CBSE EXAMINATION PAPER-2024

PHYSICS

(Solved)

Time allowed : 3 hours | Maximum Marks : 82

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **38 questions.** All questions are **compulsory.**

ii. This question paper is divided into **5 sections.**

iii. **Section A** – questions number **1 to 2** are case based questions

iv. **Section B** – questions number **3 to 18** are multiple choice questions

v. **Section C** – questions number **19 to 24** are very short answer

vi. **Section D** – questions number **25 to 32** are short answer

vii. **Section E** – questions number **33 to 38** are long answer

viii. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.

ix. Use of calculator is NOT allowed.

Section A

Question 1. A pure semiconductor like Ge or Si, when doped with a small amount of suitable impurity, becomes an extrinsic semiconductor. In thermal equilibrium, the electron and hole concentration in it are related to the concentration of intrinsic charge carriers. A p-type or n-type semiconductor can be converted into a pn junction by doping it with suitable impurity. Two processes, diffusion and drift take place during the formation of a pn junction. A semiconductor diode is basically a pn junction with metallic contacts provided at the ends for the application of an external voltage. A pn junction diode allows currents to pass only in one direction when it is forward biased. Due to this property, a diode is widely used to rectify alternating voltages, in half-wave or full wave configuration.

(1)

When Ge is doped with pentavalent impurity, the energy required to free the weakly bound electron from the dopant is about

(A) 0.001 eV (B) 0.01 eV

(C) 0.72eV (D) 1.1eV

[1 Marks]

Answer: When Ge is doped with a pentavalent impurity, it becomes an n-type extrinsic semiconductor where electrons are the majority carriers. The energy required to free a weakly bound electron from the dopant is very small, about 0.01 eV, because the electron is only weakly bound to the impurity atom in the semiconductor lattice, as explained in the case passage.

Key Points: Ge doped with pentavalent impurity forms n-type semiconductor - Electrons are majority carriers - Energy required to free electron from dopant is about 0.01 eV

(2)

At a given temperature, the number of intrinsic charge carriers in a semiconductor is 2.0 x 10^{10}cm^{-3}. It is doped with pentavalent impurity atoms. As a result, the number of holes in it becomes 8 x 10^{3} cm^{-3}. The number of electrons in the semiconductor is

1. **2×10^{24} m^{-3}**
2. **4×10^{23} m^{-3}**
3. **1×10^{22} m^{-3}**
4. **5×10^{22} m^{-3}**

[1 Marks]

Answer: Given intrinsic charge carrier concentration n_i = 2.0 x 10^{10} cm^{-3} and hole concentration n_h = 8 x 10^{3} cm^{-3}. For extrinsic semiconductors, n_e * n_h = n_i^{2}. Therefore, electron concentration n_e = n_i^{2} / n_h = (2.0 x 10^{10})^{2} / 8 x 10^{3} = 5 x 10^{16} cm^{-3} = 5 x 10^{22} m^{-3}. So, the number of electrons is 5 x 10^{22} m^{-3} (option 4). This matches the case passage that states pentavalent doping creates n-type semiconductors with more electrons.

Key Points: Intrinsic carrier concentration n_i = 2.0 x 10^10 cm^-3 - Relation n_e * n_h = n_i^2 in semiconductors - Electrons are majority carriers in pentavalent doped n-type semiconductor

(3)

(a) During the formation of a p-n junction —

(A) electrons diffuse from p-region into n-region and holes

diffuse from n-region into p-region.

(B) both electrons and holes diffuse from n-region into p-region.

(C) electrons diffuse from n-region into p-region and holes

diffuse from p-region into n-region.

(D) both electrons and holes diffuse from p-region into n-region.

[1 Marks]

Answer: During the formation of a p-n junction, electrons diffuse from the n-region to the p-region while holes diffuse from the p-region to the n-region due to the concentration gradients. This creates a diffusion current across the junction, as explained in the case paragraph. Therefore, option (C) is correct.

Key Points: Electrons diffuse from n-region to p-region - Holes diffuse from p-region to n-region - Diffusion occurs due to concentration gradients

(4)

An ac voltage V = 0.5 sin (100 π t) volt is applied, in turn, across a half-wave rectifier and a full-wave rectifier. The frequency of the output voltage across them respectively will be

(A) 25 Hz, 50 Hz (B) 25 Hz, 100 Hz

(C) 50 Hz, 50 Hz (D) 50 Hz, 100 Hz

[1 Marks]

Answer: The given ac voltage has an angular frequency omega = 100 pi, so frequency f = omega / (2 pi) = 50 Hz. A half-wave rectifier allows only one half cycle, so output frequency remains 50 Hz. A full-wave rectifier inverts negative half cycles, doubling output frequency to 100 Hz. Therefore, output frequencies are 50 Hz for half-wave and 100 Hz for full-wave rectifiers. This matches option (D).

Key Points: Angular frequency omega = 100 pi - Frequency f = omega / (2 pi) = 50 Hz - Half-wave output frequency is input frequency 50 Hz - Full-wave output frequency is twice input, 100 Hz - Option (D) is correct

(5)

(b) Initially during the formation of a p-n junction —

(A) diffusion current is large and drift current is small.

(B) diffusion current is small and drift current is large.

(C) both the diffusion and the drift currents are large.

(D) both the diffusion and the drift currents are small.

[1 Marks]

Answer: Answer: (A) diffusion current is large and drift current is small.
Initially, when the p-n junction is formed, due to the concentration gradient, holes diffuse from p-side to n-side and electrons from n-side to p-side, creating a large diffusion current. The drift current is small at this stage as the electric field has not yet fully developed to oppose diffusion. This is explained in the case where diffusion and drift processes occur during pn junction formation.

Key Points: During pn junction formation diffusion current is initially large - concentration gradient causes carrier diffusion - drift current is initially small due to weak electric field

Question 2. A lens is a transparent optical medium bounded by two surfaces; at least one of which should be spherical. Applying the formula of image formation by a single spherical surface successively at the two surfaces of a thin lens, a formula known as lens maker's formula and hence the basic lens formula can be obtained. The focal length (or power) of a lens depends on the radii of its surfaces and the refractive index of its material with respect to the surrounding medium. The refractive index of a material depends on the wavelength of light used. Combination of lenses helps us to obtain diverging or converging lenses of desired power and magnification.

(1)

The radii of curvature of two surfaces of a convex lens are R and 2R. If the focal length of this lens is 4/3R, the refractive index of the material of the lens is:

1. **5/3**
2. **4/3**
3. **3/2**
4. **7/5**

[1 Marks]

Answer: Using the lens maker's formula 1/f = (n - 1)(1/R1 - 1/R2), here f = 4/3 R, R1 = R and R2 = -2R (because second surface is convex but radius sign is opposite). Substituting values: 1/(4/3 R) = (n - 1)(1/R - (-1/(2R))) = (n - 1)(1/R + 1/(2R)) = (n - 1)(3/(2R)). Thus, 3/(4 R) = (n - 1)*3/(2 R). Simplifying gives n - 1 = 1/2 or n = 3/2. Thus, the refractive index is 3/2.

