ISC 2026 EXAMINATION
Sample Question Paper - 4
Physics

Time Allowed: 3 hours and 15 minutes **Maximum Marks: 70**

General Instructions:

- You are allowed an additional 1 5 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. Specific resistance of the material of a wire depends on: **[1]**

a) Volume of the wire.
b) Area of cross section of the wire.
c) Temperature of the wire.
d) Length of the wire.

ii. A wire of length 2 m is bent to form a circular loop of single turn. If 1 A current flows through the loop the magnetic moment is **[1]**

a) $\frac{2}{\pi}$
b) $\frac{1}{\pi}$
c) $\frac{3}{\pi}$
d) π

iii. Proper arrangement of Gamma rays, Microwave, IR wave and UV rays in ascending order of frequency is **[1]**

a) IR rays > UV rays > Microwave > Gamma rays
b) Microwave > IR rays > UV rays > Gamma rays
c) UV rays > Gamma rays > Microwave > IR rays
d) Gamma rays > UV rays > IR rays > Microwave

iv. An alternating current generator has an internal resistance R_g and an internal reactance X_g. It is used to supply power to a passive load consisting of a resistance R_g and a reactance X_L. For maximum power to be delivered from the generator to the load, the value of X_L is equal to **[1]**

a) $-X_g$
b) R_g
c) zero
d) X_g

v. Carbon, silicon and germanium have four valence electrons each. These are characterised by valence and conduction bands separated by energy band gap respectively equal to $(E_g)_C$, $(E_g)_{Si}$ and $E_g)_{Ge}$ Which of the following statements is true? **[1]**

a) $(E_g)_{\mathrm{C}} < (E_g)_{Ge} > (E_g)_{\mathrm{Si}}$
b) $(E_g)_{Si} < (E_g)_{\mathrm{Ge}} < (E_g)_{\mathrm{C}}$
c) $(E_g)_{\mathrm{C}} > (E_g)_{\mathrm{Si}} > (E_g)_{\mathrm{Ge}}$
d) $(E_g)_{\mathrm{C}} = (E_g)_{\mathrm{Si}} = (E_g)_{\mathrm{Ge}}$

vi. Magnetic field **B** at a point on the axis of (and inside) a long current-carrying solenoid is given by **[1]**

a) $\frac{\mu NI}{l\pi}$
b) $\frac{2\mu NI}{l\pi}$
c) $\frac{\mu NI}{2l}$
d) $\frac{\mu NI}{l}$

vii. For a given surface, the $\oint E \cdot dS = 0$. From this we can conclude that **[1]**

a) the total flux through the surface is zero
b) E is perpendicular to the surface at every point
c) the flux is only going out of the surface
d) E is necessarily zero on the surface

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

i. What will be the effect (if any) on the fringe width in young's double-slit experiment if red light is used in place of violet light? **[1]**

ii. why is the wave nature of matter, so insignificant in our daily life? **[1]**

iii. Why is soft iron preferred over steel in making the core of a transformer? **[1]**

iv. Why are electric field lines perpendicular at a point on an equipotential surface of a conductor? **[1]**

v. When H_α-line of the Balmer series in the emission spectrum of H-atom is obtained? **[1]**

vi. How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced by red light? Give reason. **[1]**

vii. Why nuclear fusion reaction is called thermo-nuclear reaction? **[1]**

Section B

2. The horizontal component of the earth's magnetic field at a place is B and angle of dip is 60^o. What is the value of vertical component of the earth's magnetic field at equator? **[2]**

OR

A Rowland ring of mean radius 15 cm has 3500 turns of wire wound on a ferromagnetic core of relative permeability 800. What is the magnetic field B in the core for a magnetising current of 1.2 A?

3. A radio can tune into any station in the 7.5 MHz to 12 MHz band. What is its corresponding wavelength? **[2]**

4. An AC generator consists of a coil of 1000 turns and cross-sectional area of 100 cm^2, rotating at an angular speed of 100 rpm in a uniform magnetic field of 3.6×10^{-2} T. Calculate the maximum emf produced in the coil. **[2]**

OR

An alternating voltage given by E = 140 sin 314t is connected across a pure resistor of 50Ω. Find

i. the frequency of the source.
ii. the rms current through the resistor.

