

ISC 2026 EXAMINATION
Sample Question Paper - 5
Physics

Time Allowed: 3 hours and 15 minutes

Maximum Marks: 70

General Instructions:

- You are allowed an additional 15 minutes for only reading the question paper.
- You must NOT start writing during reading time.
- This question paper has 20 questions.
- The paper has four sections: A, B, C and D. Internal choices have been provided in two questions each in Sections B, C and D.
- Section A consists of one question having fourteen sub-parts of one mark each.
- Section B consists of seven questions of two marks each.
- Section C consists of nine questions of three marks each.
- Section D consists of three questions of five marks each.
- Answer all questions.
- The intended marks for questions are given in brackets [].
- A list of useful constants and relations is given at the end of this paper.
- A simple scientific calculator without a programmable memory may be used for calculations.

Section A

1. **Answer the following questions:** **[14]**

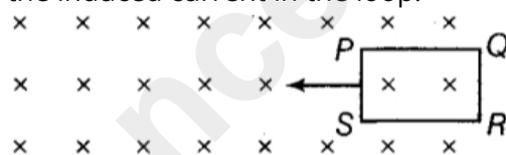
(a) **In questions (i) to (vii) below, choose the correct alternative (a), (b), (c) or (d) for each of the questions given below:**

- i. The resistance will be least in a wire with length, cross-section area respectively, **[1]**
- | | |
|------------|----------------------|
| a) L, A | b) $2L, A$ |
| c) $L, 2A$ | d) $\frac{L}{2}, 2A$ |
- ii. A magnetic dipole moment is a vector quantity directed from **[1]**
- | | |
|---------------------------|---------------------------|
| a) East to West direction | b) West to East direction |
| c) South to North pole | d) North to South pole |
- iii. Which one of the following is used to detect infrared radiations? **[1]**
- | | |
|-----------------------|-----------------------|
| a) Fluorescent screen | b) Photocell |
| c) Thermopile | d) Ionization chamber |
- iv. Relation between r.m.s. voltage and instantaneous voltage of an AC **[1]**
- | | |
|--|-------------------------------------|
| a) $V_0 = \frac{V_{RMS}}{\sqrt{2}}$ | b) $V_{RMS} = \frac{V_0}{\sqrt{2}}$ |
| c) Both $V_{RMS} = \frac{V_0}{\sqrt{2}}$ and $V_{RMS} = 0.707 V_0$ | d) $V_{RMS} = 0.707 V_0$ |

- v. n-type semiconductor is that in which [1]
- a) holes and electrons are equal in number. b) holes are majority carrier
- c) trivalent element as impurity d) free electrons are majority carrier
- vi. In a moving coil galvanometer of coil of N turns of area A have a spring of stiffness k . If coil is deflected by some angle ϕ due to flow of I current in uniform radial magnetic field B , then [1]
- a) $\phi = \left(\frac{NAB}{k}\right) I$ b) $\phi = \left(\frac{k}{BNA}\right) I$
- c) $\phi = \left(\frac{kA}{BN}\right) I$ d) $\phi = \left(\frac{BN}{kA}\right) I$
- vii. The force between two-point charges separated by a certain distance in air is F . If each of the two charges be halved and the distance between them be also halved, the new force would be [1]
- a) $3F$ b) $4F$
- c) $2F$ d) F

(b) **Answer the following questions briefly:**

- i. What is the shape of the wavefront diverging from a point source of light? [1]
- ii. Why is the Coolidge tube highly evacuated? [1]
- iii. The closed loop PQRS of wire is moved inside a uniform magnetic field at right angles to the plane of the paper as shown in the figure. Predict the direction of the induced current in the loop. [1]



- iv. A point charge $+Q$ is placed at point O as shown in the figure. Is the potential difference ($V_A - V_B$) positive, negative or zero? [1]
-
- The diagram shows a point charge $+Q$ at point O. A horizontal dashed line passes through O, with points A and B marked on it to the right of O.
- v. Name the series of lines in the hydrogen spectrum which lies in the ultraviolet region. [1]
- vi. Why all over the world, giant telescope are of the reflecting type? State any one reason. [1]
- vii. Where in our universe is the thermo-nuclear energy being released naturally? [1]

Section B

2. A short bar magnet of magnetic moment $M = 0.32 \text{ J/T}$ is placed in a uniform magnetic field of 0.15 T . If the bar is free to rotate in the plane of the field, which orientation would correspond to its (i) stable and (ii) unstable equilibrium? What is the potential energy of the magnet in each case? [2]

OR

If two magnets having magnetic moments M and $M\sqrt{3}$ are joined to form a cross (i.e. \times). The

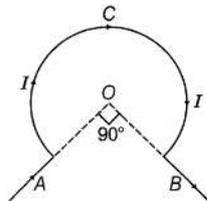
combination is suspended freely in a uniform magnetic field. In equilibrium position, the magnet having magnetic moment M makes an angle θ with the field. Calculate the value of θ .

