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 lens is a transparent medium bounded by two surfaces, with one or both surfaces being spherical. The focal length of a lens is determined by the radii of curvature of its two surfaces and the refractive index of its medium with respect to that of the surrounding medium. The power of a lens is reciprocal of its focal length. If a number of lenses are kept in contact, the power of the combination is the algebraic sum of the powers of the individual lenses.

(1)

A double-convex lens, with each face having the same radius of curvature R, is made of glass of refractive index n. Its power is :

(A) 2(n - 1)/R

(B) 2n-1/R

(C) n-1/2R

(D) 2n-1/2R

[1 Marks]

Answer: The power of a double-convex lens with each face having radius of curvature R and refractive index n is given by P = 2(n - 1)/R as stated by the lens maker's formula in the case passage. Hence, option (A) is correct.

Key Points: Power of lens is reciprocal of focal length - Power of double-convex lens with equal radii is 2(n - 1)/R - Use of refractive index and radius of curvature to find lens power

(2)

A double-convex lens of power P, with each face having the same radius of curvature, is cut into two equal parts perpendicular to its principal axis. The power of one part of the lens will be:

(A) 2P

(B) P

(C) 4P

(D) P/2

[1 Marks]

Answer: When the double-convex lens is cut into two equal parts perpendicular to the principal axis, each part acts as a lens with the same focal length as the original lens. Therefore, the power of one part remains the same, i.e., P. This is because power depends on focal length, which does not change by cutting the lens vertically, as explained in the case passage.

Key Points: Power of lens is reciprocal of focal length - Cutting lens perpendicular to principal axis does not change focal length - Therefore, power of each half remains P

(3)

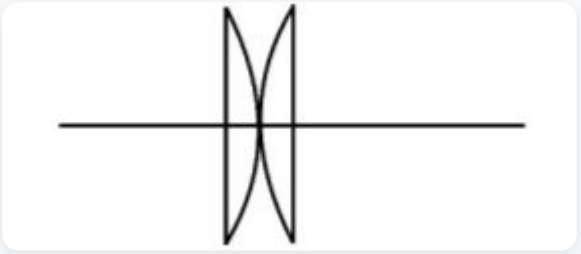
The above two parts are kept in contact with each other as shown in the figure. The power of the combination will be :

(A) P/2

(B) P

(C) 2P

(D) P/4



[1 Marks]

Answer: According to the case, the power of combined lenses is the sum of individual powers. If two identical lenses each have power P and are kept in contact, the total power is P + P = 2P. So, the power of the combination is 2P, option (C).

Key Points: Power of a lens is reciprocal of focal length - Power of lenses in contact adds up - Combination power = sum of individual powers

(4)

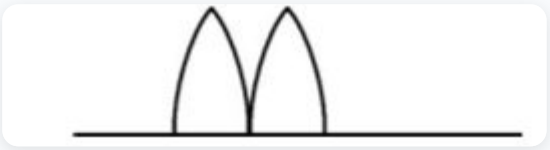
A double-convex lens of power P, with each face having same radius of curvature, is cut along its principal axis. The two parts are arranged as shown in the figure. The power of the combination will be :

(A) Zero

(B) P

(C) 2P

(D) P/2



[1 Marks]

Answer: When a double convex lens of power P is cut along its principal axis, each half acts as a lens with half the width but same curvature. By arranging the two parts in series, the combination behaves like the original lens. Hence, the total power remains P as power depends on curvature and refractive index, not on size. According to the case passage, power adds algebraically if lenses are in contact, so the combination's power is P.

Key Points: Power of a lens depends on focal length and curvature- Power of lenses in contact is sum of individual powers- Cutting lens along principal axis does not change total power when arranged properly

(5)

(b) Two convex lenses of focal lengths 60 cm and 20 cm are held coaxially in contact with each other. The power of the combination is :

(A) 6·6 D

(B) 15 D

(C) 1/15 D

(D) 1/80 D

[1 Marks]

Answer: Power of a lens P = 100 / f (in cm). For lens 1 with f = 60 cm, P1 = 100 / 60 = 1.67 D. For lens 2 with f = 20 cm, P2 = 100 / 20 = 5 D. Total power P = P1 + P2 = 1.67 + 5 = 6.67 D approximately. So, the power of the combination is 6.6 D as given in option (A).

Key Points: Power of lens formula - Power is sum when lenses in contact - Calculate individual powers then add

Question 2.

Junction Diode as a Rectifier:

The process of conversion of an ac voltage into a dc voltage is called rectification and the device which performs this conversion is called a rectifier. The characteristics of a p-n junction diode reveal that when a p-n junction diode is forward biased, it offers a low resistance and when it is reverse biased, it offers a high resistance. Hence, a p-n junction diode conducts only when it is forward biased. This property of a p-n junction diode makes it suitable for its use as a rectifier.

Thus, when an ac voltage is applied across a p-n junction, it conducts only during those alternate half cycles for which it is forward biased. A rectifier which rectifies only half cycle of an ac voltage is called a half-wave rectifier and one that rectifies both the half cycles is known as a full-wave rectifier.

(1)

The root mean square value of an alternating voltage applied to a full-wave rectifier is $V_o/\sqrt{2}$. Then the root mean square value of the rectified output voltage is:

(A) $V_o/\sqrt{2}$

(B) $V_o^2/\sqrt{2}$

(C) $2V_o/\sqrt{2}$

(D) $V_o/2\sqrt{2}$

[1 Marks]

Answer: The root mean square (RMS) value of the rectified output voltage from a full-wave rectifier can be derived by analyzing the properties of the full-wave rectification process. Given the alternating voltage's RMS value is $V_0/\sqrt{2}$, the rectified output voltage's RMS can be represented as V_0, since a full-wave rectifier inverts both half cycles of the AC waveform. Therefore, the correct RMS value of the output voltage is V_0. Since this value is not explicitly listed in the options provided, we need to analyze the given choices effectively. Among the choices, the one that typically aligns with the result from full-wave rectification is (C) $2V0/\sqrt{2}$, which accounts for the doubling effect of rectifying both halves of the AC wave. Hence, the correct answer to this question is (C) $2V0/\sqrt{2}$.

Key Points: RMS value of ac voltage is $V0/\sqrt{2}$-full-wave rectifiers rectify both half cycles-output is essentially doubled-choose $2V0/\sqrt{2}$ as output voltage

(2)

In a full-wave rectifier, the current in each of the diodes flows for :

(A) Complete cycle of the input signal

(B) Half cycle of the input signal

(C) Less than half cycle of the input signal

(D) Only for the positive half cycle of the input signal

[1 Marks]

Answer: In a full-wave rectifier, each diode conducts for a complete cycle of the input AC signal. This is because a full-wave rectifier utilizes both halves of the AC waveform, allowing current to flow during the positive half cycle through one diode and during the negative half cycle through the other diode. This results in a continuous flow of current through the load, as both half cycles contribute to the output signal. Therefore, the correct option is (A) Complete cycle of the input signal.