5. Explain with the help of a circuit diagram the working of a photodiode. Write briefly, how it is used to detect the optical signals? **[2]**

6. A galvanometer coil has a resistance of 15 Ω and the meter shows full scale deflection for a current of 4 mA. How will you convert the meter into an ammeter of range 0 to 6 A? **[2]**

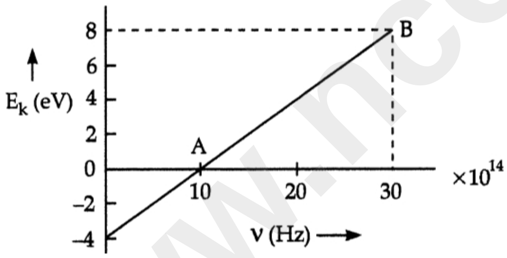
7. An ebonite rod held in hand can be charged by rubbing with flannel but a copper rod cannot be charged like this, why? **[2]**

8. Define the following terms used in electronic devices. **[2]**

i. Reverse breakdown voltage.
ii. V-I characteristic of forward biased diode.

Section C

9. In an experiment of photoelectric effect, the graph of maximum kinetic energy E_k of the emitted photoelectrons versus the frequency v of the incident light is a straight line AB as shown in figure below: **[3]**

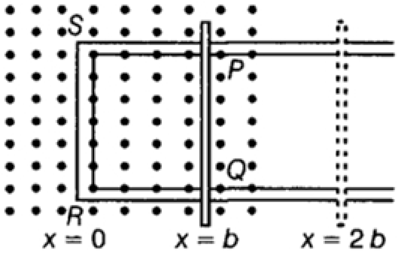


Find:

i. Threshold frequency of the metal.
ii. Work function of the metal.
iii. Stopping potential for the photoelectrons emitted by the light of frequency v = 30×10^{14} Hz.

10. State Faraday's laws of electromagnetic induction. Figure shows a rectangular conductor PQRS in which the conductor PQ is free to move in a uniform magnetic field JB perpendicular to the plane of the paper. The field extends from x = 0 to x = b and is zero for x > b. Assume that only the arm PQ possesses resistance r. When the arm PQ is pulled outward from x = 0 to x = 2b and is then moved backward to x = 0 with constant speed v, obtain the expressions for the flux and the induced emf. **[3]**

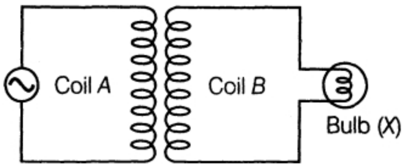
Sketch the variation of these quantities with distance $0 \leq x \leq 2b$.



OR

The figure given below shows an arrangement by which current flows through the bulb X connected with coil B, when AC is passed through coil A.

i. Name the phenomenon involved.
ii. If a copper sheet is inserted in the gap between the coils, explain how the brightness of the bulb would change?



11. Three equal charges of 5.0μC each are placed at the three vertices of an equilateral triangle of side 5.0 cm each. Calculate the electrostatic potential energy of the system of charges. **[3]**

12. Calculate mass defect and binding energy per nucleon of ${}_{10}^{20}\mathrm{Ne}$, given **[3]**
Mass of ${}_{10}^{20}\mathrm{Ne}$ = 19.992397 u
Mass of ${}_{1}^{1}\mathrm{H}$ = 1.007825 u
Mass of ${}_{0}^{1}n$ = 1.008665 u

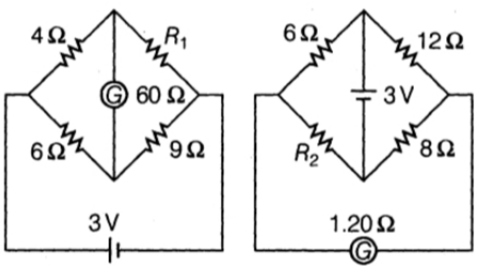
OR

Obtain the binding energy of the nuclei ${}_{26}^{56}\mathrm{Fe}$ and ${}_{83}^{209}\mathrm{Bi}$ in units of MeV from the following data:
$m\left({}_{26}^{56}\mathrm{Fe}\right)$ = 55.934939 u
$m\left({}_{83}^{209}\mathrm{Bi}\right)$ = 208.980388 u

13. Radius of curvature of an equi-convex lens of glass (n = 1.5) is 30 cm. Find its focal length. An object of height 5.0 cm is placed at a distance of 60 cm from the optical centre of the lens. Find the position and the height of the image formed. **[3]**

14. **[3]**
i. Why is the binding energy per nucleon found to be constant for nuclei in the range of mass number (A) lying between 30 and 170?
ii. When a heavy nucleus with mass number A = 240 breaks into two nuclei, A = 120, energy is released in the process.

15. Figure shows two circuits each having a galvanometer and a battery of 3 V. **[3]**
When the galvanometer in each arrangement do not show any deflection, obtain the ratio $\frac{R_1}{R_2}$.



16. Explain the following: **[3]**
i. Diamagnetism is the result of induced magnetic dipole moments.

ii. Hysteresis associated with a loss in electromagnetic energy.