3. The magnetic field of a beam emerging from a fitter facing a floodlight is given by [2]
 $B = 12 \times 10^{-8} \sin (1.20 \times 10^7 z - 3.60 \times 10^{15} t) \text{ T}$.
What is the average intensity of the beam?
4. An alternating voltage given by $E = 140 \sin 314t$ is connected across a pure resistor of 50Ω . Find [2]
i. the frequency of the source.
ii. the rms current through the resistor.

OR

A light bulb is rated 100 W for 220 V AC supply of 50 Hz. Calculate

- i. resistance of the bulb
ii. the rms current through the bulb.
5. With reference to a semiconductor diode, define the terms **depletion region** and **potential barrier**. How will the width of the depletion region change during reverse biasing? [2]
6. The wire shown in the figure carries a current of 10 A. Determine the magnitude of magnetic field [2]
induction at the centre O. Given the radius of bent coil is 3 cm.



7. A sphere S_1 of radius r_1 encloses a net charge Q . If there is another concentric sphere S_2 of [2]
radius r_2 ($r_2 > r_1$) enclosing charge $2Q$, find the ratio of the electric flux through S_1 and S_2 . How
will the electric flux through sphere S_1 change, if a medium of dielectric constant K is introduced
in the space inside S_1 in place of air?
8. Sn, C and Si, Ge are all group XIV elements. Yet, Sn is a conductor, C is an insulator while Si and [2]
Ge are semiconductors. Why?

Section C

9. i. With reference to photoelectric effect, plot a labelled graph of stopping potential (Vs) versus [3]
frequency (f) of the incident radiation.
ii. State how will you use this graph to determine the value of Planck's constant.
10. Explain briefly an experiment with a coil and magnet to demonstrate the phenomenon of [3]
electromagnetic induction.

OR

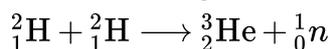
State Lenz's law. Explain, by giving examples that Lenz's law is a consequence of conservation of energy.

11. Net capacitance of three identical capacitors in series is $1 \mu\text{F}$. What will be their net capacitance, [3]
if connected in parallel?
Find the ratio of energy stored in these two configurations, if they are both connected to the
same source.
12. Half-life of a certain radioactive material is 8h. [3]
i. Find disintegration constant of this material,

ii. If one starts with 600g of this substance, how much of it will disintegrate in one day?

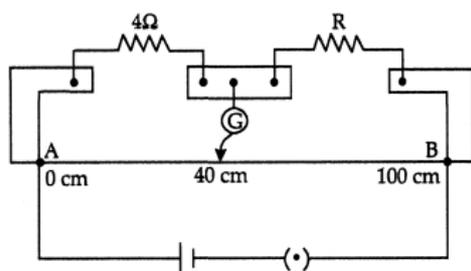
OR

In the following nuclear reaction, calculate the energy released in MeV

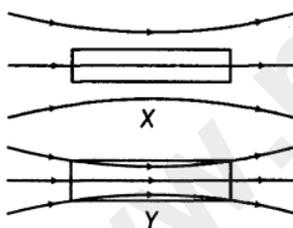


Take, mass of ${}^2_1\text{H} = 2.015\text{u}$, mass of ${}^3_2\text{He} = 3.017\text{u}$, mass of ${}^1_0n = 1.009\text{u}$.

13. A compound microscope has an objective of focal length 1 cm and an eyepiece of focal length 2.5 cm. An object has to be placed at a distance of 1.2 cm away from the objective for the normal adjustment. Determine the angular magnification and length of microscope tube. [3]
14. i. Write three characteristic properties of nuclear force. [3]
 ii. Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from the graph.
15. In a meter bridge circuit, resistance in the left gap is 4Ω and an unknown resistance R is in the right hand gap as shown in Figure 2 below. The null point is found to be 40 cm from the left end of the wire. [3]
- a. Calculate the value of the unknown resistance R.
 b. What change will you make in R to bring the null point to the midpoint of the wire AB?