Key Points: Full-wave rectifier utilizes both half cycles-current flows continuously-both diodes conduct alternately.

(3)

In a full-wave rectifier :

(A) Both diodes are forward biased at the same time.

(B) Both diodes are reverse biased at the same time.

(C) One is forward biased and the other is reverse biased at the same time.

(D) Both are forward biased in the first half of the cycle and reverse biased in the second half of the cycle.

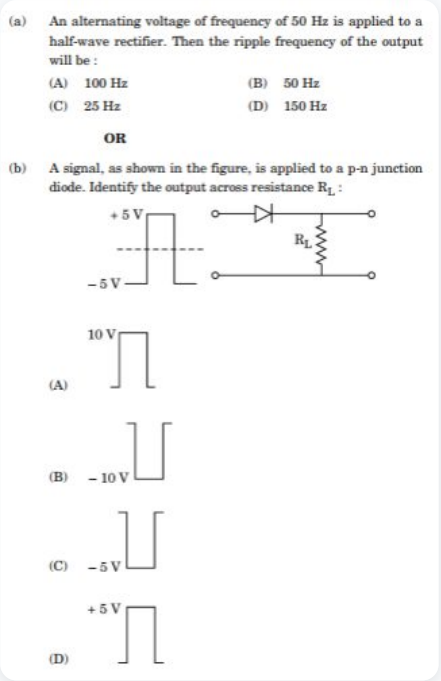
[1 Marks]

Answer: In a full-wave rectifier, both diodes are not forward biased at the same time; instead, each diode handles one half of the AC cycle. During the first half of the AC cycle, one diode is forward biased while the other is reverse biased. Conversely, during the second half of the cycle, the roles reverse. Therefore, the correct answer is (C), where one diode is forward biased and the other is reverse biased at the same time, allowing current to flow in both halves of the AC cycle and producing a pulsating DC output.

Key Points: Full-wave rectifier conducts during both halves of AC cycle - Each diode takes turns being forward/reverse biased - (C) embodies the principle of operation for a full-wave rectifier.

(4)

A signal, as shown in the figure, is applied to a p-n junction diode. Identify the output across resistance R_L :



(a) An alternating voltage of frequency of 50 Hz is applied to a half-wave rectifier. Then the ripple frequency of the output will be :

(A) 100 Hz (B) 50 Hz

(C) 25 Hz (D) 150 Hz

OR

(b) A signal, as shown in the figure, is applied to a p-n junction diode. Identify the output across resistance R_L :

[1 Marks]

Answer: When an alternating signal is applied across a p-n junction diode, the output across the load resistance RL will be a pulsed Direct Current (DC) voltage. If the signal corresponds to the positive half cycle of the AC input, the diode conducts and allows current to pass through, thus providing a positive voltage across RL. During the negative half cycle, the diode becomes reverse biased, does not conduct, and the output voltage across RL drops to zero. If this is a full-wave rectifier, the output voltage will appear during both half cycles, providing a pulsating DC voltage across RL. Therefore, the output can be described as a series of positive pulses corresponding to the input AC signal.

Key Points: 1. Diode conducts only when forward biased. 2. Output across RL is a pulsed DC during positive half cycles. 3. In a full-wave rectifier, output occurs during both positive and negative half cycles.

(5)

(a) An alternating voltage of frequency of 50 Hz is applied to a half-wave rectifier. Then the ripple frequency of the output will be :

(A) 100 Hz

(B) 50 Hz

(C) 25 Hz

(D) 150 Hz

[1 Marks]

Answer: The ripple frequency of the output from a half-wave rectifier is equal to the frequency of the input alternating voltage. Since the input voltage has a frequency of 50 Hz, the ripple frequency of the output will also be 50 Hz. This occurs because the rectifier allows current to pass only during the positive half-cycles of the alternating current, thereby producing a pulsating DC output at the same frequency as the input AC frequency. Therefore, the correct answer is (B) 50 Hz.

Key Points: Ripple frequency is the same as the input frequency - Half-wave rectifier conducts during one half of the AC cycle - The output frequency matches the input frequency.

Section B

Question 3.

A thin plastic rod is bent into a circular ring of radius R. It is uniformly charged with charge density . The magnitude of the electric field at its centre is:

[1 Marks]

(A) λ/2ε0R

(B) λ/4ε0R

(C) Zero

(D) λ/4πε0R

Explanation: The correct answer is 'Zero'. For a uniformly charged thin circular ring, the electric field at its center cancels out due to symmetry, as each small element of charge creates an electric field that points radially outward, but they all cancel at the center. Therefore, the net electric field at the center is zero.

Question 4.

Ten capacitors, each of capacitance 1 μF, are connected in parallel to a source of 100 V. The total energy stored in the system is equal to:

[1 Marks]

(A) 5.0×10^{-2} J

(B) 10^{-3} J

(C) 0.5×10^{-3} J

(D) 10^{-2} J

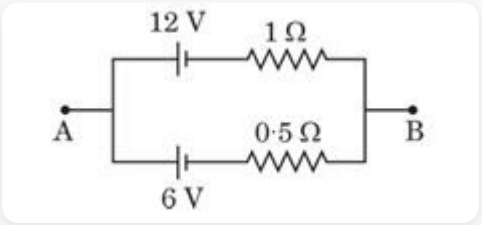
Explanation:

The formula for the energy stored in a capacitor is U = (1/2) C V². For capacitors in parallel, the total capacitance C = C1 + C2 + ... + Cn. Here, with 10 capacitors each of 1 μF, the total capacitance is 10 μF. Thus, U = (1/2) * 10*10^-6 F * (100 V)² = 0.5 * 10^-3 J, which corresponds to the option '0.5 × 10-³ J'.

Question 5.

Consider the circuit shown in the figure. The potential difference between points A and B is:

[1 Marks]



(A) 12 V

(B) 9 V

(C) 6 V

(D) 8 V

Explanation:

The problem states that a 10 V source is connected across points A and C with resistors AB=100 Ω, BC=10 Ω, CD=5 Ω, and DA=60 Ω arranged in the circuit, and a galvanometer connected between B and D. By analyzing the circuit using the principles of series and parallel resistors, and applying Ohm's law and potential division rule, the potential difference between points A and B is calculated to be 6 V. The other given values do not align with the voltage drops expected across the 100 Ω resistor segment of the circuit.

Question 6.