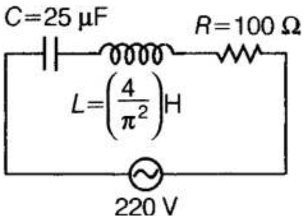
17. Suppose that the electric field amplitude of an electromagnetic wave is E_0 = 120 N/C and that its frequency is v = 50.0 MHz. **[3]**

i. Determine B_0, ω, k and λ.

ii. Find expressions for **E** and **B**.

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. A coil having self-inductance of 0.7 H and resistance of 165 Ω is connected to an a.c. source of 275 V, 50 Hz. if π = $\frac{22}{7}$. then Calculate:

a. Reactance of the coil

b. Impedance of the coil

c. Current flowing through the coil.

ii. Draw a labelled graph showing variation of impedance of a series L-C-R circuit with frequency of the AC supply.

19. In Young's double slit experiment, the two slits 0.15 mm apart are illuminated by monochromatic light of wavelength 450 nm. The screen is 1 m away from the slits. Find the distance of the second **[5]**

i. bright fringe.

ii. dark fringe from the central maxima

OR

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.

20. i. Using Ampere's circuital law, derive the expression for the magnetic field in the vector from at a point on the axis of a solenoid. **[5]**

ii. What does a toroid consist of? Find out the expression for the magnetic field inside a toroid for N turns of the coil having the average radius r and carrying a current I. Show that the magnetic field in the open space interior and exterior to the toroid is zero.

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. **(c)** Temperature of the wire.
Explanation:
Specific resistance depends on the temperature and the nature of the material.

ii. **(b)** $\frac{1}{\pi}$
Explanation:
Perimeter of the loop = 2 πr = 2
$\therefore$ r = $\frac{1}{\pi}$
$\therefore$ Area = πr^2 = $\therefore$ x $(\frac{1}{\pi})^2$ = $\frac{1}{\pi}$
Magnetic dipole moment = NiA = 1 $\times$ 1 $\times$ $\{\frac{1}{\pi}\}$ = $\frac{1}{\pi}$

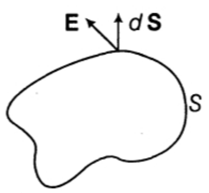
iii. **(d)** Gamma rays > UV rays > IR rays > Microwave
Explanation:
Frequency range of Gamma rays: 10^{22} - 10^{19} Hz
Frequency range of UV rays: 10^{17} - 10^{15} Hz
Frequency range of IR rays: 10^{14} - 10^{12} Hz
Frequency range of Microwave: 10^{13} - 10^{9} Hz

iv. **(a)** $-X_g$
Explanation:
As internal resistance of generator is already equal to the external resistance R_g. So to deliver maximum power, i.e., to make reactance equal to zero, the reactance in external circuit will be $-X_g$. In order to deliver maximum power, the generator to the load, the total reactance must be equal to zero, i.e., $X_L + X_g = 0$, $X_L = -X_g$.

v. **(c)** $(E_g)_{\mathrm{C}} > (E_g)_{\mathrm{Si}} > (E_g)_{\mathrm{Ge}}$
Explanation:
From above mentioned three given elements, the energy band gap of carbon is the maximum and that of germanium is the least. The energy band gaps of these elements are related as:
$(E_g)_{\mathrm{C}} > (E_g)_{\mathrm{Si}} > (E_g)_{\mathrm{Ge}}$

vi. **(d)** $\frac{\mu NI}{l}$
Explanation:
$B = \mu_0 nI = \frac{\mu_0 NI}{l}$ where n = $\frac{N}{l}$

vii. **(a)** the total flux through the surface is zero
Explanation:
This means total charge and so total flux is zero.



$\oint E \cdot dS$ = Total flux through the surface.
Given, total flux through surface = $\oint E \cdot dS = 0$ ...(i)

By Gauss's law (total flux through) = $\frac{1}{\varepsilon_0}$ (net charge enclosed in S) ...(ii)

From Eqs. (i) and (ii), we get

Net charge inside S = 0

Total flux through the surface S is zero.

(b) Answer the following questions briefly:

i. We know, $\beta = \frac{D\lambda}{d}$

As wavelength increases, fringe width increases. Since, $\lambda_{red} > \lambda_{violet'}$, the fringe width increases.

ii. In our daily life, we deal with bigger (macroscopic) particles and their wavelength is of the order of 10^{-35} m or less. Hence, wave effect is insignificant.

iii. Soft iron in preferred because in soft iron, energy loss per unit volume due to hysteresis is low.

iv. Electric field is always normal to the equipotential surface at every point, because no work is done, as

W = $q_0(V_A - V_B)$

$\Rightarrow V_A - V_B = 0$

hence W = 0.