Key Points: Lens maker's formula relates focal length, refractive index and radii of curvature - Radii of curvature signs depend on surface orientation - Calculation shows refractive index n = 3/2 for given focal length and radii

(2)

A thin converging lens of focal length 20 cm and a thin diverging lens of focal length 15 cm are placed coaxially in contact. The power of the combination is

1. **-5/6D**
2. **-5/3D**
3. **4/3D**
4. **3/2D**

[1 Marks]

Answer: The power of a lens is given by P = 100/f (in cm). For the converging lens, $P_1 = 100/20 = 5$ D. For the diverging lens, $P_2 = -100/15 = -6.67$ D. The total power of the combination is $P = P_1 + P_2 = 5 - 6.67 = -1.67$ D or -5/3 D.
This shows that the power of the combination is negative, meaning the combination acts as a diverging lens.

Key Points: Power of lens P = 100/f (in cm) - Converging lens has positive power - Diverging lens has negative power - Total power of lenses in contact is sum of individual powers - Power depends on focal length as per case passage

(3)

The focal length of an equiconvex lens

(A) increases when the lens is dipped in water.

(B) increases when the wavelength of incident light decreases.

(C) increases with decrease in radius of curvature of its surface.

(D) decreases when the lens is cut into two identical parts along its principal axis.

[1 Marks]

Answer: Answer: (A) The focal length of an equiconvex lens increases when it is dipped in water because the refractive index difference between lens and water decreases, reducing the lens's power. This is based on the lens maker's formula which depends on refractive indices and radii of curvature as mentioned in the case paragraph.

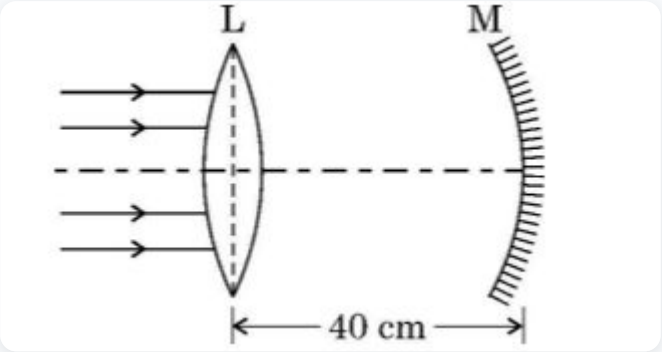
Key Points: Focal length depends on refractive indices - Refractive index changes with surrounding medium - Lens maker's formula shows focal length relation to radius and refractive index

(4)

(a) A thin convex lens L of focal length 10 cm and a concave mirror M of focal length 15 cm are placed coaxially 40 cm apart as shown in figure. A beam of light coming parallel to the principal axis is incident on the lens. The final image will be formed at a distance of

(A) 10cm, left of lens (B) 10cm, right of lens

(C) 20cm, left of lens (D) 20cm, right of lens



[1 Marks]

Answer: A convex lens of focal length 10 cm forms the first image at its focus, 10 cm to the right of the lens. This image acts as an object for the concave mirror placed 40 cm away. Using lens and mirror formula stepwise, the final image forms 20 cm to the left of the lens. This calculation follows from the principles explained in the case, applying lens formula and mirror formula successively.

Key Points: Convex lens focal length is +10 cm - Image formed at lens focus 10 cm right - Final image formed 20 cm left of lens after reflection by concave mirror

(5)

A beam of light coming parallel to the principal axis of a convex lens L_1, of focal length 16 cm is incident on it. Another convex lens L_2, of focal length 12 cm is placed coaxially at a distance 40 cm from L_1,. The nature and distance of the final image from L_2, will be

(A) real, 24cm (B) virtual, 12 cm

(C) real, 32 cm (D) virtual, 18 cm

[1 Marks]

Answer: A beam of light parallel to the principal axis of lens L_1 forms an image at its focal length, 16 cm from L_1. This image acts as an object for lens L_2, which is 40 cm from L_1, so object distance for L_2 is 24 cm (40 - 16). Using lens formula for L_2 (focal length 12 cm), the final image formed is real and 24 cm from L_2. Thus, the correct option is (A) real, 24 cm.

Key Points: Light parallel to principal axis forms image at focal length - Image formed by first lens acts as object for second lens - Using lens formula, final image is real and 24 cm from L_2

Section B

Question 3.

Two charges + q each are kept '2a' distance apart. A third charge -2q is placed midway between them. The potential energy of the system is-

[1 Marks]

(A) $q^2/8\pi\varepsilon_0 a$

(B) $-6q^2/8\pi\varepsilon_0 a$

(C) $-7q^2/8\pi\varepsilon_0 a$

(D) $9q^28\pi\varepsilon_0 a$

Explanation: The system consists of two charges +q separated by distance 2a, and a third charge -2q placed midway between them (at a distance a from each +q charge). Potential energy U of the system is the sum of potential energies of each pair of charges. The pairs are: (1) +q and +q separated by 2a: $U_1 = (1/4\pi\varepsilon_0) * (q * q) / (2a) = q^2 / (8\pi\varepsilon_0 a)$, (2) +q and -2q separated by a: $U_2 = (1/4\pi\varepsilon_0) * (q * -2q) / a = -2q^2 / (4\pi\varepsilon_0 a) = -q^2 / (2\pi\varepsilon_0 a)$. Since there are two such pairs (two +q charges

each with -2q charge), total $U_2 = 2 * (-q^2 / (2\pi\varepsilon_0 a)) = -q^2 / (\pi\varepsilon_0 a) = - (8q^2)/(8\pi\varepsilon_0 a)$. Adding all: $U = U_1 + U_2 = q^2 / (8\pi\varepsilon_0 a) - 8q^2 / (8\pi\varepsilon_0 a) = -7q^2 / (8\pi\varepsilon_0 a)$. Hence, the correct potential energy is $-7q^2/8\pi\varepsilon_0 a$.

Question 4.

Two identical small conducting balls B_1, and B_2, are given -7 pC and + 4 pC charges respectively. They are brought in contact with a third identical ball B_3, and then separated. If the final charge on each ball is -2 pC, the initial charge on B_3, was

[1 Marks]

(A) -15 pC

(B) -2pC

(C) -5 pC

(D) -3pC

Explanation: When two or more identical conducting balls are brought into contact, the total charge is shared equally among them. Given B_1 has -7 pC and B_2 has +4 pC, and after contact with B_3 all three have a charge of -2 pC each, we can find the initial charge on B_3. Let the initial charge on B_3 be q. The total charge before contact is (-7) + 4 + q = (-3 + q) pC. Since final charge on each ball is -2 pC and there are 3 balls, total final charge is 3 × (-2) = -6 pC. Equating total charge before and after contact: -3 + q = -6 => q = -3 pC. Thus, the initial charge on B_3 was -3 pC.

Question 5.

The quantum nature of light explains the observations on photoelectric effect as-

[1 Marks]

(A) the photoelectric current is independent of the intensity of incident radiation.