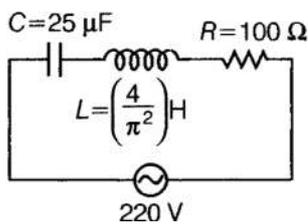
16. i. How does angle of dip change as line goes from magnetic pole to magnetic equator of the earth? [3]



- ii. A uniform magnetic field gets modified as shown in the figure below, when two specimens X and Y are placed in it. Identify whether specimens X and Y are diamagnetic, paramagnetic or ferromagnetic.
17. In a plane, electric field oscillates sinusoidally at a frequency of 2×10^{10} Hz and amplitude 48 V/m. [3]
- i. What is the wavelength of the wave?
 ii. What is the amplitude of the oscillating magnetic field?
 iii. Show that the average energy density of the E field equals the average energy density of the B field.

Section D

18. i. Figure below shows a capacitor C, an inductor L and a resistor R connected in series to an AC supply of 220 V. [5]

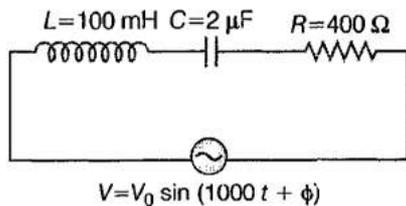


Calculate

- a. the resonant frequency of the given L-C-R circuit.
 - b. current flowing through the circuit.
 - c. average power consumed by the circuit.
- ii. In a series L-C-R circuit, what is the phase difference between V_L and V_C , where V_L is the potential difference across the inductor and V_C is the potential difference across the capacitor?

OR

- i. Find the value of the phase difference between the current and the voltage in the series L-C-R circuit shown below. Which one leads in phase, current or voltage?



- ii. Without making any other change, find the value of the additional capacitor C' , to be connected in parallel with the capacitor C , in order to make the power factor of the circuit unity.

19. Light waves from coherent sources arrive at two points on a screen with path difference of 0 and $\lambda/2$. Find the ratio of intensities at the points. [5]

OR

In a double slit experiment using light of wavelength 600 nm, the angular width of the fringe formed on a distant screen is 0.1° . Find the spacing between the two slits.

20. State Biot-Savart's law expressing it in the vector form. Use it to obtain the expression for the magnetic field at an axial point distance d from the centre of a circular coil of radius a carrying current I . Also, find the ratio of the magnitudes of the magnetic field of this coil at the centre and at an axial point for which $d = a\sqrt{3}$. [5]

Solution

Section A

1. Answer the following questions:

(a) In questions (i) to (vii) below, choose the correct alternative (a), (b), (c) or (d) for each of the questions given below:

i. (d) $\frac{L}{2}, 2A$

Explanation:

$$\therefore R = \frac{\rho l}{A} \text{ or } R \propto \frac{l}{A}$$

$$\therefore R_a \propto \frac{L}{4A}, R_b \propto \frac{2L}{A}, R_c \propto \frac{L}{A} .$$

Thus, resistance is least in a wire of length $\frac{L}{2}$ and area of cross-section is $2A$.

ii. (c) South to North pole

Explanation:

Magnetic dipole moment vector is directed from the South pole to the North pole of a bar magnet.

iii. (c) Thermopile

Explanation:

Thermopile sensors are used to measure temperature of a body by detecting the infrared radiation emitted by it.

iv. (c) Both $V_{\text{RMS}} = \frac{V_0}{\sqrt{2}}$ and $V_{\text{RMS}} = 0.707 V_0$

Explanation:

$$V_{\text{RMS}} = \frac{V_0}{\sqrt{2}} = 0.707 V_0$$

v. (d) free electrons are majority carrier

Explanation:

free electrons are majority carrier

vi. (a) $\phi = \left(\frac{NAB}{k} \right) I$

Explanation:

When a current flows through the coil, a torque acts on it. This torque is given by $\tau = NIAB$. where, the symbols have their usual meaning. Since, the field is radial by design, we have taken $\sin \theta = 1$ in the above expression for the torque. The magnetic torque $NIAB$ tends to rotate the coil.

A spring S_p provides a counter torque $k\phi$ that balances the magnetic torque $NIAB$; resulting in a steady angular deflection ϕ . In equilibrium $k\phi = NIAB$.

where, k is the torsional constant of the spring, i.e. the restoring torque per unit twist. The deflection ϕ is indicated on the scale by a pointer attached to the spring. We have

$$\phi = \left(\frac{NAB}{k} \right) I$$

vii. (d) F

Explanation:

$$F = K \frac{q_1 q_2}{r^2}$$

$$F' = \frac{K \left(\frac{q_1 q_2}{4} \right)}{\left(\frac{r^2}{4} \right)}$$

So, $F' = F$

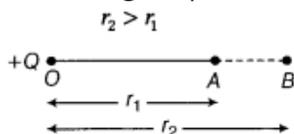
(b) Answer the following questions briefly:

i. Shape of wavefronts diverging from Point source is spherical.