If the field were not normal to the equipotential surface, it would have a non-zero component along the surface. So, to move a test charge against this component, a work would have to be done.

v. H_α-line of the Balmer series in the emission spectrum of H-atom is obtained in visible region, because

$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$

where, n = 3, 4, 5, ...

vi. Wavelength of violet light is smaller than that of red light. Also, angle of minimum deviation,

$\delta_m = (\mu - 1)$ A

$\Rightarrow \delta_m \propto \mu$

As, $\mu_R < \mu_V$

$\Rightarrow (\delta_m)_R < (\delta_m)_V$

As deviation is less for red light, hence angle of deviation decreases.

vii. Nuclear fusion involves the fusion of two or more very light nuclei to form a single nucleus. Since the nuclei to be fused are positively charged, they would repel each other strongly. Thus, they must be brought close together by high pressure as well as high kinetic energies. For this, very high temperatures of the order of 10^θ K are required. since very high temperatures are required for nuclear fusion, it is also called thermo-nuclear reaction.

Section B

2. The horizontal and vertical components of the earth's magnetic field are perpendicular to each other.

Horizontal component of earth's magnetic field,

H = $B_e \cos 60^o$ = B (given)

$\Rightarrow B_e \times \frac{1}{2} = B$ or $B_e = 2B$

Vertical component of earth's magnetic field,

V = $B_e \sin 60^o \Rightarrow$ V = 2B $\times \frac{\sqrt{3}}{2} \Rightarrow B_e = \sqrt{3}B$

OR

Given, radius of Rowland ring, r = 15 cm = 0.15 m

Number of turns, N = 350

Relative permeability of ferromagnetic core, μ_r = 800

Current, I =1.2 A

Magnetic field due to the toroid,

$B = \mu nI \left[\because n = \frac{\text{number of turns (N)}}{\text{length}}\right]$

$= \mu_0 \mu_r \frac{N}{2\pi r} \cdot I$ [$\because$ length of toroid = $2\pi r$]

= $4 \times 3.14 \times 10^{-7} \times 800 \times \frac{3500 \times 1.2}{2 \times 3.14 \times 0.15}$ = 4.48 T

3. For 7.5 MHz band,

   Wavelength, $\lambda_1 = \frac{c}{v} = \frac{3 \times 10^8}{7.5 \times 10^6} = 40 \text{ m}$

   For 12 MHz band,

   Wavelength, $\lambda_2 = \frac{c}{v} = \frac{3 \times 10^8}{12 \times 10^6} = 25 \text{ m}$

   So, wavelength range is from 25 m to 40 m.

4. Given, N = 1000,

   A = 100 cm^2 = 10^{-2} m^2,

   v = 100 rpm = $\frac{100}{60}$ rps,

   B = 3.6×10^{-2} T, e_0 = ?

   $\therefore$ Maximum emf produced in the coil is

   e_0 = NBA ω

   = NBA (2πv)

   = $1000 \times 3.6 \times 10^{-2} \times 10^{-2} \times 2 \times \frac{22}{7} \times \frac{100}{60}$

   = 3.77 V

OR

i. As given, E = 140 sin 314t

   On comparing with E = E_0 sin ωt, we have

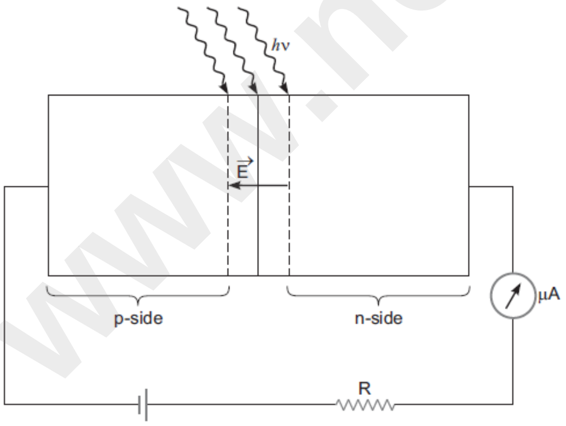
   ω = 314, E_0 = 140 V

   $\because \omega = 2\pi v \Rightarrow v = \frac{\omega}{2\pi} = \frac{314}{2 \times 3.14}$ = 50 Hz

ii. E_0 = 140 V

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

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

5. 

Circuit diagram of photodiode

Working: In diode (any type of diode), an electric field 'E' exists across the junction from n-side to p-side, when light with energy h_n greater than energy gap E_g. illuminates the junction. Then electron- hole pairs are generated due to absorption of photons, in or near the depletion region of the diode. Due to existing electric field, electrons and holes get separated. The free electrons are collected on n-side and holes are collected on p-side, giving rise to an emf.

