29. i. Electromagnetic waves are formed as a result of accelerating (electric) charges under electric field. Electric charges exhibit electrostatic behavior and once they start moving magnetic effects come into play. As a result of this, a duality is established which is called electromagnetism. The electromagnetic waves are emitted by those charged particles. These waves move with the velocity of light and they do not need any medium for propagation

    ii. The cross product of electric and magnetic field vectors i.e. $\vec{E} \times \vec{B}$ gives the direction in which the wave travels.

    It is given that wave is propagating along the +z-axis. This means that electric field vector is oscillating in positive x-direction and magnetic field vector in the positive y-direction.

The propagation of the electromagnetic wave in +z direction is shown here:



OR

i. Given, E_0 = 120 NC^{-1}, ν = 50.0 MHz = 50 × 10^6 Hz

a. $B_0 = \frac{E_0}{c} = \frac{120}{3\times10^8}$ = 4 × 10^{-7} T = 400 nT

b. $\omega = 2\pi\nu$ = 2 × 3.14 × 50 × 10^6 = 3.14 × 10^8 rad s^{-1}

c. $k = \frac{2\pi}{\lambda} = \frac{2\pi\nu}{c} = \frac{3.14\times10^8}{3\times10^8}$= 1.047 rad m^{-1}

d. $\lambda = \frac{2\pi}{k} = \frac{2\times3.14}{1.047}$ = 6 m

ii. Let electromagnetic wave travel along x-axis, where $\vec{E}$ and $\vec{B}$ are along y-axis and z-axis respectively.

Then $E_y = E_0 \sin(kx - \omega t)$

= 120 sin (1.05x - 3.14 × 10^8t) NC^{-1}

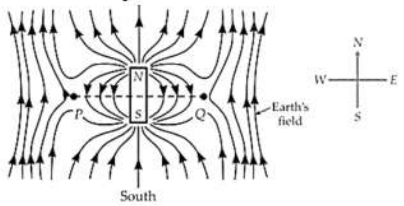
$B_z = B_0 \sin(kx - \omega t)$

= 400 sin (1.05x - 3.14 × 10^8t) NC^{-1}

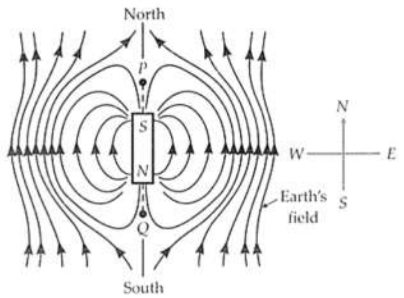
where x and t are in metre and second respectively.

30. **Neutral point:** It is the point where the magnetic field due to a magnet is equal and opposite to the horizontal component of earth's magnetic field. The resultant magnetic field at the neutral point is zero.

i. **Magnet placed in the magnetic meridian with its north pole pointing north:** In figure shows the magnetic lines of force of a bar magnet placed in the magnetic meridian with its north-pole pointing towards the geographic north of the earth. The fields due to the magnet and the earth are in same directions at points on the axial line and are in opposite directions at points on the equatorial line. So the resultant field is stronger at axial points and weaker at equatorial points. The two neutral points P and Q lie on the equatorial line.



ii. **Magnet placed in the magnetic meridian with its south-pole pointing north:** In a figure shows the magnetic lines of force of a bar magnet placed in the magnetic meridian with its south-pole pointing towards the geographic north of the earth. Here the fields due to the magnet and the earth are in the same direction at points on the equatorial line and are in opposite directions at points on the axial line of the magnet. So the resultant field is weaker at axial points and is stronger at equatorial points. In this case the two neutral points P and Q lie on the axial line near the ends of the magnet.

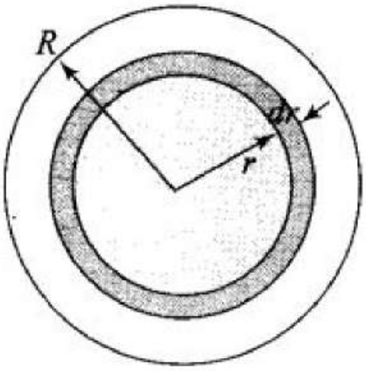


Section D

31. a. The symmetry of the problem suggests that the electric field is radial.