ii. So that striking electrons may not lose energy by colliding with gas atoms.

iii. Since, magnetic flux increases, when the loop moves into a uniform magnetic field. So, the induced current should oppose this increase. Thus, the flow will be from QPSRQ, i.e. anti-clockwise.

iv. According to question,



Potential at point A due to charge $+Q$, $(V_A) = \frac{kQ}{r_1}$

Potential at point B due to charge $+Q$, $(V_B) = \frac{kQ}{r_2}$

As $V_A \propto \frac{1}{r_1}$ and $V_B \propto \frac{1}{r_2}$ and $r_1 > r_2$

so, $V_A > V_B$ Thus, $(V_A - V_B)$ is positive.

v. Lyman series lies in ultraviolet region in hydrogen spectrum.

vi. Giant telescopes are of reflecting type because the image formed is brighter and free from chromatic aberration.

vii. From the Sun.

Section B

2. Given, magnetic moment of magnet, $M = 0.32 \text{ J/T}$

Magnitude of magnetic field, $B = 0.15 \text{ T}$

i. For stable equilibrium, the angle between magnetic moment M and magnetic field B is $\theta = 0^\circ$.

[\therefore In this position, it will be in a direction parallel to the magnetic field, thus no torque will act on it.]

\therefore The potential energy of the magnet,

$$U = -M \cdot B = -MB \cos\theta \quad [\because M \cdot B = MB \cos\theta]$$

$$= -0.32 \times 0.15 \cos 0^\circ = -4.8 \times 10^{-2} \text{ J}$$

Thus, for the stable equilibrium the potential energy is $-4.8 \times 10^{-2} \text{ J}$.

ii. For the unstable equilibrium, the angle between the magnetic moment and magnetic field is 180° .

(\because At $\theta = 180^\circ$, although torque zero but if it is displaced by small angle $d\theta$, then resulting torque would not restore it to the original position).

Potential energy of the magnet,

$$U = -MB \cos 180^\circ$$

$$= -0.32 \times 0.15 (-1)$$

$$= 4.8 \times 10^{-2} \text{ J}$$

Thus, for the unstable equilibrium the potential energy is $4.8 \times 10^{-2} \text{ J}$.

OR

If magnet of magnetic moment M makes an angle θ with the field, then other magnet of magnetic moment $M\sqrt{3}$ makes an angle $(90^\circ - \theta)$ with the field.

In equilibrium, $\tau_1 = \tau_2$

$$\Rightarrow MB \sin\theta = M\sqrt{3} B \cos\theta \Rightarrow \frac{\sin\theta}{\cos\theta} = \sqrt{3}$$

$$\Rightarrow \tan\theta = \sqrt{3} \Rightarrow \theta = 60^\circ$$

3. Magnetic field, $B = B_0 \sin \omega t$

Given equation,

$$B = 12 \times 10^{-8} \sin(1.20 \times 10^7 z - 3.60 \times 10^{15} t) \text{ T}$$

On comparing this equation with standard equation, we get

$$B_0 = 12 \times 10^{-8} \text{ T}$$

The average intensity of the beam,

$$I_{av} = \frac{B_0^2}{2\mu_0} \cdot c = \frac{1}{2} \times \frac{(12 \times 10^{-8})^2 \times 3 \times 10^8}{4\pi \times 10^{-7}}$$

$$\Rightarrow I_{av} = 1.71 \text{ W/m}^2$$

4. i. As given, $E = 140 \sin 314t$
 On comparing with $E = E_0 \sin \omega t$, we have
 $\omega = 314$, $E_0 = 140 \text{ V}$
 $\therefore \omega = 2\pi v \Rightarrow v = \frac{\omega}{2\pi} = \frac{314}{2 \times 3.14} = 50 \text{ Hz}$

ii. $E_0 = 140 \text{ V}$

$$E_{\text{rms}} = \frac{E_0}{\sqrt{2}} = \frac{140}{\sqrt{2}} = 99.29 \text{ V}$$

$$\therefore I_{\text{rms}} = \frac{E_{\text{rms}}}{R} = \frac{99.29}{50} = 1.98 \text{ A}$$

OR

i. Power, $P = EI \Rightarrow P = E \times \frac{E}{R}$ [$\because I = \frac{E}{R}$]

$$\Rightarrow R = \frac{E^2}{P} = \frac{(220)^2}{100} = \frac{48400}{100} = 484 \Omega$$

ii. The peak voltage of the source is $E_{\text{rms}} = \frac{E_0}{\sqrt{2}}$

$$\Rightarrow E_0 = E_{\text{rms}} \times \sqrt{2}$$

$$= 200\sqrt{2} = 311.13 \text{ V}$$

$$\therefore I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{E_0}{R\sqrt{2}}$$

$$= \frac{311.13}{484\sqrt{2}} = 0.45 \text{ A}$$

5. **Potential barrier:** The potential difference established across the p-n junction due to diffusion of electrons from n-region to p-region and holes from p-region to n-region is called potential barrier.
Depletion region: It is a layer created around the p-n junction which is devoid of free charge carriers and has immobile ions only. The width of the depletion region increase in reverse biasing.

