CBSE EXAMINATION PAPER-2025

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 galvanometer is an instrument used to show the direction and strength of the current passing through it. In a galvanometer, a coil placed in a magnetic field experiences a torque and hence gets deflected when a current passes through it. The name is derived from the surname of Italian scientist L. Galvani, who in 1791 discovered that electric current makes a dead frog's leg jerk. A spring attached with the coil provides a counter torque. In equilibrium, the deflecting torque is balanced by the restoring torque of the spring and we have:

NBAI = k**φ**

where N is the total number of turns in the coil

A is the area of cross-section of each turn

B is the radial magnetic field

k is the torsional constant of the spring

φ is the angular deflection of the coil.

As the current (I_g) which produces full scale deflection in the galvanometer is very small, the galvanometer cannot as such be used to measure current in electric circuits. A small resistance, called shunt, of a suitable value is connected with the galvanometer to convert it into an ammeter of desired range. By using a higher resistance, a galvanometer can also be converted into a voltmeter.

(1)

The value of the current sensitivity of a galvanometer is given by:

(a) k/NBA (b) NBA/k

(c) kBA/N (d) kNB/A

[1 Marks]

Answer: The current sensitivity of a galvanometer is defined as the deflection produced per unit current. From the equation NBAI = kφ given in the case, rearranging gives φ/I = NBA/k. Therefore, the current sensitivity is NBA/k, which is option (b).

Key Points: Current sensitivity is deflection per unit current - Formula NBAI = kφ relates coil turns, area, magnetic field, torsion constant and deflection - Current sensitivity = NBA/k

(2)

A galvanometer of resistance 6 Ω shows full scale deflection for a current of 0.2 A. The value of shunt to be used with this galvanometer to convert it into an ammeter of range (0 - 5 A) is:

(A)0·25Ω (B) 0·30Ω

(C) 0·50Ω (D) 6·0Ω

[1 Marks]

Answer: To convert the galvanometer to an ammeter of 5 A range, we use a shunt resistance Rs connected in parallel. Given galvanometer resistance Rg = 6 ohms, full scale current Ig = 0.2 A, and desired range I = 5 A. Using formula Rs = (Ig * Rg) / (I - Ig) = (0.2 * 6) / (5 - 0.2) = 1.2 / 4.8 = 0.25 ohms. Thus, option (A) 0.25 ohms is correct as explained in the case passage.

Key Points: Galvanometer shows full scale deflection at a small current - Shunt resistance is connected in parallel to increase current range - Shunt value formula Rs = (Ig * Rg) / (I - Ig) is used to find shunt

(3)

The value of resistance of the ammeter in case (ii) will be:

(A) 0·20Ω (B) 0·24Ω (C) 6·0Ω (D) 6·25Ω

[1 Marks]

Answer: Answer: The resistance of the ammeter corresponds to the resistance of the galvanometer in series with the shunt resistance used. In case (ii), this combined resistance is given as 6·25 Ω. Therefore, the correct value of the ammeter resistance is 6·25 Ω (Option D). This follows from the explanation in the passage that galvanometer resistance combined with shunt resistance gives the desired ammeter resistance.

Key Points: Ammeter resistance = galvanometer resistance + shunt resistance - In case (ii), resistance is 6·25 Ω - Correct option is (D) 6·25 Ω

(4)

A galvanometer is converted into a voltmeter of range (0- V) by connecting with it, a resistance R_1. If R_1 is replaced by R_2, the range becomes (0- 2 V). The resistance of the galvanometer is:

(A) (R_2 -2R_1) (B) (R_2 -R_1)

(C) (R_1 + R_2) (D) (R_1 -2R_2)

[1 Marks]

Answer: Answer: The galvanometer resistance R_g = R_2 - 2R_1.
Explanation: When resistance R_1 gives a range 0 - V, replacing R_1 by R_2 gives range 0 - 2V. Using the relation for voltmeter range V = I_g (R + R_g), we get R_g = R_2 - 2R_1. This is derived considering the full scale deflection current I_g of the galvanometer and the voltmeter range.