For points r < R, consider spherical Gaussian surfaces. Then on the surface

Consider Gaussian surfaces as shown in the figure given below.let us consider a sphere of radius R.



For points at r < R

$\oint \overrightarrow{E} \overrightarrow{dS} = \frac{1}{\varepsilon_0} \int p dV$

Now, $V = \frac{4}{3}\pi r^3 \Rightarrow dV = 3 \times \frac{4}{3}\pi r^3 dr$ or $dV = 4\pi r^2 dr$

$\Rightarrow \oint E \cdot dS = \frac{1}{\varepsilon_0} 4\pi K \int_0^r r^3 dr [\because p(r) = Kr]$

$\Rightarrow (E) 4\pi r^2 = \frac{4\pi K}{\varepsilon_0} \frac{r^4}{4}$

$\Rightarrow E = \frac{1}{4\varepsilon_0} K r^2$

Here, charge density is positive. Therefore, the direction of E is radially outwards.

For points r>R, electric field intensity is given by:

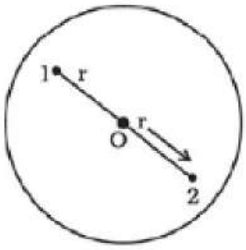
$\oint E \cdot dS = \frac{1}{\varepsilon_0} \int p dV$

$\Rightarrow E\left(4\pi r^2\right) = \frac{4\pi K}{\varepsilon_0} \int_0^R r^3 dr = \frac{4\pi K}{\varepsilon_0} \frac{R^4}{4}$

$\Rightarrow E = \frac{K}{4\varepsilon_0} \frac{R^4}{r^2}$

Now charge density is again positive. So, the direction of E is radially outward.

b. The two protons must be on the opposite sides of the center along a diameter. Suppose the protons are at a distance r from the center.



$q = \int_0^R p dV = \int_0^R (Kr) 4\pi r^2 dr$

$q = 4\pi K \frac{R^4}{4} = 2e$

$\therefore k = \frac{2e}{\pi R^4}$

two protons are embedded at a distance r from the center of sphere. Consider the forces on proton 1. The attractive force due to the charge distribution is

$F_1 = -eE = \frac{-ehr^2}{4\varepsilon_0}$

Repulsive force on proton 1 due to proton 2 is

$F_2 = \frac{e^2}{4\pi\varepsilon_0 (2r)^2}$

Net force on proton 1, $F_{Net} = F_1 + F_2$

$F = \frac{-ekr^2}{4\varepsilon_0} + \frac{e^2}{16\pi\varepsilon_0 r^2}$

So, $F_{\log} = \left[\frac{-er^2}{4\varepsilon_0} \frac{Ze}{\pi R^4} + \frac{e^2}{16\pi\varepsilon_0 r^4}\right]$

Thus, the net force on proton 1 will be zero, when

$\frac{er^2 2^*}{4\varepsilon_0 \pi R^4} = \frac{e^2}{16\pi\varepsilon_0 r}$

$\Rightarrow r^4 = \frac{R^4}{8}$

$\Rightarrow r = \frac{R}{(8)^{1/4}}$

Therefore, the distance of both the protons from the centre must be $r = \frac{R}{(8)^{1/4}}$.

OR

a. Suppose universe is a perfect sphere of radius R and its constituents are Hydrogen atom are distributed uniformly.

As hydrogen atom contains one proton and one electron, charge on each hydrogen atom

$e_H = e_P + e = -(1 + y)e + e = -ye = |ye|$

According to Gauss' theorem. $\oint E \cdot ds = \frac{q}{\varepsilon_0}$

$\Rightarrow E\left(4\pi R^2\right) = \frac{1}{\varepsilon_0}\left[\frac{4}{3}\left(\pi R^3 N|ye|\right)\right]$

$\Rightarrow E = \frac{1}{3}\frac{N|ye|R}{\varepsilon_0}$ ...(i)

Let, mass of each hydrogen atom $\sim m_{p=}$(mass of a proton), G_R= gravitational field at distance R on the sphere.