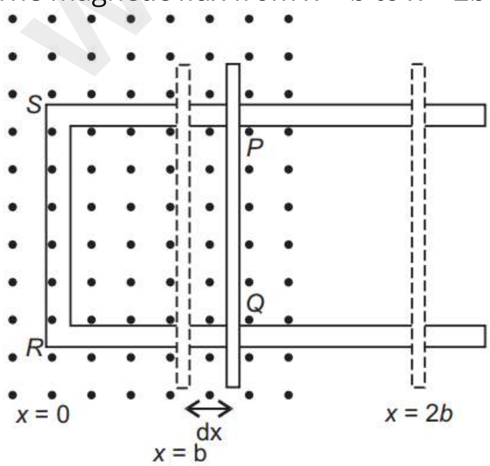
Due to this generated emf, an electric current of μ_A order flows through the external

resistance. Detection of Optical Signals: It is easier to observe the change in the current with change in the light intensity if a reverse bias is applied. Thus, photodiode can be used as a photodetector to detect optical signals.

6. G = 15Ω
   Current for which, the galvanometer shows full scale deflection, i = 4mA.
   Range of ammeter is 4 mA, which needs to be converted to 6A.
   $\therefore$ I = 6A
   A short resistance R is to be connected in parallel to the galvanometer.
   R = $\frac{iG}{(I-i)}$ = 10mΩ
7. Both the human body and the copper rod conduct electricity. When it is attempted to charge a copper rod by rubbing, the charge flows from the rod to the earth through the hand. However, when ebonite rod is charged by rubbing, the charges so produced stay on the ebonite rod as it is a bad conductor of electricity.
8. i. Reverse breakdown, also known as reverse breakdown voltage, is the voltage at which a diode or other semiconductor device begins to conduct in the reverse direction.
   ii. The forward V-I characteristic of the P-N junction diode shows that the current grows exceptionally slowly at the beginning. The curve is nonlinear because the external voltage delivered to the p-n junction is used to overcome the potential barrier in this region.

Section C

9. i. Threshold frequency (v_0) = 10 $\times$ 10^{14} Hz
   ii. W = (hv_0)
   = 6.6 $\times$ 10^{-34} $\times$10 $\times10^{14}$
   = 6.6 $\times$ 10^{-19} J = 4.125 eV
   iii. E_K = 8 $\times$1.6 $\times10^{-19}$ J = 8 eV
   $V_S = \frac{8\times1.6\times10^{-19}}{1.6\times10^{-19}}$
   V_S = 8.0 V
10. Faraday's First Law : The changing magnetic field linked with a conductor induces an electromotive force in the conductor.
   Faraday's Second Law : The induced electromotive force is proportional to the rate of change of magnetic field linked with the conductor.
   Faraday’s law of electromagnetic induction states that whenever there is a change in magnetic flux linked with of a coil, an emf is induced in the coil. The induced emf is proportional to the rate of change of magnetic flux linked with the coil. i.e., e$\propto\frac{\Delta\phi}{\Delta t}$
   If the coil contains N-turns, then e = - N ($\frac{\Delta\phi}{\Delta t}$)
   Let length of conductor PQ = l As x = 0, magnetic flux ϕ = 0.
   When PQ moves a small distance from x to x + dx, then magnetic flux linked = BdA = Bldx
   The magnetic field is from x = 0 to x = b, so final magnetic flux = ∑Bldx =Bl∑dx = Blb (increasing) Mean magnetic flux from x = 0 to x = b is $\frac{1}{2}$Blb.
   The magnetic flux from x = b to x = 2b is zero

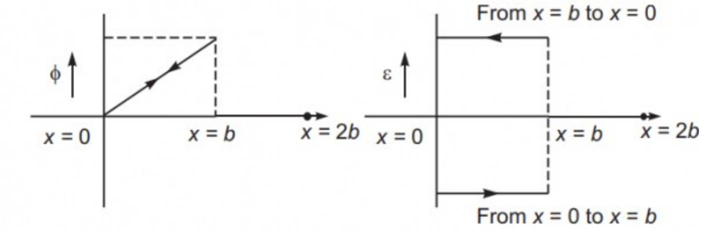


   = -Bl $\frac{dx}{dt}$ = -Blv

where v = $\frac{dx}{dt}$ = velocity of arm PQ from x = 0 to x = b.

During return from x = 2b to x = b, the induced emf is zero; but now area is decreasing so magnetic flux is decreasing, and induced emf will be in opposite direction. ε = Blv Graph is shown in figure.