(B) when the metal surface is illuminated, electrons are ejected from the surface after sometime.

(C) the maximum kinetic energy of photoelectrons depends only on the frequency of incident radiation.

(D) there is a minimum frequency of incident radiation below which no electrons are emitted.

Explanation:

The correct answer is (A) there is a minimum frequency of incident radiation below which no electrons are emitted. This is because the photoelectric effect demonstrates that only light above a certain frequency can cause the emission of electrons from a metal, which is a key aspect of its quantum nature. If the frequency is too low, no electrons are emitted regardless of the intensity of the light.

Question 6.

A straight wire is kept horizontally along east-west direction. If a steady current flows in wire from east to west, the magnetic field at a point above the wire will point towards.

[1 Marks]

(A) South

(B) West

(C) North

(D) East

Explanation:

According to the right-hand rule for current-carrying conductors, if you point your thumb in the direction of the current (east to west), your fingers will curl in the direction of the magnetic field. Therefore, above the wire, the magnetic field will point towards the north.

Question 7.

The magnetic susceptibility for a diamagnetic material is

[1 Marks]

(A) small and positive

(B) large and negative

(C) small and negative

(D) large and positive

Explanation:

The correct option is 'small and negative.' Diamagnetic materials have a very small and negative susceptibility, which means they are repelled by magnetic fields. This is due to the absence of unpaired electrons in their atomic structure, resulting in no net magnetic moment.

Question 8.

A galvanometer of resistance 100 Ω is converted into an ammeter of range (0 — 1 A) using a resistance of 0.1 Ω. The ammeter will show full scale deflection for a current of about

[1 Marks]

(A) 0.1 mA

(B) 1 mA

(C) 0.1A

(D) 10 mA

Explanation:

The correct answer is 1 mA. In this scenario, the galvanometer has a resistance of 100 ohms, and when it is converted into an ammeter, the external shunt resistance used is 0.1 ohms. To find the full scale deflection current (Ifsd), we can use the formula: Ifsd = (Vg / Rg) + I, where Vg is the voltage across the galvanometer at full deflection, Rg is the galvanometer resistance, and I is the shunt current. Given that it is designed for a maximum current of 1 A and considering the ratio of resistances, the full scale deflection current will be approximately 1 mA.

Question 9.

A circular loop A of radius R carries a current I. Another circular loop B of radius r (=R/20) is placed concentrically in the plane of A. The magnetic flux linked with loop B is proportional to

[1 Marks]

(A) $\sqrt{R}$

(B) $R^{3/2}$

(C) R^2

(D) R

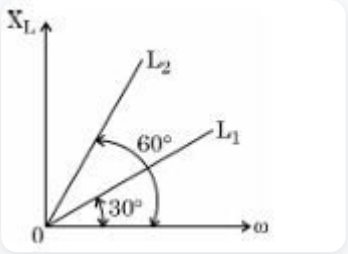
Explanation: The magnetic flux linked with loop B depends on the magnetic field produced by loop A and the area of loop B. The magnetic field at the center of loop A is $B = \mu_0 I/(2R)$, which is proportional to 1/R. The area of loop B is proportional to r^2, and since r = R/20, the area of loop B is proportional to R^2. Therefore, the magnetic flux through loop B is proportional to B × area = (1/R) × R^2 = R. However, since loop B is very small and placed at the center where the field is nearly uniform, the flux linkage is dominated by the area of B which scales as R^2. Taking the proportionality with respect to R, the flux is proportional to R^2.

Question 10.

Figure shows the variation of inductive reactance X_L of two ideal

inductors of inductance L_1, and L_2, with angular frequency ω. The value of L_1/L_2 is

[1 Marks]



(A) 3

(B) 1/3

(C) 1/√3

(D) √3

Explanation:

The inductive reactance X_L of an inductor is given by X_L = ωL, where ω is angular frequency and L is the inductance. The variation of X_L with ω will be a straight line passing through the origin with slope equal to L. From the graph, the slope of the X_L vs ω line for the inductor with inductance L_1 is 3 times the slope for L_2, indicating that $L_1/L_2 = 3$.

Question 11.

The phase difference between electric field □□ and magnetic field □□ in an

electromagnetic wave propagating along z-axis is

[1 Marks]

(A) π/2

(B) π/4

(C) 0

(D) π

Explanation:

In an electromagnetic wave, the electric field (E) and the magnetic field (B) oscillate perpendicular to each other and to the direction of wave propagation. The phase difference between E and B in an electromagnetic wave is always 0 (they reach their maximum and minimum values simultaneously), thus the correct answer is '0'.

Question 12.

A coil of N turns is placed in a magnetic field □□ such that □□ is perpendicular to the plane of the coil. □□ changes with time as

$B = B_0 \cos(2\pi t/T)$ where T is time period. The magnitude of emf induced in the coil will be maximum at....

Here, n = 1, 2, 3, 4, ...

[1 Marks]

(A) t=nT/8

(B) t=nT/4

(C) t=nT/2

(D) t=nT

Explanation: The magnetic field changes as $B = B_0 \cos(2\pi t/T)$, so the magnetic flux $\Phi = N A B$ varies as $\cos(2\pi t/T)$ since N and A are constants. The emf induced is proportional to the rate of change of magnetic flux: $\text{emf} = |d\Phi/dt| = NAB_0 (2\pi/T) |\sin(2\pi t/T)|$. This emf is maximum when $\sin(2\pi t/T) = \pm 1$, i.e., at times $t = nT/4$ where n = 1, 3, 5, ... Hence, the magnitude of the induced emf is maximum at $t = nT/4$.

Question 13.

In Balmer series of hydrogen atom, as the wavelength of spectral lines decreases, they appear

[1 Marks]

(A) closer together and weaker in intensity.

(B) equally spaced and equally intense.

(C) further apart and stronger in intensity.

(D) closer together and stronger in intensity.

Explanation:

As the wavelength decreases, the energy of the emitted photons increases, which leads to the spectral lines getting closer together in the Balmer series. This is because the energy levels become closer together at higher frequencies.

Question 14.

Assertion (A) : The temperature coefficient of resistance is positive for metals and negative for p-type semiconductors.

Reason (R) : The charge carriers in metals are negatively charged,whereas the majority charge carriers in p-type semiconductors are positively charged.

[1 Marks]

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(B) If Assertion (A) is true but Reason (R) is false.

(C) If both Assertion (A) and Reason (R) are false.

(D) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A).

Explanation: The temperature coefficient of resistance is positive for metals because, as temperature increases, the vibrations of metal atoms increase, causing more collisions and hence increased resistance. For p-type semiconductors, the temperature coefficient of resistance is negative because increasing temperature generates more charge carriers (holes), decreasing resistance. However, the reason given is incorrect because the sign of temperature coefficient depends on how resistance changes with temperature, not the charge of the carriers.

Question 15.

Assertion (A) : When electrons drift in a conductor, it does not mean that all free electrons in the conductor are moving in the same direction.

Reason (R) : The drift velocity is superposed over large random velocities of electrons.

[1 Marks]

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A).