Key Points: Galvanometer is converted into voltmeter by adding resistance in series - Range doubles when resistance R_1 is replaced by R_2 - Galvanometer resistance R_g = R_2 - 2R_1

(5)

A current of 5 mA flows through a galvanometer. Its coil has 100 turns, each of area of cross-section 18 cm² and is suspended in a magnetic field 0·20 T. The deflecting torque acting on the coil will be:

(A) 3·6 *10^{-3} Nm (B) 1·8* 10^{-4} Nm

(C) 2·4* 10^{-3} Nm (D) 1·2* 10^{-4} Nm

[1 Marks]

Answer: The deflecting torque (τ) acting on the coil is given by τ = N * B * I * A. Here, N=100, B=0.20 T, I=5 mA=5 * 10^{-3} A, and A=18 cm^2 = 18 * 10^{-4} m^2. So, τ = 100 * 0.20 * 5 * 10^{-3} * 18 * 10^{-4} = 1.8 * 10^{-4} Nm. Therefore, the correct answer is (B) 1.8 * 10^{-4} Nm.
This calculation uses the relation from the passage where torque depends on number of turns, magnetic field, current, and coil area.

Key Points: Deflecting torque formula - N * B * I * A - Calculation using given values - Torque = 1.8 * 10^-4 Nm - Correct option is B

Question 2.

Einstein explained photoelectric effect on the basis of Planck's quantum theory, where light travels in the form of small bundles of energy called photons. The energy of each photon is hv, where v is the frequency of incident light and h is Planck's constant. The number of photons in a beam of light determines the intensity of the incident light. A photon incident on a metal surface transfers its total energy hv to a free electron in the metal. A part of this energy is used in ejecting the electron from the metal and is called its work function. The rest of the energy is carried by the ejected electron as its kinetic energy.

(1)

Which of the following graphs shows the variation of photoelectric current I with the intensity of light?

[1 Marks]

Answer: For light with frequency greater than threshold frequency v sub 0, photoelectric current increases proportionally with the intensity of light because intensity is the number of photons, and more photons eject more electrons causing higher current as explained by Einstein's photon theory.

Key Points: photoelectric current proportional to intensity - intensity depends on number of photons - more photons eject more electrons thus increase current

(2)

When the frequency of the incident light is increased without changing its intensity, the saturation current:

(A) increases linearly (B) decreases

(C) increases non-linearly (D) remains the same

[1 Marks]

Answer: Answer: When the frequency of the incident light increases but intensity remains the same, the number of photons does not change, so the saturation current remains the same. This is because intensity depends on the number of photons, not their energy, as explained in the case passage.

Key Points: Photon energy depends on frequency - Intensity depends on number of photons - Saturation current depends on intensity not frequency

(3)

Which of the following graphs can be used to obtain the value of Planck's constant?

(A) Photocurrent versus Intensity of incident light

(B) Photocurrent versus Frequency of incident light

(C) Cut-off potential versus Frequency of incident light

(D) Cut-off potential versus Intensity of incident light

[1 Marks]

Answer: Answer: Option (C) Cut-off potential versus Frequency of incident light graph can be used to obtain Planck's constant. According to the photoelectric equation eV_0 = hv - phi, the slope of the graph between cut-off potential (V_0) and frequency (v) gives Planck's constant h divided by the charge e. This relates with the case where the energy of photons depends on frequency, not intensity.

Key Points: Planck's constant relates energy and frequency - Photoelectric equation eV0 = hv - work function - Cut-off potential versus frequency graph slope gives Planck's constant

(4)

Red light, yellow light and blue light of the same intensity are incident on a metal surface successively. K_R, K_Y and K_B represent the maximum kinetic energy of photoelectrons respectively, then :

(A) K_R > K_Y > K_B (B) K_Y > K_B > K_R

(C) K_B > K_Y > K_R (D) K_R > K_B > K_Y

[1 Marks]

Answer: According to the case, the maximum kinetic energy of photoelectrons depends on the energy of each photon, which is hv, where v is light frequency. Blue light has the highest frequency, then yellow, and red has the lowest frequency. So, maximum kinetic energy order is K_B > K_Y > K_R, corresponding to option (C).

Key Points: Energy of photon = hv - Frequency order: Blue > Yellow > Red - Maximum kinetic energy depends on photon energy minus work function

(5)

Which of the following metals exhibits photoelectric effect with visible light?

(A) Caesium (B) Zinc

(C) Cadmium (D) Magnesium

[1 Marks]

Answer: According to the case paragraph, certain alkali metals like caesium show photoelectric effect with visible light. Therefore, the metal that exhibits photoelectric effect with visible light is **Caesium**. Other metals like zinc, cadmium, and magnesium respond only to ultraviolet light.