6. Here, $I = 10 \text{ A}$, $r = 3 \text{ cm}$, $r = 3 \times 10^{-2} \text{ m}$
 Angle subtended by coil at the centre,

$$\theta = 360^\circ - 90^\circ = 270^\circ = \frac{3\pi}{2} \text{ rad}$$

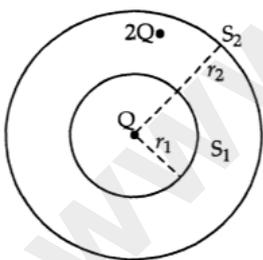
Magnetic field induction at O due to current through circular path ACB is

$$B = \frac{\mu_0}{4\pi} \cdot \frac{I}{r} \theta = 10^{-7} \times \frac{10}{(3 \times 10^{-2})} \times \frac{3\pi}{2}$$

$$= 1.57 \times 10^{-4} \text{ T}$$

7. Flux through S_1 , $\phi_1 = \frac{Q}{\epsilon_0}$

$$\text{Flux through } S_2, \phi_2 = \frac{Q+2Q}{\epsilon_0} = \frac{3Q}{\epsilon_0}$$



$$\frac{\phi_1}{\phi_2} = 1 : 3$$

When a medium of dielectric constant K is introduced in the space inside S_1 , the flux through

$$S_1 \text{ becomes } \phi'_1 = \frac{Q}{K\epsilon_0}$$

8. A material is a conductor, if in its energy band diagram, there is no energy gap between conduction band and valence band. For insulator, the energy gap is large and for semiconductor, the energy gap is moderate.

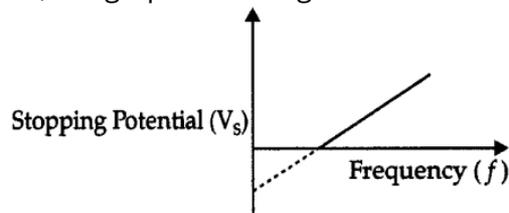
The energy gap for Sn is 0 eV, for C is 5.4 eV, for Si is 1.1 eV and for Ge is 0.7 eV, related to their atomic size. Therefore, Sn is a conductor, C is an insulator and Ge and Si are semiconductors.

Section C

9. i. The photoelectric equation is
 $hf = eV_s + \phi$

$$\text{or, } V_s = \left(\frac{h}{e}\right) f - \left(\frac{\phi}{e}\right)$$

So, the graph is a straight line.



ii. Slope of the graph = $\frac{h}{e}$.

Hence, $h = e \times \text{slope}$.

e being known h can be determined from the slope of the graph.

10. The experimental arrangement consists of a cylindrical coil C made up of several turns of insulated copper wire connected in series to a sensitive galvanometer G . A strong bar magnet NS with its north pole pointing towards the coil is moved up and down. The following inferences were made by Faraday:

- i. Whenever there is a relative motion between the coil and the magnet, the galvanometer shows deflection indicating the flow of induced current. The deflection is momentary. It lasts so long as there is relative motion between the coil and the magnet.
- ii. The direction of the flow of current is opposite the magnet is moved towards and when it is moved away. The deflection is more when the magnet is moved faster and less when the magnet is moved slowly. However, on reversing the magnet i.e. the south pole pointing towards the coil, the same results are obtained, but induced current flows in the opposite direction.

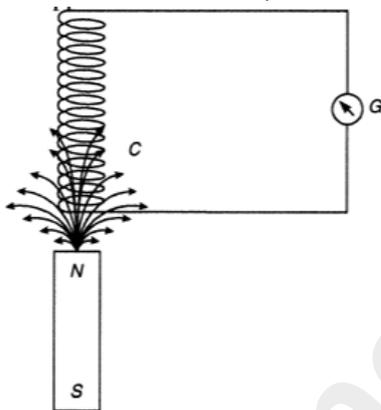
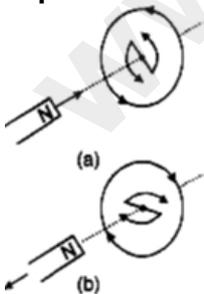


Fig. Electromagnetic induction

OR

Lenz law states that induced current always tends to oppose the cause which produces it. So work is done against opposing force. This work is transformed into electrical energy. So it is a consequence of law of conservation of energy.