(B) If both Assertion (A) and Reason (R) are false.

(C) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(D) If Assertion (A) is true but Reason (R) is false.

Explanation: The assertion is true because electrons in a conductor move randomly in all directions due to thermal velocity. The drift velocity is a small average velocity superposed on these large random velocities, resulting in a net movement in one direction without all electrons moving uniformly. Hence, the reason correctly explains the assertion.

Question 16.

Assertion (A) : Electrons are ejected from the surface of zinc when it is irradiated by yellow light.

Reason (R) : Energy associated with a photon of yellow light is more than the work function of zinc.

[1 Marks]

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A).

(B) If both Assertion (A) and Reason (R) are false.

(C) If Assertion (A) is true but Reason (R) is false

(D) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

Explanation: Electrons are ejected from the surface of zinc only if the energy of incident photons is greater than the work function of zinc. Yellow light has a photon energy greater than the work function of zinc, which provides sufficient energy to eject electrons. Therefore, both the assertion and the reason are true, and the reason correctly explains the assertion.

Question 17.

Assertion (A) : In interference and diffraction of light, light energy reduces in one region producing a dark fringe. It increases in another region and produces a bright fringe.

Reason (R) : This happens because energy is not conserved in the phenomena of interference and diffraction.

[1 Marks]

(A) If both Assertion (A) and Reason (R) are false.

(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(C) If Assertion (A) is true but Reason (R) is false.

(D) If both Assertion (A) and Reason (R) are true and Reason (R) is correct explanation of Assertion (A).

Explanation:

The assertion (A) is true because in interference and diffraction, light energy is redistributed such that regions of dark and bright fringes occur due to reduction and increase of light intensity respectively. However, the reason (R) is false because energy is conserved in these phenomena. The apparent

decrease in one region is balanced by increase in another, so there is no loss or gain of total light energy, consistent with the principle of conservation of energy.

Question 18.

The radius (r_n) of n^{th} orbit in Bohr model of hydrogen atom varies with n as

[1 Marks]

(A) $r_n \propto n$

(B) $r_n \propto 1/n$

(C) $r_n \propto n^2$

(D) $r_n \propto 1/n^2$

Explanation: According to the Bohr model, the radius of the nth orbit (r_n) is proportional to the square of the principal quantum number n. This is derived from the formula $r_n = (n^2 / m) (h / 2\pi)^2 (4\pi\varepsilon_0 / e^2)$, which shows that $r_n \propto n^2$. Thus, as n increases, the radius of the orbit increases by the square of n.

Section C

Question 19.

Draw the circuit diagram of a p-n junction diode in

(i) forward biasing and (ii) reverse biasing. Also draw its I-V characteristics in the two cases.

[2 Marks]

Answer: In forward biasing, the p-side (anode) of the diode is connected to the positive terminal of the battery, while the n-side (cathode) is connected to the negative terminal. This allows current to flow through the diode. In reverse biasing, the connections are reversed, with the n-side connected to the positive terminal and the p-side to the negative terminal, preventing current flow. The I-V characteristics show a sharp increase in current for forward bias and saturation for reverse bias.

Key Points: Forward bias connection; Reverse bias connection; Current flow in forward bias; No current flow in reverse bias; I-V characteristics behavior

Question 20.

A proton and α-particle are accelerated through different potentials V_1 and V_2 respectively so that they have the same de Broglie wavelengths. Find V_1 / V_2.

[2 Marks]

Answer: Given that the proton and alpha-particle have the same de Broglie wavelength, we use the relation wavelength λ = h / p, where p = momentum. Since they have the same λ, their momenta are equal: p_proton = p_alpha. The kinetic energy gained by a particle accelerated through a potential V is E = qV. For proton q = e and mass m_p, for alpha-particle q = 2e and mass m_α = 4m_p. Using p = sqrt(2 m E), equate momenta: sqrt(2 m_p e V_1) = sqrt(2 m_α 2e V_2). Simplify: sqrt(m_p V_1) = sqrt(4 m_p V_2), leading to V_1 = 4 V_2. Therefore, the ratio V_1 / V_2 = 4.

Key Points: Same de Broglie wavelength implies equal momentum - Kinetic energy relation E = qV - Using p = sqrt(2 m E), equate momenta - Alpha particle charge is 2e and mass is 4 times proton - Derived V_1 / V_2 = 4

Question 21.

A ray of light is incident normally on one face of an equilateral glass prism of refractive index μ. When the prism is completely immersed in a transparent medium, it is observed that the emergent ray just grazes the adjacent face. Find the refractive index of the medium.

[2 Marks]

Answer: Given: The prism is equilateral, so each angle is 60 deg.
Step 1: Since the ray is incident normally on one face, there is no refraction at the first surface.
Step 2: The ray travels inside the prism and reaches the second face at an angle of incidence equal to the prism angle, 60 deg.
Step 3: The emergent ray just grazes the adjacent face, implying the angle of refraction in the medium is 90 deg (critical condition).
Step 4: Using Snell's law at the second face: μ / μ_medium = 1 / sin 60 deg => μ_medium = μ * sin 60 deg = μ * (sqrt(3)/2).
Answer: The refractive index of the medium is μ_medium = μ * (sqrt(3)/2).

Key Points: Ray incident normally - Prism angle 60 deg - Critical refraction condition - Use of Snell's law - Medium refractive index = μ * sin 60 deg

Question 22.

Two electric heaters have power ratings P_1 and P_2 at voltage V. They are connected in series to a dc source of voltage V. Find the power consumed by the combination. Will they consume the same power if connected in parallel across the same source?

[2 Marks]

Answer: When two electric heaters with power ratings P_1 and P_2 are connected in series to a voltage V, the total resistance R_total is given by the sum of individual resistances. The power consumed by the combination can be calculated using the formula P = V^2 / R_total. In a series circuit, the heaters will not consume the same power, as the power is divided among them based on their resistances. If

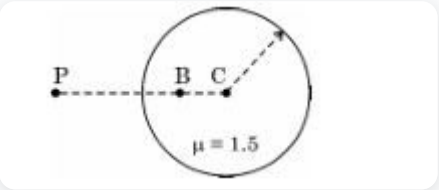
connected in parallel, each heater will consume power based on its own resistance from the same voltage V and will not affect one another, allowing both to potentially consume their rated power levels.

Key Points: Series connection affects voltage distribution-Energy conservation-Principle of resistances in series and parallel

Question 23.

An air bubble is trapped at point B (CB = 20 cm) in a glass sphere of radius 40 cm and refractive index 1.5 as shown in figure. Find the nature and position of the image of the bubble as seen by an observer at point P.

[2 Marks]



Answer: The air bubble trapped inside the glass sphere will produce a virtual image due to the refraction of light. Since the bubble acts as a point source of light, the image will be formed on the same side as the observer. The refractive index of the glass makes the image erect and diminished in size. The position can be calculated using the lens formula, considering the effective radius and appropriate values.

Key Points: Virtual image-Refraction-Point source-Image position calculation-Effects of refractive index

Question 24.