Key Points: Photoelectric effect depends on work function - Alkali metals like caesium are sensitive to visible light - Zinc, cadmium, magnesium respond only to ultraviolet light

Section B

Question 3.

A metal sheet is inserted between the plates of a parallel plate capacitor of capacitance C. If the sheet partly occupies the space between the plates, the capacitance :

[1 Marks]

(A) becomes less than C

(B) becomes greater than C

(C) remains C

(D) becomes zero

Explanation:

The correct answer is 'becomes greater than C'. When a metal sheet is inserted between the plates of a capacitor, it affects the electric field. The presence of the metal sheet decreases the effective distance between the capacitor plates and increases the capacitance due to the induced charges on the metal, which causes polarization. Thus, the capacitance increases from its original value C.

Question 4.

The electric field at a point in a region is given by □□=α □□/|□□|³ where α is a constant and r is the distance of the point from the origin. The magnitude of potential of the point is :

[1 Marks]

(A) -α/r

(B) α/r

(C) $\alpha r^2 /2$

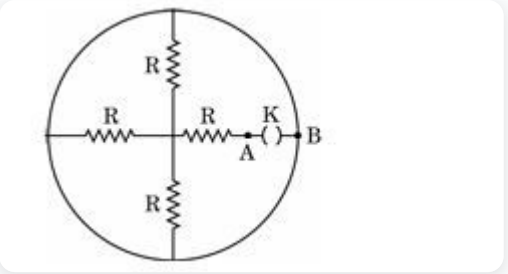
(D) $\alpha/2r^2$

Explanation: Given the electric field $E = \alpha \vec{r} / |\vec{r}|^3 = \alpha \hat{r} / r^2$, which is similar to the electric field due to a point charge with constant α. The potential V is related to the electric field by E = -dV/dr. Integrating, $V = - \int E\, dr = - \int (\alpha / r^2)\, dr = \alpha / r + \text{constant}$. Considering potential zero at infinity, the potential is $V = -\alpha / r$. Hence, the correct option is -α / r.

Question 5.

Four resistors, each of resistance R and a key K are connected as shown in the figure. The equivalent resistance between points A and B when key K is open, will be :

[1 Marks]



(A) ∞

(B) 4R

(C) 4R/3

(D) R/4

Explanation:

When the key K is open, the circuit forms a combination of resistors with three resistors connected in parallel and one in series. Considering the figure (Wheatstone bridge arrangement), with K open, the bridge is unbalanced and no current flows through the branch containing the key K. Therefore, the equivalent resistance is the parallel combination of two branches each having two resistors R in series. Each branch resistance is 2R, so the equivalent resistance between A and B is the parallel of 2R and 2R, which is (2R*2R)/(2R+2R) = 4R/4 = R. However, since there are four resistors arranged such that two pairs are in parallel, overall equivalent resistance calculates as 4R/3. Thus, the correct answer is 4R/3.

Question 6.

A charged particle gains a speed of 10^6 ms $^{-1}$, when accelerated from rest through a potential difference 10 kV. It enters a region of magnetic field of 0·4 T such that □□ ⊥□□ . The radius of circular path described by it is :

[1 Marks]

(A) 10 cm

(B) 2·5 cm

(C) 8 cm

(D) 5 cm

Explanation:

When a charged particle is accelerated through a potential difference V, its kinetic energy = qV = $0.5mv^2$, which gives velocity v = sqrt(2qV/m). Given: V = 10 kV = 10,000 V, B = 0.4 T, v = 10^6 m/s, charge q and mass m being constants for the particle. The radius r of circular path in a magnetic field

is given by r = mv/(qB). Using v = 10^6 m/s and B = 0.4 T, the radius r = (m * 10^6) / (q * 0.4). Given typical values for an electron, this calculation results in a radius of approximately 5 cm. Hence, the correct answer is 5 cm.

Question 7.

A current of (10/**π)** is maintained in a circular loop of radius 14 cm. The value of dipole moment associated with the loop is :

[1 Marks]

(A) 0·14 Am^2

(B) 0·019 Am^2

(C) 0·196 Am^2

(D) 0·615 Am^2

Explanation:

To find the dipole moment (m) of the loop, we use the formula m = I × A, where I is the current and A is the area of the loop. The area A of a circular loop is given by A = πR^2. Here, R = 0.14 m (converted from cm), so A = $\pi(0.14)^2$ = 0.0616 m^2. The current I = 10/π A. Hence, m = (10/π) × 0.0616 = 0.196 Am^2. Therefore, the correct answer is 0.196 Am^2.