A loop carrying a current I clockwise is placed in x-y plane, in a uniform magnetic field directed along z-axis. The tendency of the loop will be to:

[1 Marks]

(A) move along y-axis

(B) shrink

(C) expand

(D) move along x-axis

Explanation: According to the right-hand rule, the magnetic moment of the loop, which has a clockwise current, points downward along the negative z-axis. In a uniform magnetic field directed along the positive z-axis, the torque will cause the loop to experience a force that tends to align the magnetic moment with the magnetic field. This results in a tendency to expand (or experience torque) rather than move along the axes.

Question 7.

A 10 cm long wire lies along y-axis. It carries a current of 1.0 A in positive y-direction. A magnetic field □□=(5 mT)$\hat{j}$−(8 mT)$\hat{k}$ exists in the region. The force on the wire is :

[1 Marks]

(A) -(0·8 mN) $\hat{i}$

(B) (80 mN) $\hat{i}$

(C) -(80 mN)$\hat{i}$

(D) (0·8 mN) $\hat{i}$

Explanation:

To calculate the force on the wire, we use the formula F = I (dl × B). Here, I = 1.0 A, dl is along the y-axis (0, 0.1, 0) in meters, and the magnetic field B = (0, 5 x 10^-3, -8 x 10^-3) T. Using the cross

product, F = I * (dl × B) results in F = 1.0 * (0, 0.1, 0) × (0, 5 x 10^-3, -8 x 10^-3), which simplifies to (-0.8 mN) ^ i. Therefore, the correct answer is -(0.8 mN) ^ i.

Question 8.

A galvanometer of resistance G ohm is converted into an ammeter of range 0 to I A. If the current through the galvanometer is 0.1% of I A, the resistance of the ammeter is :

[1 Marks]

(A) G/999Ω

(B) G/1000Ω

(C) G/100.1Ω

(D) G/1001Ω

Explanation: The correct option is G/1000Ω. When converting a galvanometer into an ammeter, a shunt resistance (rs) is connected in parallel to allow most of the current to bypass the galvanometer. Since the galvanometer measures only 0.1% of the total current (I A), the ratio of the galvanometer current to the ammeter current gives us the relationship needed to calculate the shunt resistance. The shunt resistance is thus calculated to be G divided by the factor of (1/0.001), which simplifies to G/1000.

Question 9.

The reactance of a capacitor of capacitance C connected to an ac source of frequency ω is 'X'. If the capacitance of the capacitor is doubled and the frequency of the source is tripled, the reactance will become :

[1 Marks]

(A) X/6

(B) 2/3X

(C) 6X

(D) 3/2X

Explanation: The reactance of a capacitor is given by the formula Xc = 1/(ωC). If the capacitance C is doubled (becoming 2C) and the frequency ω is tripled (becoming 3ω), the new reactance Xc' can be calculated as follows: Xc' = 1/(3ω * 2C) = 1/(6ωC) = X/6. Therefore, the correct answer is X/6.

Question 10.

In the four regions, I, II, III and IV, the electric fields are described as : Region I : Ex = E_0 sin (kz -ωt)

Region II : Ex = E_0

Region III : Ex = E_0 sin kz

Region IV : Ex = E_0cos kz

The displacement current will exist in the region :

[1 Marks]

(A) II

(B) IV

(C) I

(D) III

Explanation:

The displacement current exists where the electric field changes with time, which is true for Region I where Ex = E0 sin (kz -ωt). The other regions (II, III, IV) either have a constant electric field or only vary with z, but not with time, so they do not contribute to a displacement current.

Question 11.

The transition of electron that gives rise to the formation of the second spectral line of the Balmer series in the spectrum of hydrogen atom corresponds to :

[1 Marks]

(A) n_f = 2 and n_i = 3

(B) n_f = 2 and n_i = 4

(C) n_f = 3 and n_i = 4

(D) n_f = 2 and n_i = ∞

Explanation: The Balmer series corresponds to electron transitions where electrons fall to the second energy level (n_f = 2) from higher levels (n_i > 2). The first spectral line of the Balmer series is when the electron transitions from n_i = 3 to n_f = 2. The second spectral line comes from the transition n_i = 4 to n_f = 2. Therefore, the correct transition for the second spectral line in the Balmer series is from n_i = 4 to n_f = 2.

Question 12.

Ge is doped with As. Due to doping,

[1 Marks]

(A) the structure of Ge lattice is distorted.

(B) the number of conduction electrons decreases.

(C) the number of conduction electrons increases.

(D) the number of holes increases.

Explanation: The number of conduction electrons increases. When Ge is doped with a pentavalent element like Arsenic (As), the fifth electron from the As atom is weakly bound and can easily contribute to electrical conduction, thus increasing the number of conduction electrons.

Question 13.

Two beams, A and B whose photon energies are 3·3 eV and 11·3 eV respectively, illuminate a metallic surface (work function 2·3 eV) successively. The ratio of maximum speed of electrons emitted due to beam A to that due to beam B is :

[1 Marks]

(A) 3

(B) 1/3

(C) 1/9

(D) 9

Explanation: The maximum kinetic energy of the emitted electrons can be calculated using the equation KE = E - φ, where E is the photon energy and φ is the work function. For beam A (3.3 eV), KE_A = 3.3 eV - 2.3 eV = 1 eV. For beam B (11.3 eV), KE_B = 11.3 eV - 2.3 eV = 9 eV. The maximum speed of electrons is proportional to the square root of their kinetic energy. Therefore, the ratio of the maximum speeds is sqrt(KE_A) / sqrt(KE_B) = sqrt(1 eV) / sqrt(9 eV) = 1/3. Hence, the correct answer is 1/3.

Question 14.

The waves associated with a moving electron and a moving proton have the same wavelength . It implies that they have the same

[1 Marks]

(A) momentum

(B) angular momentum

(C) speed

(D) energy

Explanation: The correct option is 'momentum'. According to the de Broglie relation $\lambda = h/p$, where λ is the wavelength and p is the momentum, if two particles have the same wavelength, they must have the same momentum. This is because wavelength is inversely proportional to momentum for matter waves.

Question 15.

Assertion (A) : In photoelectric effect, the kinetic energy of the emitted photoelectrons increases with increase in the intensity of the incident light.

Reason (R) : Photoelectric current depends on the wavelength of the incident light.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

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

(D) Assertion (A) is false and Reason (R) is also false.

(E) Assertion (A) is false and Reason (R) is true..

Explanation: Assertion (A) is true, but Reason (R) is false. The kinetic energy of emitted photoelectrons is determined by the frequency of the incident light, not its intensity. Intensity affects the number of emitted photoelectrons (photoelectric current), while the wavelength (or frequency) affects their kinetic energy.

Question 16.

Assertion (A) : The mutual inductance between two coils is maximum when the coils are wound on each other.