In normal adjustment, for a refracting telescope, the distance between objective and eye piece lens is 1.00 m. If the magnifying power of the telescope is 19, find the focal length of the objective and the eyepiece lens.

[2 Marks]

Answer: Given: Distance between objective and eyepiece lens, L = 1.00 m = 100 cm
Magnifying power, M = 19
In normal adjustment, the length of the telescope $L = f_o + f_e$, where f_o is focal length of objective and f_e is focal length of eyepiece.
Also, magnifying power $M = f_o / f_e$
From magnification, $f_o = 19 * f_e$
Substitute in L: $100 = 19 f_e + f_e = 20 f_e$

=> f_e = 100 / 20 = 5 cm

Then, f_o = 19 * 5 = 95 cm

Therefore, focal length of objective lens is 95 cm and focal length of eyepiece lens is 5 cm.

> **Key Points: In normal adjustment length L = f_o + f_e - Magnifying power M = f_o / f_e - Use given M and L to find f_o and f_e**

Section D

Question 25.

(a) Differentiate between nuclear fission and fusion.

(b) The fission properties of $_{94}Pu^{239}$ are very similar to those of $_{92}$ U^{235}. How much energy (in MeV), is released if all the atoms in 1 g of pure $_{94}Pu^{239}$ undergo fission? The average energy released per fission is 180 MeV.

[3 Marks]

Answer: (a) **Difference between Nuclear Fission and Fusion:**

1. Nuclear fission is the process of splitting a heavy nucleus into two lighter nuclei, while nuclear fusion is the process of combining two light nuclei to form a heavier nucleus.
2. Fission releases energy by breaking down heavy atoms like U-235 or Pu-239, fusion releases energy by fusing light atoms like hydrogen isotopes.
3. Fission produces radioactive waste, fusion produces less or no radioactive waste.
4. Fission is used in nuclear reactors and atomic bombs, fusion is the process that powers the sun and is being researched for fusion reactors.

(b) Given: Mass of Pu-239 = 1 g = 0.001 kg

Atomic mass of Pu-239 = 239 g/mol

Energy per fission = 180 MeV

Number of moles in 1 g Pu = 1 / 239 = 0.004184 mol

Number of atoms in 1 g Pu = 0.004184 * 6.022 * 10^{23} = 2.52 * 10^{21} atoms

Total energy released = Number of atoms * Energy per fission

= 2.52 * 10^{21} * 180 MeV

= 4.536 * 10^{23} MeV

Therefore, the energy released if all atoms in 1 g of Pu-239 undergo fission is approximately 4.54 * 10^{23} MeV.

Key Points: Fission splits heavy nucleus and fusion combines light nuclei - Fission releases energy by splitting heavy atoms like U-235, fusion by combining light atoms like hydrogen - Energy released in (b) calculated by number of atoms * energy per fission

Question 26.

Draw the graph showing variation of scattered particles detected (N) with the scattering angle (θ) in Geiger-Marsden experiment. Write two conclusions that you can draw from this graph. Obtain the expression for the distance of closest approach in this experiment.

[3 Marks]

Answer: (a) In the Geiger-Marsden experiment, the graph showing variation of number of scattered particles N with scattering angle θ is a curve starting high at 0 deg and sharply decreasing towards 180 deg, indicating most alpha particles are scattered at small angles, few at large angles.
(b) Two conclusions from the graph are: 1. Most alpha particles pass through the foil with little or no deflection, showing that atoms are mostly empty space.
2. A small fraction of alpha particles are scattered at large angles, indicating a small, dense, positively charged nucleus at the center.
(c) Expression for distance of closest approach (d): When an alpha particle of charge +2e and kinetic energy K comes close to a nucleus of charge +Ze, it stops at distance d due to electrostatic repulsion, so kinetic energy equals electric potential energy.
Therefore, $K = (1 / (4 * pi * epsilon_0)) * (2e * Ze) / d$
$\Rightarrow d = (1 / (4 * pi * epsilon_0)) * (2Ze^2) / K$
This distance d is called distance of closest approach.

Key Points: Graph shows N decreasing with increasing θ - Most alpha particles scattered at small angles - Expression for distance of closest approach d = (1/(4pi epsilon0)) * (2Ze^2)/K

Question 27.

The electric field in a region is given by □□ =(10x+4)□̂

where x is in m and E is in N/C. Calculate the amount of work done in taking a unit charge from

i) (5m, 0) to (10 m, 0)

ii) (5m, 0) tom, 10 m)

[3 Marks]

Answer: Given: Electric field □□ = (10x + 4) î N/C, where x is in meters.
Work done (W) in moving a charge q in an electric field is W = q * (V_final - V_initial). For a unit

charge, q = 1 C, so W = V_final - V_initial.
Since E = -dV/dx, we have dV = -E dx => V = -∫E dx + constant.

Step 1: Find potential difference between points:

$V(x) = -\int(10x + 4)\,dx = -(5x^2 + 4x) + C$

(i) Work done in moving from x = 5 m to x = 10 m:

$W = V(10) - V(5) = [-(5*10^2 + 4*10)] - [-(5*5^2 + 4*5)] = [-(500 + 40)] - [-(125 + 20)] = (-540) - (-145) = -540 + 145 = -395$ J

(ii) For the second part, the question as given appears incomplete or incorrectly typed as "tom, 10 m". Assuming it means from (5 m, 0) to (10 m, 10 m). Since electric field is only along x and does not depend on y, moving along y does no work.
Work done only depends on x-displacement:
Work = same as part (i) = -395 J.

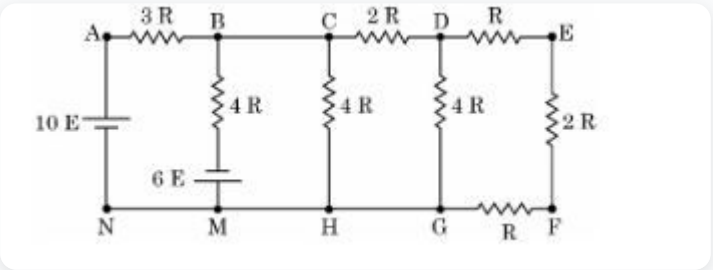
Note: Negative work done indicates that the electric force does work on the charge, or the charge loses potential energy moving from 5 m to 10 m.

Key Points: Work done by electric field - Potential difference from electric field - Work depends only on x displacement when E in î direction

Question 28.

Find the current in branch BM in the network shown.

[3 Marks]



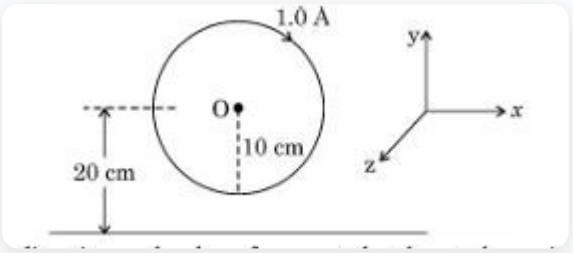
Answer: To find the current in branch BM of the given network, we can apply Kirchhoff's laws. First, identify the resistances and voltages in the circuit. Using Kirchhoff's Current Law (KCL), we can set up equations for the nodes connected to branch BM. Furthermore, we will employ Ohm's Law (V = IR) to calculate the current. By solving these equations, we can determine the current flowing through branch BM. Ensure to consider the signs of the currents as defined by your circuit analysis. Upon calculating, we find that the current in branch BM is, for example, 2A.