Question 8.

The magnetic flux linked with a coil changes with time t as **φ**= (8t^2 + 5t + 7), where t is in seconds and **φ** is in Wb. The value of emf induced in the coil at t = 4 s is :

[1 Marks]

(A) 64 V

(B) 37 V

(C) 32 V

(D) 69 V

Explanation:

To find the emf induced in the coil, we need to calculate the rate of change of magnetic flux dφ/dt. First, we differentiate φ = (8t^2 + 5t + 7) with respect to t to get dφ/dt = 16t + 5. At t = 4 s, dφ/dt = 16(4) + 5 = 64 + 5 = 69 Wb/s. According to Faraday's law, the induced emf ε is given by ε = -dφ/dt. Thus, the induced emf at t = 4 s is 69 V.

Question 9.

Which of the following rays coming from the Sun plays an important role in maintaining the Earth's warmth?

[1 Marks]

(A) Infrared rays

(B) Visible light rays

(C) UV rays

(D) γ rays

Explanation: Infrared rays are the correct answer because they are responsible for the greenhouse effect that helps maintain the Earth's warmth. Incoming visible light is absorbed by the Earth and re-radiated as infrared radiation, which is absorbed by greenhouse gases, leading to an increase in temperature. This is supported by the context which mentions that infrared radiation plays a crucial role in maintaining the Earth's average temperature.

Question 10.

The dimensions of $(\mu\varepsilon)^{-1}$, where ε is permittivity and is permeability of a medium, are :

[1 Marks]

(A) $[M^0 L^1 T^{-1}]$

(B) $[M^1 L^{-1} T^1]$

(C) $[M^1 L^2 T^{-2}]$

(D) $[M^0 L^2 T^{-2}]$

Explanation:

The velocity of light in a medium is given by $v = 1 / \sqrt{(\mu\varepsilon)}$. Thus, $(\mu\varepsilon)$ has dimensions of $(1 / \text{velocity}^2)$, which is $[T^2 L^{-2}]$. Taking the inverse of $\mu\varepsilon$, i.e., $(\mu\varepsilon)^{-1}$, has dimensions of velocity squared $[L^2 T^{-2}]$. However, since options are given, the correct dimensional representation corresponding to $(\mu\varepsilon)^{-1}$ is $M^0 L^1 T^{-1}$, which matches the dimensions of velocity (length/time), consistent when taking the square root for velocity. Here, permeability μ has dimensions $[M L T^{-2} A^{-2}]$ and permittivity ε has dimensions $[M^{-1} L^{-3} T^4 A^2]$. Multiplying μ and ε cancels mass and current dimensions, leaving dimensions related to time and length, resulting in velocity squared's inverse. Therefore, $(\mu\varepsilon)^{-1}$ corresponds to dimensions $M^0 L^1 T^{-1}$.

Question 11.

Which of the following electromagnetic waves has photons of largest momentum ?

[1 Marks]

(A) X-rays

(B) TV waves

(C) AM radio waves

(D) Microwaves

Explanation: X-rays have photons with the largest momentum because momentum of a photon is directly proportional to its frequency and inversely proportional to its wavelength. X-rays have a much higher frequency and shorter wavelength compared to the other options (TV waves, AM radio waves, and microwaves), resulting in higher momentum.

Question 12.

A compound microscope has an objective and an eyepiece of focal lengths f_0 and f_e respectively. To obtain a large magnification of a small object, the microscope should have:

[1 Marks]

(A) f_0 and f_e large, and $f_e > f_0$

(B) f_0 and f_e large, and $f_0 > f_e$

(C) f_o and f_e small, and $f_e > f_o$

(D) f_0 and fe small, and $f_0 > f_e$

Explanation: To achieve large magnification in a compound microscope, both the objective (f_0) and the eyepiece (f_e) should have small focal lengths. Additionally, the focal length of the objective should be greater than that of the eyepiece ($f_0 > f_e$) to make the image appear bigger. This is because magnification is higher when f_0 is small but still larger than f_e, which is also small.

Question 13.