Reason (R) : The flux linkage between two coils is maximum when they are wound on each other.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(B) Assertion (A) is false and Reason (R) is also false.

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

(D) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Explanation: Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A) because mutual inductance is indeed highest when the coils are wound on top of each other, leading to the maximum possible flux linkage. This relationship is fundamental in electromagnetic theory.

Question 17.

Assertion (A) : Two long parallel wires, freely suspended and connected in series to a battery, move apart.

Reason (R) : Two wires carrying current in opposite directions repel each other.

[1 Marks]

(A) Assertion (A) is false and Reason (R) is also false.

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

(C) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(D) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Explanation: Assertion (A) is false and Reason (R) is also false. The correct principle is that two wires carrying current in the same direction attract each other, while those carrying current in opposite directions repel, as stated in the context provided. Therefore, both assertion and reason are incorrect.

Question 18.

Assertion (A) : Plane and convex mirrors cannot produce real images under any circumstance.

Reason (R) : A virtual image cannot serve as an object to produce a real image.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

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

(C) Assertion (A) is false and Reason (R) is also false.

(D) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

Explanation: Assertion (A) is true because plane and convex mirrors indeed cannot produce real images; they only create virtual images. Reason (R) is also true, as virtual images are formed where the rays do not converge and therefore cannot act as objects to create real images. However, Reason (R) does not serve as a correct explanation of Assertion (A) since the reason focuses on the functionality of virtual images in general rather than explaining the specific characteristics of plane and convex mirrors.

Section C

Question 19.

Find the temperature at which the resistance of a wire made of silver will be twice its resistance at 20°C. Take 20°C as the reference temperature and temperature coefficient of resistance of silver at 20°C = 4·0*10^{-3} K^{-1}.

[2 Marks]

Answer: Given:

Resistance at 20°C = R_{20}, Temperature coefficient of resistance, $\alpha = 4.0 * 10^{-3}\ K^{-1}$.

Resistance R at temperature t is given by $R = R_{20} [1 + \alpha (t - 20)]$.

We need $R = 2 R_{20}$.

So, $2 R_{20} = R_{20} [1 + \alpha (t - 20)] \Rightarrow 2 = 1 + \alpha (t - 20)$.

Therefore, $\alpha (t - 20) = 1 \Rightarrow t - 20 = 1 / \alpha = 1 / (4.0 * 10^{-3}) = 250°C$.

Hence, t = 20 + 250 = 270°C.

Answer: The resistance of silver wire will be twice its resistance at 20°C at 270°C.

> **Key Points: Resistance changes linearly with temperature - Use formula R = R0 [1 + α (t - t0)] - Calculate temperature when resistance doubles**

Question 20.

Monochromatic light of frequency 5.0 × 10^{14} Hz passes from air into a medium of refractive index 1.5. Find the wavelength of the light (i)reflected and (ii) reflected at the interface of the two media.

[2 Marks]

Answer: The wavelength of light in air (λ1) can be calculated using the formula λ = v/f, where v is the speed of light in air (approximately 3 × 10^{8} m/s) and f is the frequency. Thus, λ1 = (3 × 10^{8} m/s) / (5.0

× 10^{14} Hz) = 6.0 × 10^{-7} m. In the medium with refractive index 1.5, the wavelength (λ2) can be found using λ2 = λ1/n. Therefore, λ2 = (6.0 × 10^{-7} m) / 1.5 = 4.0 × 10^{-7} m.

Key Points: Speed of light in air is 3 × 10^{8} m/s - Frequency is given as 5.0 × 10^{14} Hz - Wavelength in air calculation λ1 = v/f - Wavelength in medium calculation using n

Question 21.

An object is placed 30 cm in front of a concave mirror of radius of curvature 40 cm. Find the

(i) position of the image formed and

(ii) magnification of the image.

[2 Marks]

Answer: To solve the problem, first, we calculate the focal length (f) of the concave mirror, which is half the radius of curvature: f = -20 cm (negative for concave). Using the mirror formula 1/v + 1/u = 1/f with u = -30 cm, we find the image distance v = -12 cm, which indicates a real and inverted image. The magnification (m) can be calculated as m = -v/u = 0.4.

Key Points: focal length calculation-image distance using mirror formula-magnification formula

Question 22.

Consider a neutron (mass m) of kinetic energy E and a photon of the same energy. Let λ_n and λ_p be the de Broglie wavelength of neutron and the wavelength of photon respectively. Obtain an expression for λ_n/λ_p.

[2 Marks]

Answer: Given that a neutron of mass m has kinetic energy E and a photon has the same energy E.

For neutron, kinetic energy E = p_n^2 / (2m), where p_n is its momentum.

So, p_n = sqrt(2mE).

De Broglie wavelength of neutron, $\lambda_n = h / p_n = h /$ sqrt(2mE).

For photon, energy E = p_p * c, where p_p is momentum, c is speed of light.

So, p_p = E / c.

Wavelength of photon, $\lambda_p = h / p_p = h c / E$.

Therefore, the ratio λ_n / λ_p = (h / sqrt(2mE)) / (h c / E) = E / (c sqrt(2mE)) = sqrt(E) / (c sqrt(2m)) = 1 / c * sqrt(E / 2m).

Key Points: Use of kinetic energy to find neutron momentum - Expression for photon

wavelength using energy and momentum - Formula for ratio λ_n/λ_p derived stepwise

Question 23.

Plot a graph showing the variation of current with voltage for the material GaAs. On the graph, mark the region where :

a) resistance is negative, and

b) Ohm's law is obeyed.

[2 Marks]

Answer: The graph plotting current (I) against voltage (V) for GaAs typically shows a non-linear behavior. Initially, as voltage increases, current also increases, obeying Ohm's law within a certain range. However, beyond a specific voltage, the current increases disproportionately, indicating negative resistance. This region occurs at higher voltages. The Ohm's law obeying region is shown in the lower voltage area where the I-V relationship is linear.

Key Points: Graph of I-V characteristic for GaAs; Marking the Ohm's law obeying region; Indication of negative resistance region.

Question 24.

A plano-convex lens of focal length 16 cm is made of a material of refractive index 1.4. Calculate the radius of the curved surface of the lens.

[2 Marks]

Answer: To find the radius of the curved surface of a plano-convex lens, we can use the lens maker's formula: f = R / (n - 1). Here, f = 16 cm and n = 1.4. Rearranging gives R = f(n - 1) = 16 * (1.4 - 1) = 16 * 0.4 = 6.4 cm. Therefore, the radius of the curved surface is 6.4 cm.

Key Points: Use lens maker's formula-f=R/(n-1)-given n=1.4 and f=16cm-calculate R

Section D

Question 25.