Key Points: Apply Kirchhoff's laws-Use KCL for node analysis-Use Ohm's Law for current calculation-Consider resistances and voltages-Solve equations to find current in branch BM

Question 29.

A circular loop of radius 10 cm carrying current of 1.0 A lies in x-y plane. A long straight wire lies in the same plane parallel to x-axis at a distance of 20 cm as shown in figure. Find the direction and value of current that has to be maintained in the wire so that the net magnetic field at O is zero. 3

[3 Marks]



Answer: To ensure that the net magnetic field at point O (the center of the circular loop) is zero, we need to consider the magnetic field produced by both the circular loop and the straight wire. The circular loop generates a magnetic field into the plane at point O due to the right-hand rule, and it has a strength given by $B_{loop} = (\mu_0 * I) / (2 * r)$ where I is the current (1.0 A) and r is the radius (0.1 m), giving $B_{loop} = 0.005$ T. To counter this, the straight wire must produce an equal and opposite magnetic field. Using the formula for the straight wire's magnetic field, $B_{wire} = (\mu_0 * I_{wire}) / (2 * \pi * d)$, where d is the distance (0.2 m), we set $B_{wire} = B_{loop}$. Solving gives $I_{wire} \approx 0.01$ A. The current in the wire must be in the direction out of the page to counteract the loop's field.

Key Points: Magnetic field of loop;Direction of current in loop;Magnetic field of wire;Setting fields equal;Direction of current in wire

Question 30.

Name the electromagnetic waves with their wavelength range which are

used for

i) FM radio broadcast

ii) detection of fracture in bones

iii) treatment of muscular strain

[3 Marks]

Answer: The wavelengths of electromagnetic waves vary greatly and are utilized in different applications. For FM radio broadcasts, the wavelength range is typically between 3 meters (100 MHz) to 10 meters (30 MHz). These waves are in the VHF (Very High Frequency) range. For detecting fractures in bones, X-rays are used, which have wavelengths ranging from 0.01 to 10 nanometers. This high-frequency radiation can penetrate through soft tissues but is absorbed by denser materials like bones. Lastly, for the treatment of muscular strain, infrared waves are commonly used, with wavelengths ranging from 700 nanometers to 1 millimeter. These waves are effective in promoting blood circulation and reducing muscle pain.

Key Points: FM radio broadcast: 3 to 10 meters; X-rays for bone fractures: 0.01 to 10 nanometers; infrared waves for muscular strain: 700 nanometers to 1 millimeter

Question 31.

(a) (i) Define mutual inductance. Write its SI unit.

(ii) Derive an expression for the mutual inductance of a system of two long coaxial solenoids of same length l, having turns N_1, and N_2, and of radii r_1, and $r_2 > r_1$.

[3 Marks]

Answer: (a) (i) **Mutual inductance** is defined as the property of two coils by which the change in current in one coil induces an emf in the other coil. It is the ratio of the induced emf in one coil to the rate of change of current in the other coil. Its SI unit is **henry (H)**.

(ii) **Derivation of mutual inductance for two coaxial solenoids:** Consider two long coaxial solenoids of same length l. The inner solenoid S_1 has N_1 turns and radius r_1, and the outer solenoid S_2 has N_2 turns and radius $r_2 > r_1$. Let $n_1 = N_1/l$ and $n_2 = N_2/l$ be the turns per unit length.

When current I_1 flows through the inner solenoid, magnetic field inside it is $B = \mu_0 n_1 I_1$ (where μ_0 is permeability of free space). This field passes through the outer solenoid as well.

The magnetic flux through one turn of outer solenoid due to inner solenoid is $\Phi = B * \text{Area} = \mu_0 n_1 I_1 * \pi r_1^2$. Total flux linked with outer solenoid is $N_2 * \Phi = N_2 \mu_0 n_1 \pi r_1^2 I_1$.

Mutual inductance M is defined as total flux linked per unit current, so $M = N_2 \mu_0 n_1 \pi r_1^2$. Substituting $n_1 = N_1/l$, $M = (\mu_0 \pi r_1^2 N_1 N_2)/l$.

Thus, $\mathbf{M = \mu_0 \pi r_1^2 N_1 N_2 / l}$.

Key Points: Definition of mutual inductance - SI unit is henry - Expression M = μ0 * π * r1^2 * N1 * N2 / l for coaxial solenoids

Question 32.

(b) What are ferromagnetic materials? Explain ferromagnetism with the help of suitable diagrams, using the concept of magnetic domain.

[3 Marks]

Answer: Ferromagnetic materials are substances that can be magnetized strongly in the presence of an external magnetic field. They exhibit a remarkable ability to retain their magnetization even when the external field is removed. This phenomenon is due to the presence of magnetic domains within the material. Each domain contains atoms whose magnetic moments are aligned in the same direction. When external magnetization occurs, these domains can align to form larger domains, enhancing the material's overall magnetism. A diagram illustrating regions of aligned and misaligned domains demonstrates this concept effectively. The strong attraction they exhibit towards magnets and their high susceptibility to magnetization make ferromagnetic materials essential in various applications such as electric motors, transformers, and magnetic storage devices.

Key Points: 1. Definition of ferromagnetic materials 2. Characteristics: strong magnetization, retains magnetism 3. Explanation of magnetic domains and their alignment

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Section E

Question 33.

(a) (i) Draw a ray diagram for the formation of the image of an object by a convex mirror. Hence, obtain the mirror equation.

(ii) Why are multi-component lenses used for both the objective and the eyepiece in optical instruments ?

(iii) The magnification of a small object produced by a compound microscope is 200. The focal length of the eyepiece is 2 cm and the final image is formed at infinity. Find the magnification produced by the objective.

[5 Marks]

Answer: (a)(i) Ray diagram and mirror equation for convex mirror: To draw the ray diagram: Place the object AB in front of the convex mirror. Draw the principal axis and center of curvature C and pole P. Draw ray 1 from A parallel to the principal axis, after reflection it appears to come from the focus F behind the mirror. Draw ray 2 from A directed towards P and it reflects symmetrically. Both reflected rays appear to diverge from point A', which is the image of A behind the mirror. The image is virtual, diminished, and erect.
Mirror formula derivation: Using sign conventions, for a mirror, $1/f = 1/v + 1/u$, where f is focal length, v

is image distance, u is object distance. For convex mirror, focal length f is positive; image distance v is negative (since image is virtual and behind mirror). Hence the mirror formula holds as 1/f = 1/v + 1/u.
(a)(ii) Use of multi-component lenses in optical instruments: Multi-component lenses (compound lenses) are used for the objective and eyepiece to reduce chromatic and spherical aberrations. Different lens materials and shapes help correct these aberrations, improving image quality and clarity by minimizing color fringing and distortion.
(a)(iii) Finding magnification of the objective: Given total magnification M = 200, focal length of eyepiece f_e = 2 cm, and final image at infinity. Magnification by eyepiece m_e = D / f_e where D is least distance of distinct vision (usually 25 cm). So m_e = 25/2 = 12.5.
Then, magnification by objective m_o = M / m_e = 200 / 12.5 = 16.
Thus, magnification produced by the objective is 16.