Then $4\pi R^2 G_R = 4\pi G m_p\left(\frac{4}{3}\pi R^3\right)N$

$\Rightarrow G_R = \frac{-4}{3}\pi G m_p N R$ ...(ii)

$\therefore$ Gravitational force on this atom is $F_\sigma = G_R \times m_p = \frac{-4}{3}\pi G m^2 p N R$ ...(iii)

Coulomb force on hydrogen atom at R is $F_C = E(\text{ye}) = \frac{1}{3}\frac{Ny^2e^2R}{\varepsilon_0}$ [from Eq.(i)]

Expansion of the universe will start when coulomb repulsion $F_C > F_G$ on the hydrogen atom.

Now, the critical value of y (say y_2 to start expansion would be when, $F_C = F_O$

$\Rightarrow \frac{1}{3}\frac{Ny^2e^2R}{\varepsilon_0} = \frac{4\pi}{3}Gm_p^2NR$

$\Rightarrow y^2 = (4\pi\varepsilon_0)G\left(\frac{m_p}{e}\right)^2 = \frac{1}{9\times10^9}\times\left(6.67\times10^{-11}\right)\left(\frac{\left(1.66\times10^{-27}\right)^2}{\left(1.6\times10^{-19}\right)^2}\right) = 79.8\times10^{-38}$

$\Rightarrow y = \sqrt{79.8\times10^{-39}} = 8.910^{-19}$

$y=10^{-18}$

Hence 10^{-18} is the required critical value of y corresponding to which expansion of universe would start.

b. Net force experience by the hydrogen atom is given by:

$F_{Nr} = F_e - F_C = \frac{1}{3}\frac{Ny^2e^2R}{\varepsilon_0} - \frac{4\pi}{3}GNm_p^2R$

Due to net force, the hydrogen atom experiences an acceleration given by $m_p\frac{d^2R}{dt^2}$

$F = m_p\frac{d^2R}{dt^2} = \frac{1}{3}\frac{NY^2e^2}{\varepsilon_0}R - \frac{4\pi}{3}Gm_p^2NR$

$m_p\frac{d^2R}{dt^2} = \left(\frac{1}{3}\frac{NY^2e^2R}{\varepsilon_0} - \frac{4\pi}{3}Gm_p^2N\right)R$

$\frac{d^2R}{dt^2} = \frac{1}{m_p}\left[\frac{1}{3}\frac{NY^2e^2R}{\varepsilon_0} - \frac{4\pi}{3}Gm_p^2N\right]R = \alpha^2R$ ...(iv)

Where, $\alpha^2 = \frac{1}{m_p}\left[\frac{1}{3}\frac{NY^2e^2R}{\varepsilon_0} - \frac{4\pi}{3}Gm_p^2N\right]$

The general solution of Eq (iv) is given by $R = Ae^{\alpha t} + B^{-at}$

Here, we are looking for expansion, here, so B = 0 and $R = Ae^{\alpha t}$

$\Rightarrow$ Velocity of expansion,$v = \frac{dR}{dt} = Ae^{\alpha t}(\alpha) = \alpha Ae^{at} = \alpha R$

Hence, $v \propto R$ i.e., the velocity of expansion is proportional to the distance from the centre.

32. Here, f_1 = 30 cm, f_2 = -20 cm, d = 8.0 cm

Let a parallel beam be incident on the convex lens first. If second lens were absent, then

$\therefore u_1 = \infty$ and f_1 = 30 cm

As $\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$

$\therefore \frac{1}{v_1} - \frac{1}{\infty} = \frac{1}{30}$

or v_1 = 30 cm

This image would now act as virtual object for second lens.

$\therefore u_2 = +(30 - 8) = +22$ cm

f_2 = -20 cm

Since, $\frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2}$

$\therefore \frac{1}{v_2} = \frac{1}{-20} + \frac{1}{22}$

$= \frac{-11+10}{220} = \frac{-1}{220}$

v_2 = -220 cm

$\therefore$ Parallel incident beam would appear to diverge from a point 220 - 4 = 216 cm from the centre of the two lens system.