Explanation:



When the north pole of a bar magnet is pushed towards the closed coil, the magnetic flux through coil increases and the current is induced in the coil in such a direction that it opposes the increase in flux. This is possible when the induced current in the coil is in the anticlockwise direction. Opposite will happen when the north pole is moved away from the coil.

In either case, it is the work done against the force of magnetic repulsion/attraction that gets 'converted' into the induced emf.

11. If n identical capacitors, each of capacitance C are connected in series combination give equivalent capacitance, $C_s = \frac{C}{n}$ and when connected in parallel combination, then equivalent capacitance, $C_p = nC$. Also, for same voltage, energy stored in the capacitor is given by

$$U = \frac{1}{2} CV^2 \text{ [for } V = \text{Constant]}$$

$$\Rightarrow U \propto C$$

$$\text{In series combination, } C_s = \frac{C}{n}$$

$$\Rightarrow C_s = 1 \mu\text{F}$$

$$\Rightarrow C = nC_s = 3 \times 1 \mu\text{F} = 3 \mu\text{F} \text{ [}\therefore n = 3\text{]}$$

In parallel combination,

$$C_p = nC = 3 \times 3 = 9 \mu\text{F}$$

For same voltage, $U \propto C$

$$\Rightarrow \frac{U_s}{U_p} = \frac{C_s}{C_p} \Rightarrow \frac{U_s}{U_p} = \frac{\frac{C}{n}}{nC} = \frac{1}{n^2}$$

$$\Rightarrow \frac{U_s}{U_p} = \frac{1}{(3)^2} = \frac{1}{9}$$

$$\text{or } U_s : U_p = 1 : 9$$

12. i. Given, half-life of a radioactive material, $T = 8 \text{ h}$

$$\therefore \text{Disintegration constant, } \lambda = \frac{0.693}{8 \times 60 \times 60}$$

$$\lambda = 2.41 \times 10^{-5} \text{ per second}$$

- ii. Since, number of half-lives, $n = \frac{t}{T}$

$$\Rightarrow n = \frac{24}{8} = 3$$

In duration 1 to 8 h, it will disintegrate by $\frac{600}{2} = 300 \text{ g}$

In duration 9 to 16 h, it will disintegrate by $\frac{300}{2} = 150 \text{ g}$

In duration 17 to 24 h, it will disintegrate by $\frac{150}{2} = 75 \text{ g}$

So, in 1 day, 525 g ($300 + 150 + 75$) of material will disintegrate.

OR

$$\text{Mass of reactants} = 2.015 \times 2 = 4.03 \text{ u}$$

$$\text{Mass of products} = 3.017 + 1.009 = 4.026 \text{ u}$$

$$\text{Mass defect, } \Delta m = \text{Mass loss} = 4.03 - 4.026 = 0.004 \text{ u}$$

$$\text{Energy released, } E = \Delta mc^2 = 0.004 \times 931 = 3.724 \text{ MeV}$$

13. Given, focal length of objective, $f_0 = 1 \text{ cm}$

Focal length of eyepiece, $f_e = 2.5 \text{ cm}$

Object distance, $u_0 = -1.2 \text{ cm}$

$$\therefore \frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$$

$$\Rightarrow \frac{1}{v_o} = \frac{1}{u_o} + \frac{1}{f_o}$$

$$\Rightarrow \frac{1}{v_o} = 1 - \frac{1}{1.2} = \frac{0.2}{1.2}$$

$$\Rightarrow v_o = \frac{1.2}{0.2} \Rightarrow v_o = 6 \text{ cm}$$

$$\therefore \text{Angular magnification, } m = \frac{v_o}{|u_o|} \left(1 + \frac{D}{f_e} \right)$$

$$\Rightarrow m = \frac{6}{|-1.2|} \left(1 + \frac{25}{2.5} \right) = 55$$

\therefore Length of microscope tube,

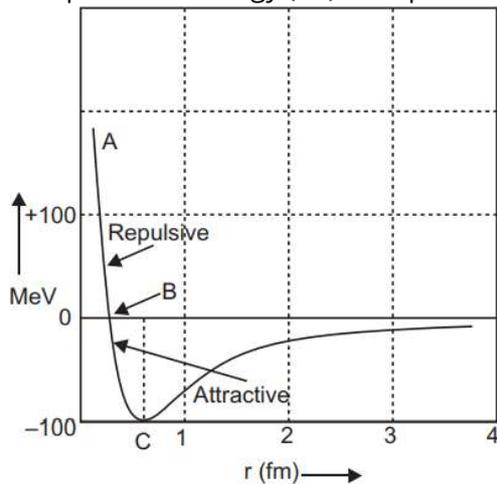
$$L = v_o + f_e = (6 + 2.5) = 8.5 \text{ cm}$$

14. i. The following are the few characteristics of nuclear force:

1. It is attractive in nature but with a repulsive core. That is the reason that the nucleus is held together without collapsing in itself
2. Nuclear force is identical for all nucleons.