ε = Blv



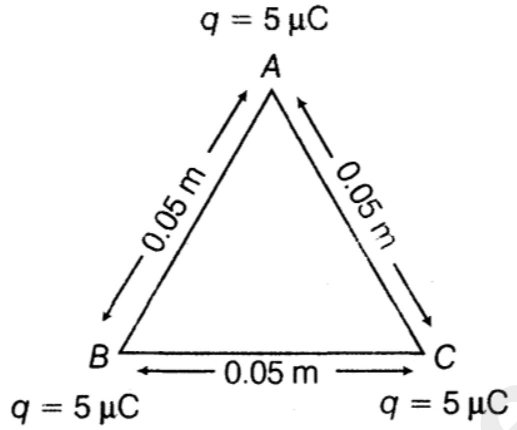
OR

i. Mutual induction
ii. Due to magnetic induction bulb will glow and due to change in magnetic flux a induced current is produce in coil B so bulb will glow

11. Potential energy (PE) of a system of two charges q_1 and q_2 separated by r is

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

For a system of three charges q_1, q_2 and q_3 the total potential energy U is



$U = U_{AB} + U_{BC} + U_{CA}$

$=\frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_2}{r_{12}}+\frac{q_2q_3}{r_{23}}+\frac{q_1q_3}{r_{13}}\right)=\frac{1}{4\pi\varepsilon_0}\cdot 3\frac{q^2}{r}$

[∵ $r_{12} = r_{23} = r$ and $q_1 = q_2 = q_3 = q$]

$=9\times10^9\times\frac{5\times10^{-6}\times5\times10^{-6}}{5\times10^{-2}}\times3=13.5\text{ J}$

12. In a nucleus of $^{20}_{10}\mathrm{Ne}$

Number of protons = 10

Number of neutrons = 20 - 10 = 10

Total mass of 10 protons and 10 neutrons

= 10 m_p + 10 m_n = 10 (m_p + m_n)

= 10 × (1.007825 + 1.008665)

= 10 × 2.01649 u = 201649 u

Mass defect, Δm = 20.1649 - 19.992397

= 0.172503 u

Total binding energy = 0.172503 × 931

= 160.600293 MeV

Eb per nucleon = $\frac{160.600293}{20}$

=8.03001465 MeV/ nucleon

OR

Given, m_p = 1.00783 u, m_n = 1.00867 u

i. For $^{56}_{26}\mathrm{Fe}$, there are 26 protons and (56 - 26) = 30 neutrons.

$\Delta m=$ mass of nucleons - mass of nucleus

$= 26m_p + 30m_n - m$

$= 26 \times 1.00783 + 30 \times 1.00867 - 55.934939 = 0.528741$ u

Total binding energy = $\Delta m \times 931$ MeV

$= 0.528741 \times 931$

= 492.26 MeV

Binding energy per nucleon

$= \frac{\text{Binding energy}}{\text{Number of nucleons}}$

$= \frac{492.26}{56}$ = 8.790 MeV

ii. For $^{209}_{83}\mathrm{Bi}$, there are 83 protons and (209 - 83) =126 neutrons.

$\Delta m =$ mass of nucleons - mass of nucleus

$= 83\, m_p + 126\, m_n - m$

$\Delta m = 83 \times 1.00783 + 126 \times 1.00867 - 208.980388 = 1.761922$ u

Binding energy = $\Delta m \times 931$ MeV

$= 1.761922 \times 931 = 1640.35$ MeV

Binding energy per nucleon

$= \frac{\text{Binding energy}}{\text{Number of nucleons}}$

$= \frac{1640.35}{209}$ = 7.848 MeV

Thus, binding energy per nucleon of Fe is more than Bi.

13. Using Lens Maker's Formula

$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{1}{f} = (1.5-1)\left(\frac{1}{30} + \frac{1}{30}\right)$

$= \frac{0.5\times2}{30} = \frac{1}{30}$

f = 30 cm

$m = \frac{f}{f+u} = \frac{30}{30-60} = \frac{30}{-30} = -1$

and $m = \frac{v}{u}$

$-1 = \frac{v}{-60}$

$\therefore$ v = 60 cm

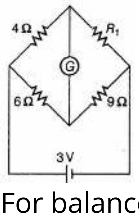
$|m| = \frac{h_i}{h_o}$

$1 = \frac{h_i}{5}$

$h_i = 5\ \mathrm{cm}$

14. i. The binding energy per nucleon for nucleus of range, 30 < A < 170 is close to its maximum value. So, the nucleus belongs to this region is highly stable and does not show radioactivity.

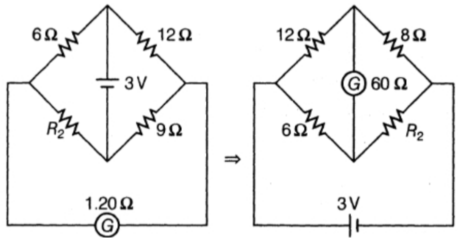
ii. Binding energy per nucleon is smaller for heavier nuclei them the middle ones, i.e. heavier nuclei are less stable. When a heavier nucleus such as a nucleus of mass number 240 splits into lighter nuclei (mass number 120), the BE/nucleon changes from about 7.6 MeV to 8.4 MeV. Greater BE of the product nuclei result in the liberation of energy.