Assume that a parallel beam of light from the left is incident first on the concave lens.

$\therefore u_1 = -\infty$, f_1 = -20 cm

As $\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$

$\therefore \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1} = \frac{1}{-20} + \frac{1}{-\infty} = -\frac{1}{20}$

v_1 = -20cm

This image acts as a real object for the second lens

u_2 = -(20 + 8) = -28cm, f_2 = 30 cm

Since, $\frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f_2}$

$\therefore \frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2} = \frac{1}{30} - \frac{1}{28} = \frac{14-15}{420}$

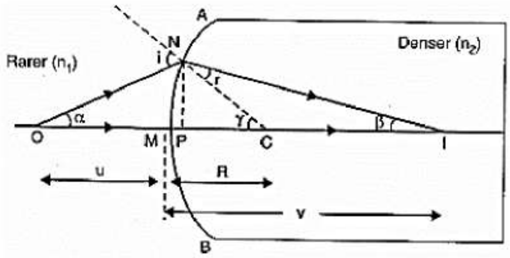
v_2 = -420 cm

The parallel beam appears to diverge from a point 420 - 4 = 416 cm, on the left of the centre of the two lens system.

We finally conclude that the answer depends on the side of the lens system where the parallel beam is incident. Therefore, the notion of effective focal length does not seem to be meaningful here.

OR

AMB is a convex surface separating two media of refractive indices n_1 and n_2 ($n_2 > n_1$). Consider a point object O placed on the principal axis. A ray ON is incident at N and refracts along NI. The ray along ON goes straight and meets the previous ray at I. Thus I is the real image of O.



From Snell's law,

$\frac{n_2}{n_1} = \frac{\sin i}{\sin r}$

$n_1 \sin i = n_2 \sin r$

or $n_1 i = n_2 r$ [$\because \sin\theta \cong \theta$ as θ is very small]

From $\Delta NOC, i = \alpha + \gamma$

From $\Delta NIC, \gamma = r - \beta$

or $r = \gamma - \beta$

$\therefore n_1(\alpha + \gamma) = n_2(\gamma - \beta)$

or $n_1\alpha + n_2\beta = (n_2 - n_1)\gamma$

But $\alpha \cong \tan\alpha = \frac{NP}{OP} = \frac{NP}{OM}$ [P is close to M]

$\beta \cong \tan\beta = \frac{NP}{PI} = \frac{NP}{MI}$

$\gamma \cong \tan\gamma = \frac{NP}{PC} = \frac{NP}{MC}$

$\therefore n_1 \cdot \frac{NP}{OM} + n_2 \cdot \frac{NP}{MI} = (n_2 - n_1)\frac{NP}{MC}$

or $\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$

Using Cartesian sign convention,

OM = -u, MI = +v, MC = +R

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

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

The lens maker formula gives us the relationship,

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

i.e. focal length, f and refractive index, μ have inverse dependence.

Now, as refractive index of water is greater than the air, the focal length of the lens will reduce when immersed in water.

33. $A = 1mm^2 = 10^{-6}m^2$

$R = 6\Omega$

$n = 10^{29}/m^3$

V = 6V

e = 1.6×10^{-19}C

$I = \frac{V}{R} = \frac{6}{6} = 1$ amp

m_e= 9.1×10^{-31}Kg

L = 10cm = 10^{-1}m

a. $\because$ I = Anev_d (here v_d is the drift velocity and n is the number density)

$\therefore v_d = \frac{I}{Ane} = \frac{1}{10^{-6}\times 10^{29}\times 1.6\times 10^{-19}}\mathrm{m/s}$

$\Rightarrow v_d = \frac{10^{-4}}{1.6}$ m/s

$KE = \frac{1}{2}mv_d^2$ per electron

Number of electrons (free) in wire = n (volume of wire)

= n $\times$ Al

$\therefore$ KE of all electrons $= \frac{1}{2}mv_d^2 Anl$

$KE = \frac{1}{2} \times 9.1 \times 10^{-31} \times \frac{10^{-4}\times 10^{-4}}{1.6\times 1.6} \times 10^{-6} \times 10^{29} \times 10^{-1}$

$= \frac{9.1}{2\times 2.56} \times 10^{-31-8-7+29}$ =1.78 $\times$ 10^{-46+29}

= 1.78 $\times$ 10^{-17} J

So, to start flow of current I, the electrons will take energy from cell

= KE of all electrons= 1.78 $\times$ 10^{-17}J

b. Loss of energy during current flowing =I^2R.