3. At a distance less than 0.7 Fermi, this force becomes repulsive. It is one of the most interesting properties of nuclear force, as this repulsive component of the force is what decides the size of the nucleus.

ii. The potential energy (PE) vs separation graph is shown below:



Conclusions: (i) Nuclear forces are attractive and stronger, than electrostatic force. (ii) Nuclear forces are charge-independent.

15. a. $\frac{4}{R} = \frac{l_1}{(100-l_1)}$
 Or, $\frac{4}{R} = \frac{40}{60}$
 $\therefore R = 6 \Omega$

b. When null point is at mid point then,

$\frac{4}{R} = \frac{l_2}{(100-l_2)}$
 Or, $\frac{4}{R'} = \frac{50}{50}$
 $\therefore R' = 40$

Say R_1 resistance is to be connected in parallel with R.

So, $R' = \frac{RR_1}{(R+R_1)}$
 Or, $4 = \frac{6R_1}{(6+R_1)}$
 $\therefore R_1 = 12 \Omega$

So, a 6Ω resistance is to be connected in parallel with the existing R resistance.

16. i. The angle of dip decreases from 90° to 0° .

ii. For paramagnetic materials, no magnetic lines of force enter in it. So, specimen X is paramagnetic. For ferromagnetic materials, all magnetic lines of force prefer to go through it. So, specimen Y is ferromagnetic.

17. Given, frequency of oscillation, $\nu = 2 \times 10^{10}$ Hz

Speed of wave, $c = 3 \times 10^8$ m/s

Electric field amplitude, $E_0 = 48$ V/m

i. Wavelength of wave,

$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{2 \times 10^{10}} = 1.5 \times 10^{-2}$ m

ii. The amplitude of the oscillating magnetic field,

$B = \frac{E_0}{c} = \frac{48}{3 \times 10^8} = 1.6 \times 10^{-7}$ T

iii. The average energy density of electric field,

$u_e = \frac{1}{4} \epsilon_0 E_0^2 \dots(i)$

As, $E_0 = cB_0$

Putting the value of E_0 in Eq. (i), we get

$u_e = \frac{1}{4} \epsilon_0 \cdot c^2 B_0^2 \dots(ii)$

Speed of electromagnetic waves, $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

Putting the value of c in Eq. (ii), we get

$$u_e = \frac{1}{4} \epsilon_0 B_0^2 \cdot \frac{1}{\mu_0 \epsilon_0} = \frac{1}{4} \cdot \frac{B_0^2}{\mu_0} = u_b$$

(u_b is average energy density of magnetic field)

Thus, the average energy density of the E field equals the average energy density of B field.

Section D

18. i. Given, $E_{rms} = 220V$, $C = 25\mu F = 25 \times 10^{-6} F$,

$$L = \frac{4}{\pi^2} H, R = 100\Omega$$

a. Resonant frequency is given by

$$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14 \times \sqrt{\frac{4}{\pi^2} \times 25 \times 10^{-6}}}$$

$$= \frac{1}{2 \times 3.14 \times \frac{2}{314} \times 5 \times 10^{-3}} = 50\text{Hz}$$

b. Impedance of the circuit is given by

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \dots(i)$$

$$\text{We know that, } X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$= \frac{1}{2 \times 3.14 \times 50 \times 25 \times 10^{-6}} = 127.3\Omega$$

$$X_L = \omega L = 2\pi f L = 2 \times 3.14 \times \frac{4}{\pi^2} \times 50 = 127.3\Omega$$

Substituting the all values in Eq. (i), we get

$$Z = \sqrt{(100)^2 + (127.3 - 127.3)^2}$$

$$= \sqrt{(100)^2} = 100\Omega$$

$$\text{We know that, } I_{rms} = \frac{E_{rms}}{Z} = \frac{220}{100} = 2.2 A$$

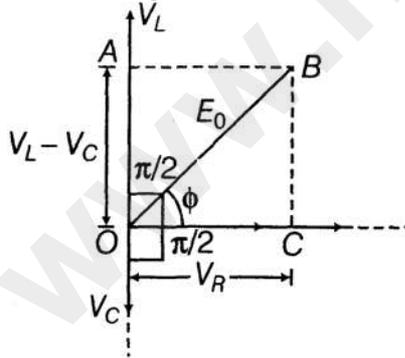
c. Average power consumed by the circuit

$$= E_{rms} \times I_{rms} \times \frac{R}{\sqrt{R^2 + (L\omega - \frac{1}{C\omega})^2}}$$

$$\therefore Z = R = 100\Omega$$

$$\text{So, power} = E_{rms} \times I_{rms} = 220 \times 2.2 = 484 W$$

ii. Phasor diagram of L-C-R circuit is shown below.