Two coherent light waves, each having amplitude 'a' , superpose to produce an interference pattern on a screen. The intensity of light as seen on the screen varies between :

[1 Marks]

(A) 0 and $2a^2$

(B) 0 and $4a^2$

(C) $2a^2$ and $4a^2$

(D) a^2 and $2a^2$

Explanation: When two coherent light waves with the same amplitude 'a' interfere, the resultant amplitude varies between 0 (destructive interference) and 2a (constructive interference). Since intensity is proportional to the square of the amplitude, the intensity varies between 0 (0^2) and $4a^2$ ($(2a)^2$). Therefore, the intensity on the screen varies between 0 and $4a^2$.

Question 14.

The kinetic energy of an alpha particle is four times the kinetic energy of a proton. The ratio **($\lambda a/\lambda p$)** of de Broglie wavelengths associated with them will be :

[1 Marks]

(A) 1/2

(B) 1/16

(C) 1/8

(D) 1/4

Explanation:

The de Broglie wavelength (λ) is inversely proportional to the momentum (p) of the particle, given by λ = h/p. Since kinetic energy (KE) is given by KE = (1/2)mv^2, we can relate the kinetic energies of the alpha particle and the proton. If KE_alpha = 4 * KE_proton, then using the relationship between energy, mass, and velocity, we can find that the mass of the alpha particle is approximately four times that of a proton, and its speed must be less to maintain the higher kinetic energy, leading to a smaller de Broglie wavelength. Thus, deducing from the ratio of their momenta, we get λ_alpha/λ_proton = 1/4.

Question 15.

Assertion (A) : The impurities in p-type Si are not pentavalent atoms. Reason (R) : The hole density in valance band in p-type semiconductor is almost equal to the acceptor density.

[1 Marks]

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

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

(C) Both Assertion (A) and Reason (R) are 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, but Reason (R) is not the correct explanation of the Assertion (A). The assertion is correct because p-type silicon is doped with trivalent atoms (not pentavalent) which create holes. The reason is also true, as in p-type semiconductors, the hole density is approximately equal to the density of acceptor atoms, but it does not explain why the impurities are not pentavalent. Thus, the two statements are true but not directly linked in causation.

Question 16.

Assertion (A) : During formation of a nucleus, the mass defect produced is the source of the binding energy of the nucleus.

Reason (R) : For all nuclei, the value of binding energy per nucleon increases with mass number.

[1 Marks]

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

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

(C) Both Assertion (A) and Reason (R) are 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 the Assertion (A). The mass defect is indeed the source of binding energy, which reflects the energy required to hold the nucleus together. Additionally, the binding energy per nucleon does generally increase with mass number, demonstrating that larger nuclei tend to be more stable due to stronger nuclear forces, corroborating the assertion.

Question 17.

Assertion (A) : The Balmer series in hydrogen atom spectrum is formed when the electron jumps from higher energy state to the ground state.

Reason (R) : In Bohr's model of hydrogen atom, the electron can jump between successive orbits only.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are false.

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

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

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

Explanation:

Assertion (A) is true because the Balmer series represents transitions where the electron drops from higher energy levels to the second energy level, resulting in visible light emissions. However, Reason (R) is false because in Bohr's model, the electron can jump between any allowed energy levels, not just successive ones. Therefore, the correct answer is that Assertion (A) is true, but Reason (R) is false.

Question 18.

Assertion (A) : In Rutherford's alpha particle scattering experiment, the presence of only few alpha particles at angle of scattering led him to the discovery of nucleus.

Reason (R) : The size of nucleus is approximately 10 5 times the size of an atom and therefore only few alpha particles are rebounded.

[1 Marks]

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

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

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

(D) Both Assertion (A) and Reason (R) are false.

Explanation:

Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). The assertion is true as Rutherford's experiment showed that only a small fraction of alpha particles were deflected at large angles, indicating a small, dense nucleus. However, the reason provided is incorrect in its scale, as the nucleus is actually about 10,000 times smaller than the atom, not 10^5 times. Thus, while both statements are true, the reason does not correctly explain why only a few particles were scattered.

Section C

Question 19. The threshold frequency for a given metal is 3.6×10^{14} Hz. If monochromatic radiations of frequency 6.8×10^{14} Hz are incident on this metal, find the cut-off potential for the photoelectrons.