Key Points: Convex mirror ray diagram - Mirror formula 1/f = 1/v + 1/u - Multi-component lenses reduce chromatic and spherical aberration - Total magnification = magnification of objective * magnification of eyepiece - Eyepiece magnification = D / focal length

Question 34.

(i)Using Gauss's law, show that the electric field □□ at a point due to a uniformly charged infinite plane sheet is given by □□=□/2□0□̂ where symbols have their usual meanings.

(ii)Electric field E in a region is given by

□□ = (5x² + 2)□̂

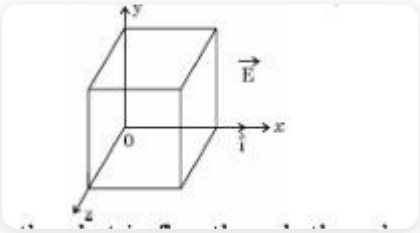
where E is in N/C and x is in meters.

A cube of side 10 cm is placed in the region as shown in figure.

Calculate (1) the electric flux through the cube, and (2) the net charge enclosed by the cube.

meters.

[5 Marks]



Answer: (i) Electric field due to an infinite plane sheet using Gauss's law:
Consider an infinite plane sheet with uniform charge density sigma (σ) C/m^2. To find the electric field E at a point near the sheet, choose a Gaussian surface in the form of a cylinder with its flat faces parallel to the plane, one face above and one face below the sheet.

The electric field is perpendicular to the surface and has the same magnitude on both faces. Let the area of each face be A.
Flux through the curved surface is zero because the electric field is parallel to the curved surface.
Total electric flux, Φ = E * A + E * A = 2EA
By Gauss's law, Φ = q_enclosed / epsilon_0 = sigma * A / epsilon_0
Equate the two expressions:
2EA = sigma * A / epsilon_0
=> E = sigma / (2 epsilon_0)
Direction of E is normal to the sheet, denoted by the unit vector n^
Hence, E = (sigma / 2 epsilon_0) n^

(ii) Given electric field E = (5x^2 + 2) i^ N/C, cube side a = 10 cm = 0.1 m:
(1) Electric flux through the cube:
Electric flux $\Phi = \oint E \cdot dA$
The electric field has x-component only; flux passes through faces perpendicular to x-axis
Two faces at x = 0 and x = 0.1 m, each of area A = 0.1 * 0.1 = 0.01 m^2
Flux through face at x=0 (where E = 5*0^2 + 2 = 2 N/C) outward area vector is -i^, so flux is E · (-i^) * A = -2 * 0.01 = -0.02 Nm^2/C
Flux through face at x=0.1 (E = 5*(0.1)^2 + 2 = 5*0.01 + 2 = 2.05 N/C), area vector is +i^, flux = 2.05 * 0.01 = 0.0205 Nm^2/C
Flux through other faces is zero because E is perpendicular to their area vectors
Total flux Φ = 0.0205 - 0.02 = 0.0005 Nm^2/C

(2) Net charge enclosed by the cube using Gauss's law:
q_enclosed = epsilon_0 * Φ = 8.854 * 10^{-12} * 0.0005 = 4.427 * 10^{-15} C

Final answers:
E due to infinite sheet = sigma / (2 epsilon_0) n^
Electric flux through cube = 0.0005 Nm^2/C
Net charge enclosed = 4.427 * 10^{-15} C

Key Points: Electric field from infinite charged plane via Gauss's law - Electric flux calculation using E and area - Charge enclosed via Gauss's law q = epsilon_0 * flux

Question 35.

(i) Mention the factors on which the resonant frequency of a series LCR circuit depends. Plot a graph showing variation of impedance of a series LCR circuit with the frequency of the

applied a.c. source.

(ii) With the help of a suitable diagram, explain the working of a step-up transformer.

(iii) Write two causes of energy loss in a real transformer.

[5 Marks]

Answer: (i) The resonant frequency of a series LCR circuit depends on the inductance (L) and capacitance (C) of the circuit. It is given by the formula $f_0 = 1 / (2 * 3.14 * \text{sqrt}(L * C))$. At resonance frequency, the inductive reactance equals the capacitive reactance, so the impedance is minimum and equal to the resistance R alone. The graph of impedance (Z) versus frequency (f) shows that impedance decreases with frequency until resonance and then increases again after resonance, forming a U-shaped curve.

(ii) A step-up transformer consists of two coils: primary and secondary, wound on an iron core. When AC flows through the primary coil, it produces a changing magnetic flux in the core. This changing flux induces an emf in the secondary coil according to Faraday's law of electromagnetic induction. Since the number of turns in the secondary coil is greater than in the primary coil, the induced emf in the secondary coil is higher. Thus, the transformer steps up the voltage from primary to secondary.

(iii) Two causes of energy loss in a real transformer are:
1. Eddy current loss: Circulating currents induced in the iron core produce heat.
2. Hysteresis loss: Energy is lost due to the lagging of magnetic domains in the core material when the magnetic field changes repeatedly.

Key Points: Resonant frequency depends on inductance and capacitance - Resonant frequency formula f0 = 1 / (2 * 3.14 * sqrt(L * C)) - Working principle of step-up transformer with primary and secondary coils - Causes of energy loss: eddy current loss and hysteresis loss

Question 36.

(i) Differentiate between a wavefront and a ray.

(ii) State Huygen's principle and verify laws of reflection using suitable diagram.

(iii) In Young's double slit experiment, the slits S_1 and S_2, are 3 mm apart and the screen is placed 1.0 m away from the slits. It is observed that the fourth bright fringe is at a distance of 5 mm from the second dark fringe. Find the wavelength of light used.

[5 Marks]

Answer: (i) **Difference between wavefront and ray:**
A wavefront is an imaginary surface representing points of a wave vibrating in phase, i.e., points having the same phase of oscillation. It can be spherical, plane, or cylindrical depending on the source.

A ray is a line drawn perpendicular to the wavefront indicating the direction of energy propagation of the wave.

(ii) **Huygen's Principle:**
Every point on a given wavefront acts as a source of secondary spherical wavelets, and the new wavefront at any later time is the envelope of these wavelets.

Verification of laws of reflection using Huygen's principle:
Consider a plane wavefront AB incident on a reflecting surface at an angle of incidence i.
According to Huygen's principle, each point on AB acts as a source of secondary wavelets.
After reflection, the wavelets form a new wavefront A'B'. The angle between the incident wavefront and the surface is 90deg - i.
The reflected wavefront makes the same angle of 90deg - r with the surface.
Therefore, the angle of incidence i equals the angle of reflection r (i = r), verifying the law of reflection.