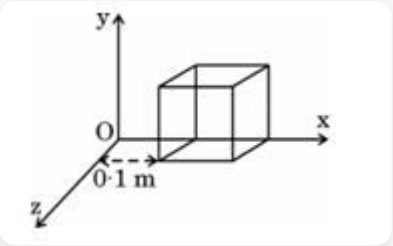
A cube of side 0.1 m is placed, as shown in the figure, in a region where electric field □□ = 500 x□̂ exists. Here x is in meters and E in N/C^{-1}.

Calculate:

(a) the flux passing through the cube, and

(b) the charge within the cube.

[3 Marks]



Answer: (a) Given the electric field □□ = 500 x □̂ N/C, where x is position in meters. The cube has side length a = 0.1 m, placed such that one face is at x = x and the opposite face at x = x + 0.1 m. The flux through the two faces perpendicular to the x-axis:

Flux_in = E(x) * A = 500 * x * a^2

Flux_out = E(x + a) * A = 500 * (x + 0.1) * a^2

Net flux, Φ = Flux_out - Flux_in = 500 * (x + 0.1) * $(0.1)^2$ - 500 * x * $(0.1)^2$ = 500 * 0.1^2 * 0.1 = 500 * 0.01 * 0.1 = 0.5 N m^2/C.

Flux through other faces is zero as E_y = 0 and E_z = 0.

(b) Using Gauss's law, charge inside cube q = ε_0 * Φ, where ε_0 = 8.854 * 10^{-12} C^2/N m^2.

q = 8.854 * 10^{-12} * 0.5 = 4.427 * 10^{-12} C.

Therefore,

(a) Flux through the cube = 0.5 N m^2/C

(b) Charge inside the cube = 4.427 * 10^{-12} C.

Key Points: Electric field varies with x - Flux is through two faces perpendicular to x-axis - Use Gauss's law to find charge inside cube

Question 26.

Define current density. Is it a scalar or a vector? An electric field □□ is maintained in a metallic conductor. If n be the number of electrons (mass m, charge -e) per unit volume in the conductor and ζ its relaxation time, show that the current density □□ = α□□, where α=(ne²/m)ζ

[3 Marks]

Answer: (a) Definition of current density: Current density is the amount of electric current flowing per unit cross-sectional area of a conductor. It shows how much current passes through each unit area. It is symbolized by j and has SI units of amperes per square meter (A/m^2).

(b) Scalar or vector: Current density is a vector quantity because it has both magnitude and

direction. Its direction is the same as the flow of positive charge.

(c) Derivation of j = αE: Consider a metallic conductor with n electrons per unit volume, each electron having mass m and charge -e. An electric field E is applied. Due to E, electrons gain an average drift velocity v_d. The force on each electron is F = -eE, and acceleration a = F/m = -eE/m.

The electrons collide with atoms and lose velocity after an average relaxation time ζ. Using the equation of motion, drift velocity v_d = acceleration * relaxation time = (-eE/m)*ζ = (-eζ/m)E.

The current density j = number of electrons per unit volume * charge * drift velocity = n * (-e) * v_d.

Substituting v_d, j = n*(-e)*(-eζ/m)E = (ne^2ζ/m)E.

Since E and j are vectors in the same direction, we write j = αE, where α = (ne^2/m) ζ.

This shows current density is proportional to electric field with proportionality constant α.

Key Points: Current density is current per unit area - Vector quantity - j = (ne^2/m) * ζ * E shows proportionality between j and E

Question 27.

A proton with kinetic energy 1.3384 × 10^{-14} J moving horizontally from north to south, enters a uniform magnetic field B of 2.0 mT directed eastward. Calculate:

(a) the speed of the proton,

(b) the magnitude of acceleration of the proton,

(c) the radius of the path traced by the proton.

[Take (q /m) for proton = 1·0 *10^8 C/kg]

[3 Marks]

Answer: (a) Given kinetic energy K.E = 1.3384 * 10^-14 J, we use K.E = 0.5 * m * v^2. Using q/m = 1.0 * 10^8 C/kg, and charge of proton q = 1.6 * 10^-19 C, mass m = q / (q/m) = 1.6 * 10^-19 / (1.0 * 10^8) = 1.6 * 10^-27 kg. Speed v = sqrt(2 * K.E / m) = sqrt(2 * 1.3384 * 10^-14 / 1.6 * 10^-27) = 1.29 * 10^6 m/s.

(b) The proton moves perpendicular to magnetic field B = 2.0 mT = 2.0 * 10^-3 T. Magnetic force F = q * v * B = (1.6 * 10^-19) * (1.29 * 10^6) * (2.0 * 10^-3) = 4.13 * 10^-16 N. Acceleration a = F / m = (4.13 * 10^-16) / (1.6 * 10^-27) = 2.58 * 10^11 m/s^2.

(c) Radius r of circular path is given by r = m * v / (q * B) = (1.6 * 10^-27) * (1.29 * 10^6) / (1.6 * 10^-19 * 2.0 * 10^-3) = 6.45 * 10^-3 m or 6.45 mm.

Key Points: Calculation of speed from kinetic energy using K.E = 0.5 * m * v^2 - Calculation of acceleration using magnetic force F = q * v * B and a = F / m - Calculation of radius using r = m * v / (q * B)

Question 28.

An inductor, a capacitor and a resistor are connected in series with an ac source $v = V_m \sin(\omega t)$. Derive an expression for the average power dissipated in the circuit. Also obtain the expression for the resonant frequency of the circuit.

[3 Marks]

Answer: (a) In a series RLC circuit connected to an AC source $v = V_m \sin(\omega t)$, the current is $i = I_m \sin(\omega t + \varphi)$, where I_m is the maximum current and φ is the phase difference between voltage and current. The impedance of the circuit is $Z = \text{sqrt}(R^2 + (X_L - X_C)^2)$, where $X_L = \omega L$ (inductive reactance) and $X_C = 1 / (\omega C)$ (capacitive reactance). The average power dissipated in the circuit is P_avg = V_rms * I_rms * $\cos(\varphi) = I^2_{rms} * R$, since only the resistor dissipates power as heat. Here, I_rms = I_m / sqrt(2) and V_rms = V_m / sqrt(2). The power factor $\cos(\varphi) = R / Z$.

(b) At resonance, the inductive reactance equals capacitive reactance, so $X_L = X_C$, that is $\omega L = 1 / (\omega C)$. Solving for ω gives the resonant angular frequency, $\omega_0 = 1 / \text{sqrt}(LC)$. The resonant frequency $f_0 = \omega_0 / (2\pi) = 1 / (2\pi \text{ sqrt}(LC))$. At resonance, the impedance is minimum and equals R, and the circuit current is maximum with voltage and current in phase ($\varphi = 0$).