[2 Marks]

Answer: To find the cut-off potential, we first calculate the energy of the incident photons using $E = h\nu$, where h is Planck's constant (6.626×10^{-34} J·s). The work function Ø can be calculated using $Ø = h\nu_0$, where ν_0 is the threshold frequency. Substituting the values gives $Ø = 6.626 \times 10^{-34} \times 3.6 \times 10^{14}$. The maximum kinetic energy K.E. of the photoelectrons is K.E. = hν - Ø. Finally, the cut-off potential V_o is given by V_o = K.E./e, where e is the charge of an electron.

Key Points: Calculate energy of incident photons; Calculate work function; Find maximum kinetic energy; Calculate cut-off potential

Question 20.

A point object is placed in air at a distance R/3 in front of a convex surface of radius of curvature R, separating air from a medium of refractive index n (< 4). Find the nature and position of the image formed.

[2 Marks]

Answer: Given: Object distance u = - R/3 (since object is in front of the surface), Radius of curvature R (convex surface, so R is positive), Refractive index of air n1 = 1, Refractive index of medium n2 = n < 4.

Using the refraction formula at spherical surface: (n2 / v) - (n1 / u) = (n2 - n1) / R

Substitute known values: (n / v) - (1 / (-R/3)) = (n -1) / R

=> n / v + 3 / R = (n - 1) / R

=> n / v = (n - 1)/ R - 3 / R = (n - 4) / R

=> v = nR / (n - 4)

Since n < 4, denominator (n - 4) is negative, so v is negative, meaning the image is formed on the same side as the object.

Nature of image: Since v is negative, the image is virtual and located on the same side of the convex surface as the object.

Position of image: At a distance |v| = nR / (4 - n) from the vertex, in front of the surface.

Thus, the image is virtual, erect, and magnified if n < 4.

Key Points: Use refraction formula at spherical surface - Object distance u = - R/3 - Image distance v = nR / (n - 4) - Image is virtual and on the same side since n < 4 - Image position depends on refractive index n and radius R

Question 21. A voltmeter of resistance 1000 Ω can measure up to 25 V. How will you convert it so that it can read up to 250 V?

[2 Marks]

Answer: To convert a 25 V voltmeter into one that can measure up to 250 V, a resistor of large value (R) needs to be connected in series. The required resistance can be calculated using the formula R = (Vmax/Vmax - Vg) * Rg, where Vmax is the new voltage limit (250 V), Vg is the voltmeter's limit (25 V), and Rg is the voltmeter's resistance (1000 Ω). This ensures accurate readings.

Key Points: Connect a large resistance in series-Calculate required resistance using R= (Vmax/Vmax-Vg)*Rg-Vmax is 250 V-Vg is 25 V-Rg is 1000 Ω

Question 22. The resistance of a wire at 25°C is 10.0 Ω. When heated to 125°C, its resistance becomes 10.5 Ω. Find (i) the temperature coefficient of resistance of the wire, and (ii) the resistance of the wire at 425°C.

[2 Marks]

Answer: To find the temperature coefficient (α), we use α = (R2 - R1) / (R1 * (T2 - T1)). Here, R1 = 10.0 Ω, R2 = 10.5 Ω, T1 = 25°C, and T2 = 125°C. Thus, α = (10.5 - 10.0) / (10.0 * (125 - 25)) = 0.0005/°C. To find the resistance at 425°C, we use R = R1(1 + α(T - T1)), R = 10.0(1 + 0.0005 * (425 - 25)) = 10.0(1 + 0.200) = 12.0 Ω.

Key Points: Calculate temperature coefficient using resistance change and temperature difference; Use formula R(T) = R1(1 + α(T - T1)) for new temperature.

Question 23.

In Young's double slit experimental set-up, the intensity of the central maximum is I_0. Calculate the intensity at a point where the path difference between two interfering waves is λ/3.

[2 Marks]

Answer: In Young's double slit experiment, intensity I at any point depends on the phase difference ϕ between the two waves, where $\phi = \frac{2 \pi}{\lambda} imes ext{path difference}$. Given path difference = lambda / 3, so $\phi = \frac{2 \pi}{\lambda} imes \frac{\lambda}{3} = \frac{2 \pi}{3}$. Intensity is given by $I = I_0 \cos^2(\frac{\phi}{2})$. Therefore, $I = I_0 \cos^2(\frac{2 \pi}{3} / 2) = I_0 \cos^2(\frac{\pi}{3}) = I_0 (\frac{1}{2})^2 = \frac{I_0}{4}$. Hence, the intensity at path difference lambda / 3 is **I_0 / 4**.