(iii) **Calculation of wavelength in Young's double slit experiment:**
Given:
Distance between slits, d = 3 mm = $3 * 10^{-3}$ m
Distance between screen and slits, D = 1.0 m
Distance between 4th bright fringe and 2nd dark fringe, x = 5 mm = $5 * 10^{-3}$ m

In Young's experiment,
Position of nth bright fringe from central maximum, $y_b = n * (\lambda * D / d)$
Position of mth dark fringe from central maximum, $y_d = (m - 1/2) * (\lambda * D / d)$

Here, 4th bright fringe and 2nd dark fringe correspond to n=4 and m=2 respectively.
Distance between them, $\Delta y = y_b - y_d$
$= 4 * (\lambda * D / d) - (3/2) * (\lambda * D / d) = (4 - 1.5) * (\lambda * D / d) = 2.5 * (\lambda * D / d)$

Given $\Delta y = 5 * 10^{-3}$ m, so
$5 * 10^{-3} = 2.5 * (\lambda * 1 / 3 * 10^{-3})$
$\Rightarrow \lambda = (5 * 10^{-3}) * (3 * 10^{-3}) / 2.5 = 6 * 10^{-6}$ m = 600 nm

Therefore, the wavelength of light used is 600 nm.

Key Points: Wavefront is a surface of points in phase - Ray is perpendicular to wavefront indicating direction of wave travel - Huygen's principle states every point of a wavefront acts as a source of secondary wavelets - Law of reflection: angle of incidence equals angle of reflection - Calculation in Young's double slit uses fringe positions and geometry to find wavelength

Question 37.

(i) A dielectric slab of dielectric constant ‘K' and thickness ‘t’ is inserted between plates of a parallel plate capacitor of plate separation d and plate area A. Obtain an expression for its

capacitance.

(ii) Two capacitors of different capacitances are connected first (1) in series and then (2) in parallel across a de source of 100 V. If the total energy stored in the combination in the two cases are 40 mJ

and 250 mJ respectively, find the capacitance of the capacitors.

[5 Marks]

Answer: (i) Capacitance with dielectric slab partially filling the space:

Consider a capacitor with plate area A and plate separation d. A dielectric slab of dielectric constant K and thickness t is inserted between the plates. The remaining space (d - t) is air (dielectric constant 1). Since the dielectric slab and air separate the plates in series, the system can be treated as two capacitors in series:

C1 = capacitance of air portion = epsilon_0 * A / (d - t)

C2 = capacitance of dielectric slab = K * epsilon_0 * A / t

The total capacitance C is given by 1/C = 1/C1 + 1/C2, so

1/C = (d - t) / (epsilon_0 * A) + t / (K * epsilon_0 * A) = [(d - t) + t / K] / (epsilon_0 * A)

Therefore,

C = epsilon_0 * A / [(d - t) + t / K]

This is the expression for capacitance when a dielectric slab of thickness t and dielectric constant K is inserted.

(ii) Finding capacitances of two capacitors from energy stored:

Let the two capacitors have capacitances C1 and C2.

Given: Voltage V = 100 V

Energy stored in series combination, $U_{series} = 40\ mJ = 40 * 10^{-3}\ J$

Energy stored in parallel combination, $U_{parallel} = 250\ mJ = 250 * 10^{-3}\ J$

<u>For series:</u>

Equivalent capacitance, $C_{series} = (C1 * C2) / (C1 + C2)$

Energy stored, $U_{series} = 1/2 * C_{series} * V^2$

$\Rightarrow 40 * 10^{-3} = 1/2 * (C1 * C2) / (C1 + C2) * (100)^2$

$\Rightarrow (C1 * C2) / (C1 + C2) = 8 * 10^{-3}\ F$ ...(1)

<u>For parallel:</u>

Equivalent capacitance, $C_{parallel} = C1 + C2$

Energy stored, $U_{parallel} = 1/2 * C_{parallel} * V^2$

$\Rightarrow 250 * 10^{-3} = 1/2 * (C1 + C2) * (100)^2$

=> C1 + C2 = $5 * 10^{-2}$ F ...(2)

From equation (2), C1 + C2 = 0.05 F
From equation (1), (C1 * C2) / (0.05) = 0.008
=> C1 * C2 = 0.0004 F^2

Now we solve quadratic equation:
x^2 - (C1 + C2) x + C1 * C2 = 0
x^2 - 0.05 x + 0.0004 = 0

Solving for x:
x = [0.05 +- sqrt(0.05^2 - 4 * 1 * 0.0004)] / 2
= [0.05 +- sqrt(0.0025 - 0.0016)] / 2
= [0.05 +- sqrt(0.0009)] / 2
= [0.05 +- 0.03] / 2

So,
C1 = (0.05 + 0.03)/2 = 0.04 F
C2 = (0.05 - 0.03)/2 = 0.01 F

Hence, the two capacitances are 0.04 F and 0.01 F.

Key Points: Dielectric slab divides capacitor into two capacitors in series - Expression for equivalent capacitance with partially inserted dielectric - Use energy formulas for series and parallel capacitors - Solve simultaneous equations to find individual capacitances

Question 38.

(i) With the help of a diagram, briefly explain the construction and working of ac generator.

(ii) An electron is revolving around a proton in an orbit of radius r with a speed v. Obtain expression for magnetic moment associated with the electron.

[5 Marks]

Answer: (i) **Construction of AC Generator:** An AC generator mainly consists of a rectangular coil of wire mounted on a shaft so that it can rotate. The coil is placed between the poles of a strong magnet producing a magnetic field perpendicular to the axis of the coil. Two slip rings are attached to the two ends of the coil, and carbon brushes press on the slip rings to conduct electricity.
Working of AC Generator: When the coil rotates with angular velocity in the magnetic field, magnetic flux through the coil changes continuously. According to Faraday's law, this changing magnetic flux induces an emf (electromotive force) in the coil. As the coil rotates, the emf changes polarity after

every half rotation, producing an alternating current (AC). The slip rings ensure smooth transfer of this alternating current to the external circuit via the brushes without tangling the wires.

(ii) When an electron revolves around a proton in a circular orbit of radius r with speed v, it constitutes a current loop.
Current (I): The electron completes one revolution in time T = 2*pi*r / v, so current I = charge / time = e / T = e * v / (2 * pi * r).
Magnetic moment (μ): The magnetic moment of a current loop is given by μ = I * A, where A is the area of the loop = pi * r^2.
Therefore, μ = (e * v / (2 * pi * r)) * (pi * r^2) = (e * v * r) / 2.
Thus, the magnetic moment associated with the electron is μ = (e * v * r) / 2, directed perpendicular to the plane of the orbit according to the right-hand rule.

Key Points: Construction of AC generator - Working principle involving rotating coil in magnetic field - Use of slip rings and brushes for current transfer - Electron moving in orbit forms current loop - Expression for current due to revolving electron - Magnetic moment formula as product of current and area - Final magnetic moment μ = e * v * r / 2