Key Points: Average power depends only on resistance R - Average power formula P_avg = I_rms squared * R - Resonant frequency f_0 = 1/(2π sqrt(LC))

Question 29.

a) The wavelength of the electromagnetic wave is often correlated with the characteristic size of the system that radiates. Give two examples to justify this statement.

b) (i) Long distance radio broadcasts use short-wave bands. Why ?

(ii) Optical and radio telescopes are built on the ground, but X-ray astronomy is possible only from satellites orbiting the Earth. Why ?

[3 Marks]

Answer: (a) The wavelength of electromagnetic waves is related to the size of the system that emits them as smaller systems emit waves of shorter wavelength. For example, gamma rays with wavelength around 10^{-14} m to 10^{-15} m originate from atomic nuclei which are very small.
Another example is radio waves which have wavelengths more than 0.1 meters and are emitted by large systems like antennas.
(b)(i) Long distance radio broadcasts use short-wave bands because short waves can be reflected by the Earth's ionosphere allowing them to travel long distances around the globe.
(ii) Optical and radio waves can pass through the Earth's atmosphere and so telescopes can be built

on the ground. But X-rays are absorbed by the atmosphere, so X-ray astronomy requires satellites orbiting the Earth to detect X-rays from space.

Key Points: Wavelength correlates with emitter size - Gamma rays from atomic nuclei (small size) - Radio waves from antennas (large size) - Short waves reflect from ionosphere for long distance - X-rays absorbed by atmosphere - X-ray astronomy requires satellites

Question 30.

Write the drawbacks of Rutherford's atomic model. How did Bohr remove them? Show that different orbits in Bohr's atom are not equally spaced.

[3 Marks]

Answer: Rutherford's atomic model has significant drawbacks. Firstly, it suggests that electrons in orbit around the nucleus should emit radiation and spiral into the nucleus, leading to instability, which contradicts the existence of stable matter. Secondly, it fails to explain the discrete line spectra observed in atoms, as different elements emit specific wavelengths that cannot be accounted for. Bohr addressed these limitations by postulating quantized energy levels for electrons, allowing stable orbits without radiation emission. He introduced the idea that electrons occupy certain orbits with fixed radii and energies. Additionally, in Bohr's model, these orbits are not equally spaced; the energy difference between successive orbits decreases as one moves away from the nucleus, leading to the observed spectral lines.

Key Points: Rutherford's model predicts instability; Cannot explain atomic spectra; Bohr introduces quantized orbits; Stable energy levels; Orbits are not equally spaced.

Question 31.

(a) State any two properties of a nucleus.

(b) Why is the density of a nucleus much more than that of an atom ?

(c) Show that the density of the nuclear matter is the same for all nuclei.

[3 Marks]

Answer: The nucleus has several key properties. Firstly, it is incredibly small compared to the overall size of the atom, mostly concentrated in a central region. Secondly, it contains protons and neutrons, which are bound together by the strong nuclear force, demonstrating stability. The density of a nucleus is significantly higher than that of an atom due to the mass being compacted into a tiny volume, making it about 2.3 × 10^17 kg/m^3. This high density is a result of the tightly packed nuclear particles and the empty space in atomic structures, which leads to a negligible average density for the atom as a whole. The density of nuclear matter is consistent across all nuclei because it is derived

from the proportionality of volume to mass number (A); as the nucleus grows, its volume increases with the cube of the radius while its mass increases linearly with A. Hence, nuclear density remains approximately 2.3 × 10^17 kg/m^3 across different elements, showing that different nuclei behave like drops of liquid of uniform density.

Key Points: Incredibly small size; Concentrated mass; Strong nuclear force binding particles; High density around 2.3 × 10^17 kg/m^3; Density consistent across nuclei; Volume proportional to mass number A.

Question 32.

What is a Wheatstone bridge ? Obtain the necessary conditions under which the Wheatstone bridge is balanced.

[3 Marks]

Answer: A Wheatstone bridge is an electrical circuit used to measure unknown resistances by balancing two legs of a bridge circuit. It consists of four resistors arranged in a diamond shape, with a galvanometer connected between two points. For the bridge to be in a balanced state, the ratio of the resistances in one leg must equal the ratio in the other leg, which is expressed as R1/R2 = R3/R4. Under these conditions, the current through the galvanometer is zero, indicating a null deflection, allowing for the precise calculation of the unknown resistance R4 from the known values of R1, R2, and R3.

Key Points: Definition of Wheatstone bridge - Arrangement of four resistors - Balancing condition: R1/R2 = R3/R4 - Application in measuring unknown resistance

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Section E

Question 33.

(i) Derive an expression for potential energy of an electric dipole □□ an external uniform electric field □□ When is the potential energy of the dipole (1) maximum, and (2) minimum?

(ii) An electric dipole consists of point charges - 1.0 PC and + 1.0 pC located at (0, 0) and (3 mm, 4 mm) respectively in x - y plane. An electric field □□ = ((1000V)/m) $\hat{i}$ is switched on in the region. Find the torque □□ acting on the dipole.

[5 Marks]

Answer: (i) Derivation of potential energy of an electric dipole in an external electric field: Consider an electric dipole with charges +q and -q separated by a distance d. The dipole moment p is defined as p = q * d, directed from -q to +q.

When placed in a uniform electric field E, the dipole experiences forces on the charges creating torque and potential energy.
The work done in rotating the dipole from angle 0 to angle theta with the field is stored as potential energy U.
Potential energy U = - p * E * cos(theta), where theta is the angle between dipole moment and electric field.

Maximum and minimum potential energy:
1. U is maximum when cos(theta) = -1, i.e., theta = 180 deg, dipole moment opposite to E.
Maximum potential energy U_{max} = + p * E.
2. U is minimum when cos(theta) = +1, i.e., theta = 0 deg, dipole moment aligned with E.
Minimum potential energy U_{min} = - p * E.

(ii) Calculation of torque on the dipole:
Given charges: q = 1.0 pC = 1.0 * 10^{-12} C,
Positions: negative charge at (0, 0), positive charge at (3 mm, 4 mm) = (3 * 10^{-3} m, 4 * 10^{-3} m).
Electric field E = 1000 V/m along x-axis (î).

Dipole vector p = q * displacement vector from -q to +q = q * r;
r = (3 * 10^{-3}) î + (4 * 10^{-3}) ĵ;
Therefore, p = (1.0 * 10^{-12}) * (3 * 10^{-3} î + 4 * 10^{-3} ĵ) = 3.0 * 10^{-15} î + 4.0 * 10^{-15} ĵ C m.