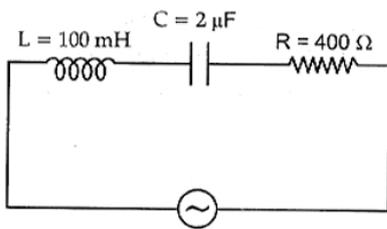
The phase difference across the inductor and phase difference across the capacitor is 180° .

OR

i. $\omega = 1000$

$$X_L = \omega L = 1000 \times 100 \times 10^{-3} \Omega$$

$$= 100\Omega$$



$$V = V_0 \sin(1000t + \phi)$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2 \times 10^{-6} \times 1000}$$

$$= \frac{1000}{2} = 500 \Omega$$

$$\cos \phi = \frac{R}{Z} = \frac{400}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{400}{400\sqrt{2}} = \frac{1}{\sqrt{2}}$$

$$\phi = 45^\circ$$

ii. For unit power factor, $\cos \phi = 1$

$$\Rightarrow \frac{R}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C''})^2}} = 1$$

where, C'' is the total capacitance.

$$\Rightarrow R^2 + \left(\omega L - \frac{1}{\omega C''}\right)^2 = R^2 \Rightarrow \omega L = \frac{1}{\omega C''}$$

$$\Rightarrow \omega L = 100 = \frac{1}{\omega C''}$$

$$\Rightarrow C'' = \frac{1}{10^5} = 10^{-5} = 10 \mu F$$

Additional capacitance C' required in parallel

$$C' = C'' - C = 10 \mu F - 2 \mu F = 8 \mu F$$

19. As, $I = I_0 \cos^2 \phi$

\therefore Phase difference, $\phi = \frac{2\pi x}{\lambda}$ path difference.

$$\text{So, } I_1 = I_0 \cos^2\left(\frac{2\pi \times 0}{\lambda}\right) = I_0$$

$$\text{and } I_2 = I_0 \cos^2\left(\frac{2\pi}{\lambda} \times \lambda/2\right)$$

$$= I_0 \cos^2(\pi) = I_0$$

$$\therefore \frac{I_1}{I_2} = \frac{1}{1}$$

OR

$$\text{Here, } \lambda = 600 \text{ nm} = 600 \times 10^{-9} \text{ m} = 6 \times 10^{-7} \text{ m}$$

$$\Rightarrow 0.1^\circ = \frac{0.1\pi}{180} \text{ rad}$$

$$\text{From angular width, } \theta = \frac{\lambda}{d}$$

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

$$= \frac{6 \times 10^{-7}}{\frac{\pi}{180} \times 0.1} = 3.44 \times 10^{-4} \text{ m}$$

20. According to Biot-Savart's law, the magnetic field due to a current element vector(dl) carrying current I at a point P with position vector r is given by

$$d\vec{B} = \frac{\mu_0}{4\pi} I \left[\frac{\vec{dl} \times \vec{r}}{r^3} \right]$$

Magnetic field at the axial point distance from the centre,

$$B_1 = \frac{\mu_0}{4\pi} \cdot \frac{2\pi a^2 I}{(a^2 + d^2)^{\frac{3}{2}}}$$

In this answer, put $r = d$.

Magnetic field induction at the centre of the circular coil carrying current is

$$B_2 = \frac{\mu_0}{4\pi} \cdot \frac{2\pi I}{a} \Rightarrow \frac{B_1}{B_2} = \frac{a^2 \times a}{(a^2 + d^2)^{\frac{3}{2}}}$$

$$= \frac{a^3}{(a^2 + d^2)^{\frac{3}{2}}} = \frac{a^3}{(a^2 + 3a^2)^{\frac{3}{2}}} [\because d = a\sqrt{3}]$$

$$= \frac{a^3}{(4a^2)^{\frac{3}{2}}} = \frac{a^3}{8a^3}$$
$$\Rightarrow \frac{B_1}{B_2} = \frac{1}{8}$$

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