15. 

For balanced Wheatstone bridge, there will be no deflection in the galvanometer.

$\frac{4}{R_1} = \frac{6}{9}$

$\Rightarrow R_1 = \frac{4\times9}{6} = 6\Omega$



For the equivalent circuit, when the Wheatstone bridge is balanced, there will be no deflection in the galvanometer.

$\therefore \frac{12}{8} = \frac{6}{R_2}$

$\Rightarrow R_2 = \frac{6\times8}{12} = 4\Omega$

$\therefore \frac{R_1}{R_2} = \frac{6}{4} = \frac{3}{2}$

16. i. Materials which lack permanent magnetic dipole moment are called diamagnetic. It is induced by a change in the orbital motion of electrons with applied magnetic field. Diamagnetic material exposed to an external magnetic field, magnetic moment is induced in a direction opposite to that of an applied magnetic field.
    ii. The hysteresis loss instead is the energy entrapped in magnetic materials exposed to a magnetic field in the form of residual magnetization - a typical behavior of FM materials - which is then lost as heat during the demagnetization step.

17. Given, amplitude of an electromagnetic wave,
    E_0 =120 N/C

    Frequency of wave, v = 50 MHz = 50 $\times$ 10^6 Hz

    i. Speed of light in vacuum,
    $c = \frac{E_0}{B_0}$
    $B_0 = \frac{E_0}{c} = \frac{120}{3\times10^8}$ = 40 $\times 10^{-8}$
    = = 400 $\times$ 10^{-9} T
    = 400nT
    Angular frequency of electromagnetic wave,
    $\omega = 2\pi v$ = 2 $\times$ 3.14 $\times$ 50 $\times$ 10^6
    ω = 3.14 $\times$ 10^8 rad/s
    Wave number of electromagnetic wave,
    $k = \frac{\omega}{c} = \frac{3.14\times10^8}{3\times10^8}$ = 1.05 rad/m
    Wavelength of electromagnetic wave,
    $\lambda = \frac{c}{v} = \frac{3\times10^8}{50\times10^6}$ = 6.00 m

    ii. Expression of electric field, E = E_0 sin (kx - ωt)

    E = 120 sin (1.05 x - 3.14 x 10^8t)
    Expression of magnetic field B,
    B = B_0 sin (kx - ωt)

    B = 4 $\times$ 10^{-7} sin (1.05x - 3.14 $\times$ 10^8 t)

Section D

18. i. Given, E_{rms} = 220V, C = 25μF = 25 $\times 10^{-6}$ F,
    L = $\frac{4}{\pi^2}$ H, R = 100Ω
    a. Resonant frequency is given by
    $f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times3.14\times\sqrt{\frac{4}{\pi^2}\times25\times10^{-6}}}$
    $= \frac{1}{2\times3.14\times\frac{2}{314}\times5\times10^{-3}}$ = 50Hz

b. Impedance of the circuit is given by

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

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

$= \frac{1}{2\times3.14\times50\times25\times10^{-6}}$ = 127.3Ω

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

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

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

= $\sqrt{(100)^2}$ = 100Ω

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

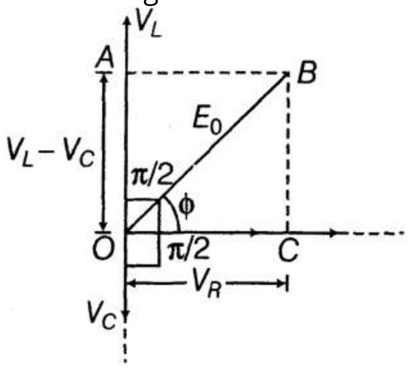
c. Average power consumed by the circuit

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

$\because$ Z = R = 100Ω

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

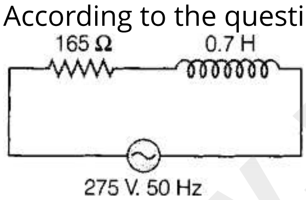
ii. Phasor diagram of L-C-R circuit is shown below.



The phase difference across the inductor and phase difference across the capacitor is 180^o.