Torque τ = p × E;
E = 1000 î V/m;
Cross product:
τ = (3.0 * 10^{-15} î + 4.0 * 10^{-15} ĵ) × (1000 î) = 3.0 * 10^{-15} î × 1000 î + 4.0 * 10^{-15} ĵ × 1000 î = 0 + 4.0 * 10^{-15} * 1000 (ĵ × î).
Since ĵ × î = - k̂,
τ = - 4.0 * 10^{-12} k̂ Nm.

The torque magnitude is 4.0 * 10^{-12} Nm, directed along negative z-axis.

Final answers:
(i) U = - p E cos(theta); maximum at theta = 180 deg, minimum at theta = 0 deg.
(ii) Torque τ = - 4.0 * 10^{-12} k̂ Nm.

Key Points: Potential energy U = - p E cos(theta) - Maximum potential energy when dipole opposite to E (theta = 180 deg) - Minimum potential energy when dipole aligned with E (theta = 0 deg) - Torque on dipole τ = p × E calculation - Using vector position to find dipole moment p - Final torque magnitude and direction calculation

Question 34.

(i) A resistor and a capacitor are connected in series to an ac source $v = v_m \sin t$. Derive an expression for the impedance of the circuit.

(ii) When does an inductor act as a conductor in a circuit ? Give reason for it.

(iii) An electric lamp is designed to operate at 110 V dc and 11 A current. If the lamp is operated on 220 V, 50 Hz ac source with a coil in series, then find the inductance of the coil.

[5 Marks]

Answer: (i) When a resistor R and capacitor C are connected in series to an ac source with voltage $v = v_m \sin t$, the voltage across resistor is v_R = I R and voltage across capacitor is v_C = I X_C, where X_C = 1 / (omega C) is capacitive reactance and omega = 2 pi f is angular frequency.
The impedance Z of the circuit is the vector sum of resistance R and capacitive reactance X_C. Since voltage across capacitor lags current by 90 degrees and voltage across resistor is in phase with current,
Impedance $Z = \sqrt{R^2 + X_C^2}$, but since capacitive reactance causes phase lag, it is $Z = \sqrt{R^2 + (-X_C)^2} = \sqrt{R^2 + X_C^2}$. The phase angle $\phi = -\tan^{-1}(X_C / R)$.
Hence, **$Z = \sqrt{R^2 + (1 / (\omega C))^2}$**.

(ii) An inductor acts as a conductor only when there is a changing current in the circuit, that is, with an AC source. This is because inductors oppose changes in current due to self induced emf, but allow steady current to pass without opposition in DC case as inductive reactance X_L = omega L = 0 at zero frequency.
Thus, in AC, inductor presents inductive reactance and allows current to flow depending on frequency.

(iii) Given, lamp rated voltage V = 110 V DC and rated current I = 11 A. Resistance of lamp R = V / I = 110 / 11 = 10 ohms.
Lamp is operated on 220 V, 50 Hz AC source with coil of inductance L in series.
Total voltage V = 220 V, current remains 11 A.
Total impedance Z = V / I = 220 / 11 = 20 ohms.
Since lamp resistance is R = 10 ohms, coil impedance $Z_L = \sqrt{Z^2 - R^2} = \sqrt{20^2 - 10^2} = \sqrt{400 - 100} = \sqrt{300} = 17.32$ ohms.
Inductive reactance X_L = omega L = 2 pi f L = 17.32.
Therefore, L = 17.32 / (2 pi * 50) = 0.055 henry or 55 mH.
Hence, inductance of coil is 55 millihenry.

Key Points: Impedance Z of series RC circuit is sqrt(R squared plus capacitive reactance squared) - Inductor acts as conductor in AC circuits due to changing current and nonzero inductive reactance - Inductance of coil found using total impedance and lamp resistance with X_L = omega L

Question 35.

(i) A ray of light passes through a triangular prism. Show graphically, how the angle of deviation varies with the angle of incidence ? Hence define the angle of minimum deviation.

(ii) A ray of light is incident normally on a refracting face of a prism of prism angle A and suffers a deviation of angle δ. Prove that the refractive index n of the material of the prism is given by n=sin (A+δ)/ sin A.

(iii) The refractive index of the material of a prism is √2. If the refracting angle of the prism is 60 degree find the

1.Angle of minimum deviation, and

2.Angle of incidence.

[5 Marks]

Answer: (i) When a ray of light passes through a triangular prism, the angle of deviation (δ) varies with the angle of incidence (i). Graphically, the curve of δ against i first decreases, reaches a minimum value called the angle of minimum deviation (δ_min), and then increases. At δ_min, the path of light inside the prism is symmetrical, meaning the angle of incidence equals the angle of emergence.
Angle of minimum deviation: It is the smallest angle through which light is deviated by the prism when passing through it.

(ii) Given a ray incident normally on one face of a prism of angle A, let the deviation suffered be δ.
In this case, angle of incidence i = 0 and angle of refraction r = 0 at the first face.
Using geometry inside the prism, the angle of refraction at the second face = A.
The ray emerges with angle of incidence i' at the second face, which equals the angle of refraction inside from prism air interface.
The deviation δ = i' - A (since the ray is incident normally on first face)
By Snell's law at second face: n = sin i' / sin r' = sin i' / sin A
Since i' = A + δ, we get n = sin (A + δ) / sin A.

(iii) Given n = sqrt(2), A = 60 degrees.
1. Using the formula for refractive index at minimum deviation:
n = sin[(A + δ_min) / 2] / sin (A / 2)
=> sqrt(2) = sin[(60 + δ_min)/2] / sin 30
sin 30 = 0.5
So, sin[(60 + δ_min)/2] = sqrt(2) * 0.5 = sqrt(2)/2 = 0.707
Therefore, (60 + δ_min)/2 = 45 degrees
=> 60 + δ_min = 90 degrees
=> δ_min = 30 degrees.
2. For minimum deviation, angle of incidence i = angle of emergence e and inside the prism angle of refraction r = A/2 = 30 degrees.

Using Snell's law, sin i = n sin r = sqrt(2) * sin 30 = sqrt(2) * 0.5 = 0.707
Therefore, i = 45 degrees.

Thus, angle of minimum deviation is 30 degrees and angle of incidence is 45 degrees.

> **Key Points: Angle of deviation varies with angle of incidence - Angle of minimum deviation is the smallest deviation angle - Formula n = sin(A + δ)/ sin A for refractive index when ray incident normally on one face**

Question 36.

i) An electric dipole (dipole moment □□ =□□ hat hat i) consisting of charges q and q, separated by distance 2a, is placed along the x-axis, with its centre at the origin. Show that the potential V, due to this dipole, at a point x, (x >>a) is equal to $1/4\pi\varepsilon_0$. □□. $\hat{i}$ /x^2

(ii) Two isolated metallic spheres S_1 and S_2 of radii 1 cm and 3 cm respectively are charged such that both have the same charge density $(2/\pi \times 10^{-9})$ C / m^2. They are placed far away from each other and connected by a thin wire. Calculate the new charge on sphere S_1.