P = 1 $\times$ 1 $\times$ 6 = 6 Joule per second

$\because$ Energy = P.t

or $t = \frac{E}{P} = \frac{1.78\times 10^{-17}}{6}$

$\cong$ 0.29 $\times$ 10^{-17} sec $\cong$ 0.3 $\times 10^{-17}$

= 3 $\times$ 10^{-18} second.

Section E

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

A charged particle moving in a magnetic field experiences a force that is proportional to the strength of the magnetic field, the component of the velocity that is perpendicular to the magnetic field and the charge of the particle.

This force is given by $\vec{F} = q(\vec{v} \times \vec{B})$ where q is the electric charge of the particle, v is the instantaneous velocity of the particle, and B is the magnetic field (in tesla). The direction of force is determined by the rules of cross product of two vectors. Force is perpendicular to both velocity and magnetic field. Its direction is given as $\vec{v} \times \vec{B}$ if q is positive and opposite of $\vec{v} \times \vec{B}$ if q is negative.

The force is always perpendicular to both the velocity of the particle and the magnetic field that created it. Because the magnetic force is always perpendicular to the motion, the magnetic field can do no work on an isolated charge. It can only do work indirectly, via the electric field generated by a changing magnetic field.

(i) Magnetic field lines are concentric circular loops in a plane perpendicular to the straight conductor. The centres of the circular magnetic field lines lie on the conductor.

(ii) remains stationary

For stationary electron, $\vec{v}$ = 0

$\therefore$ Force on the electron is, $\vec{F}_m = -e(\vec{v} \times \vec{B})$ = 0

(iii) the proton will continue to move with velocity v along the axis

Force on the proton, $\vec{F}_B = e(\vec{v} \times \vec{B})$

Since, $\vec{v}$ is parallel to $\vec{B}$

$\therefore \vec{F}_B$ = 0

Hence proton will continue to move with velocity v along the axis of solenoid.

OR

The particle is moving and magnetic field is perpendicular to the velocity.

Magnetic force on the charged particle q is

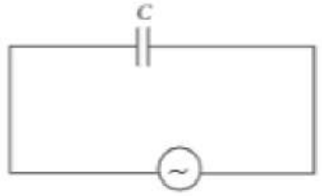
$\vec{F}_m = q(\vec{v} \times \vec{B})$ or F_m = qv B sinθ

where θ is the angle between $\vec{v}$ and $\vec{B}$.

Out of the given cases, only in case (b) it will experience the force while in other cases it will experience no force.

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

Let a source of alternating e.m.f. E = E_0 sin ωt be connected to a capacitor of capacitance C. If P is the instantaneous value of current in the circuit at instant t, then $I = \frac{E_0}{1/\omega C}\sin\left(\omega t + \frac{\pi}{2}\right)$. The capacitive reactance limits the amplitude of current in a purely capacitive circuit and it is given by $X_C = \frac{1}{\omega C}$.



(i) Ohm is the unit of capacitive reactance.

(ii) Capacitive reactance, $X_c = \frac{1}{\omega C} = \frac{1}{2\pi u C}$

$= \frac{1}{2\pi\times 10^6\times 5\times 10^{-6}}$ = 0.032 Ω

(iii) In a capacitive circuit, alternating current leads the e.m.f by the phase value of 90^{o}.

OR

Here, C = 1 μF = 10^{-6} F, E_v = 200 V, v = 50 hz, I_v =?

$I_v = \frac{E_v}{X_c} = \frac{E_v}{\frac{1}{2}\pi v C} E_v, I_v$ = 2 × 3.14 × 50 × 10^{-6} × 200 = 6.28 × 10^{-2} A