OR

i. According to the question,



a. Reactance of the coil is ωL = X_L = (2πfL)

= $2\times\frac{22}{7}\times50\times0.7$

= 220 Ω

b. Impedance of the coil = $\sqrt{X_L^2+R^2}$

= $\sqrt{(\omega L)^2+R^2}$

= $\sqrt{(2\pi\times50\times0.7)^2+(165)^2}$

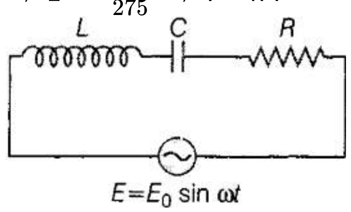
= $\sqrt{(48400+27225}$

= $\sqrt{(75625}$ = 275

c. Current flowing through the coil, V = IR

$\Rightarrow I=\frac{V}{R}$ (where, R = resistance of circuit and V = voltage applied)

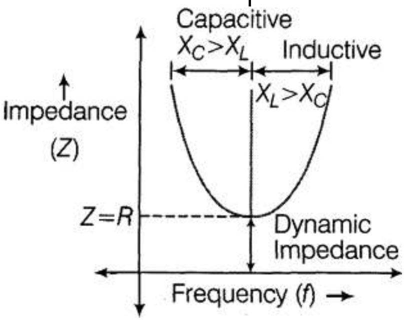
$\Rightarrow I=\frac{275}{275}$ $\Rightarrow$ I = 1A



Impedance(Z) = $\sqrt{(X_L - X_c)^2 + R^2}$

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

ii. The variation of impedance of a series L-C-R circuit with frequency of AC supply is given below.



19. i. The distance of nth order bright fringe from central fringe is given by

$y_n = \frac{nD\lambda}{d}$

For second bright fringe,

$y_2 = \frac{2D\lambda}{d}$

$= \frac{2\times1\times4.5\times10^{-7}}{1.5\times10^{-4}}$,

$y_2 = 6 \times 10^{-3}$ m

The distance of the second bright fringe

y_2 = 6 mm

ii. The distance of nth order dark fringe from central fringe is given by.

$y'_n = (2n-1)\frac{D\lambda}{2d}$

For second dark fringe, $n = 2$

$y'_n = (2\times2-1)\frac{D\lambda}{2d} = \frac{3D\lambda}{2d}$

$\Rightarrow y'_n = \frac{3}{2} \times \frac{1\times4.5\times10^{-7}}{1.5\times10^{-4}}$

$= 4.5 \times 10^{-3}$ m

$\therefore$ The distance of the second dark fringe

$y'_n = 4.5$ mm

OR

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

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

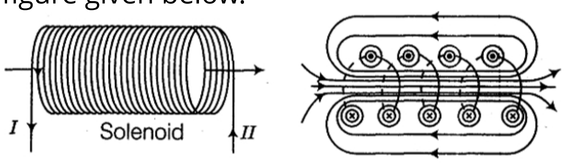
So, $I_1 = I_0 \cos^2\left(\frac{2\pi\times0}{\lambda}\right) = I_0$

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

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

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

20. i. **Magnetic Field of a Solenoid** A long coil of wire consisting of closely packed loops is called solenoid, whose magnetic field resembles that of a bar magnet of south(S) and north(N) poles as shown in the figure given below.



Magnetic field of a solenoid

For points inside the core of toroid

Consider a circle of radius r in the region enclosed by turns of toroid. Now we apply Ampere's circuital law to this circular path, i. e.

$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{l}}$ = μI ...(i)

$\oint \vec{B} \cdot d\vec{l}$ = $\oint$Bdl cos 0 = B$\cdot$ 2πr
Length of toroid = 2πr
Number of turns in toroid = n(2πr)
current in one-turn = I
$\therefore$ Current enclosed by circular path =(n2πr) • I
$\therefore$ Equation (1) gives
B 2πr = $\mu_0(n2\pi rI)$
$\Rightarrow$ B = μ_0nI

ii. **Toroid**
A **toroid** is a hollow circular ring on which a large number of insulated turns of a metallic wire are closely wound. Solenoid and toroid are two equipments which are used to produce magnetic fields.
Magnetic field inside the open space interior of the toroid Let the loop 2 be shown in the figure, experience magnetic field B.
No current threads the loop 2 which lie in the open space inside the toroid.
$\therefore$ By Ampere's circuital law,
$\oint_{\text{loop } 2} \mathbf{B} \cdot d\mathbf{l} = \mu_0$ (I) = 0
$\Rightarrow$ B = 0
Magnetic field in the open space exterior of the toroid Let us consider a coplanar loop 3 in the open space of exterior of toroid. Here, each turn of toroid threads the loop two times in opposite directions. Therefore, net current threading the loop
= NI - NI = 0
$\therefore$ By Ampere's circuital law,
$\oint_{\text{loop } 3}$ B.dl = μ_0(NI - NI) = 0
$\Rightarrow$ B = 0
Thus, there is no magnetic field in the open space interior and exterior of the toroid.