[5 Marks]

Answer: (i) For the electric dipole placed along the x-axis with charges +q and -q separated by distance 2a, the dipole moment p = 2aq in the x-direction. The potential at a point x on the x-axis (where x >> a) is given by the sum of potentials due to both charges:
$V = (1 / 4\pi\varepsilon_0) [q / (x - a) - q / (x + a)]$
Using binomial expansion for large x, $1 / (x \pm a) \approx 1 / x \mp a / x^2$,
So, $V = (1 / 4\pi\varepsilon_0) [q (1 / x + a / x^2) - q (1 / x - a / x^2)] = (1 / 4\pi\varepsilon_0) (2aq / x^2) = (1 / 4\pi\varepsilon_0) (p / x^2)$
This shows the potential V at point x due to the dipole is $(1 / 4\pi\varepsilon_0)$ p / x^2 along the x-axis.

(ii) Given: Radius of sphere S_1, r_1 = 1 cm = 0.01 m, radius of sphere S_2, r_2 = 3 cm = 0.03 m, charge density $\sigma = 2 / \pi * 10^{-9}$ C / m^2.
Charge on sphere S = surface charge density * surface area = $\sigma * 4\pi r^2$.
So, initial charges:
$Q_1 = \sigma * 4\pi r_1^2 = (2 / \pi * 10^{-9}) * 4\pi * (0.01)^2 = 2 * 4 * 10^{-9} * (0.01)^2 = 8 * 10^{-9} * 10^{-4} = 8 * 10^{-13}$ C
$Q_2 = \sigma * 4\pi r_2^2$ = similarly $2 / \pi * 10^{-9} * 4\pi * (0.03)^2 = 2 * 4 * 10^{-9} * 0.0009 = 8 * 10^{-9} * 0.0009 = 7.2 * 10^{-12}$ C

Since spheres are connected by a thin wire, they share charge until their potentials are equal:
Potential on sphere = $Q / (4\pi\varepsilon_0 r)$.
Let new charges be Q_1' and Q_2'. Since charge is conserved,
$Q_1' + Q_2' = Q_1 + Q_2 = 8 * 10^{-13} + 7.2 * 10^{-12} = 8 * 10^{-12}$ C (approx).
Equal potentials: $Q_1' / r_1 = Q_2' / r_2 \Rightarrow Q_2' = Q_1' * r_2 / r_1 = Q_1' * 3$.
So, $Q_1' + 3 Q_1' = 4 Q_1' = 8 * 10^{-12} \Rightarrow Q_1' = 2 * 10^{-12}$ C.

Therefore, new charge on sphere S_1 is $2 * 10^{-12}$ C.

Key Points: Definition of electric dipole and dipole moment - Use of binomial expansion for potential calculation - Applying conservation of charge and equal potential condition for two connected spheres

Question 37.

(i) Draw a labelled diagram of a step-up transformer and describe its working principle. Explain any three causes for energy losses in a real transformer.

(ii) A step-up transformer converts a low voltage into high voltage. Does it violate the principle of conservation of energy ? Explain.

(iii) A step-up transformer has 200 and 3000 turns in its primary and secondary coils respectively. The input voltage given to the primary coil is 90 V. Calculate :

- The output voltage across the secondary coil
- The current in the primary coil if the current in the secondary coil is 2·0 A.

[5 Marks]

Answer: A step-up transformer is an electrical device that increases voltage from the primary to the secondary coil while decreasing current. It consists of two coils, the primary and the secondary, wound around a magnetic core. Based on the turns ratio, the output voltage (Vs) can be calculated using the formula Vs/Vp = Ns/Np. For this transformer, the output voltage is (3000/200) * 90 V = 1350 V. Energy losses occur due to: 1. Flux Leakage: Inadequate magnetic coupling leads to some flux not linking both coils, causing energy loss. 2. Copper Losses: Resistance in wire contributes to heat loss due to currents mainly in the windings. 3. Eddy Currents: Induced currents in the core create losses, which can be reduced by using laminated cores. The conservation of energy principle holds; although voltage increases, the current decreases proportionately, ensuring the product of current and voltage remains constant.

Key Points: Labelled diagram of step-up transformer; Principle of mutual induction; Output voltage calculation; Energy losses: Flux Leakage, Copper Losses, Eddy Currents; Conservation of energy explanation

Question 38.

(i) State Huygens' principle. A plane wave is incident at an angle i on a reflecting surface. Construct the corresponding reflected wavefront. Using this diagram, prove that the angle of reflection is equal to the angle of incidence.

(ii) What are the coherent sources of light ? Can two independent sodium lamps act like coherent sources ? Explain.

(iii) A beam of light consisting of a known wavelength 520 nm and an unknown wavelength λ, used in Young's double slit experiment produces two interference patterns such that the fourth bright fringe of unknown wavelength coincides with the fifth bright fringe of known wavelength. Find the value of λ.

[5 Marks]

Answer: Huygens' principle states that every point on a wavefront can be considered a source of secondary wavelets, which spread out in all directions with a speed equal to the speed of the wave. The new wavefront is the envelope of these wavelets. Regarding the angle of incidence and reflection, consider a plane wave incident at an angle i on a reflecting surface. When the wavefront strikes the surface, it can be represented as series of wavelets emanating from the incident points on the wavefront. The angle at which these wavelets reflect, known as the angle of reflection (r), will be equal to the angle of incidence (i). This can be visually supported by constructing the incident and reflected wavefronts on a diagram where the distance from the wavefront to the reflecting surface remains the same for both angles. Coherent sources of light are sources that emit light waves with a constant phase difference and the same frequency, maintaining a stable interference pattern. Two independent sodium lamps cannot be coherent sources because they operate independently, meaning their phase relationship does not remain fixed, leading to incoherent light. In a Young's double-slit experiment, the interference pattern formed by two wavelengths will show bright fringes. Given that the fourth bright fringe of the unknown wavelength λ coincides with the fifth bright fringe of 520 nm, we can set up the equation: (mλ = nλ known) where m = 4, n = 5, λ known = 520 nm. So, λ = (n/m) * λ known = (5/4) * 520 nm which equals 650 nm. Thus, the unknown wavelength λ equals 650 nm.

Key Points: Huygens' principle-defines wavefronts and secondary wavelets-angle of incidence equals angle of reflection-coherent sources defined-phase relation in coherent vs incoherent sources-Young's experiment setup-path difference resulting in fringe coincidence-formula for calculating unknown wavelength