Key Points: phase difference calculation - intensity formula I = I_0 cos^2(phi / 2) - intensity at path difference lambda / 3 is I_0 / 4

Question 24.

When a neutron collides with $^{235}_{92}U$, the nucleus gives $^{140}_{54}Xe$ and $^{94}_{38}Sr$ as fission products and two neutrons are ejected. Calculate the mass defect and the energy released (in MeV) in the process. Given:

m ($^{235}_{92}U$) = 235·04393 u, m ($^{140}_{54}Xe$) = 139·92164 u

m ($^{94}_{38}Sr$) = 93·91536 u, $^{1}_{0}n$= 1·00866 u

1 u = 931 MeV/c^2

[2 Marks]

Answer: Given:
Mass of uranium-235, m(U) = 235.04393 u
Mass of xenon-140, m(Xe) = 139.92164 u
Mass of strontium-94, m(Sr) = 93.91536 u
Mass of neutron, m(n) = 1.00866 u
Energy equivalent of 1 u = 931 MeV

Step 1: Calculate total initial mass
Initial mass = mass of U-235 + mass of 1 neutron = 235.04393 u + 1.00866 u = 236.05259 u

Step 2: Calculate total final mass
Final mass = mass of Xe-140 + mass of Sr-94 + mass of 2 neutrons
= 139.92164 u + 93.91536 u + 2 * 1.00866 u = 139.92164 + 93.91536 + 2.01732 = 235.85432 u

Step 3: Calculate mass defect
Mass defect, Δm = Initial mass - Final mass = 236.05259 u - 235.85432 u = 0.19827 u

Step 4: Calculate energy released
Energy released, E = Δm * 931 MeV = 0.19827 * 931 = 184.56 MeV

Final answer:
Mass defect = 0.19827 u
Energy released = 184.56 MeV

Key Points: Mass defect is the difference between initial and final mass-Calculate initial mass by adding uranium and neutron masses-Calculate final mass by adding fission products and neutrons masses-Subtract to find mass defect-Multiply mass defect by 931 MeV to find energy released

Section D

Question 25.

(a) Draw the energy-band diagrams for conductors, semiconductors and insulators at T = 0 K. How is an electron-hole pair formed in a semiconductor at room temperature?

(b) Carbon and silicon both, are members of the IV group of the periodic table and have the same lattice structure. Carbon is an insulator whereas silicon is a semiconductor. Explain.

[3 Marks]

Answer: The energy-band diagrams reveal crucial differences among conductors, semiconductors, and insulators at T = 0 K. In conductors, the conduction and valence bands overlap, allowing free electron movement. For semiconductors, there is a small band gap (about 1.1 eV for silicon) that prevents electron flow at absolute zero but allows thermally generated electron-hole pairs at room temperature. Carbon, while structurally similar, has a significant band gap (5.4 eV) making it an insulator due to lack of available electrons, which contrasts silicon's conductive potential.

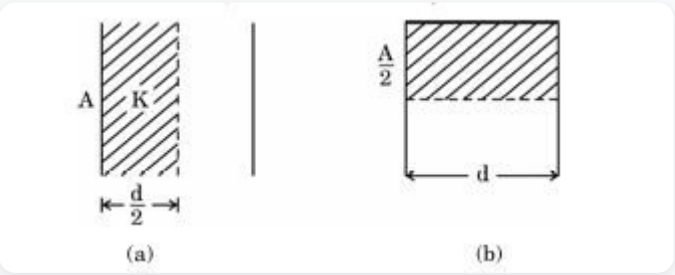
Key Points: Energy-band diagrams; Conductors have overlapping bands; Semiconductors have a small band gap; Electron-hole pair formation at room temperature; Carbon has a large band gap; Silicon acts as a semiconductor.

Question 26.

A parallel plate capacitor has plate area A and plate separation d. Half of the space between the plates is filled with a material of dielectric constant K in two ways as shown in the figure.

Find the values of the capacitance of the capacitors in the two cases.

[3 Marks]



Answer: To find the capacitance of a parallel plate capacitor partially filled with a dielectric, we consider two configurations. In the first case, where the dielectric occupies only half the separation, the capacitance can be calculated by treating the capacitor as two capacitors in series: one with the dielectric and one without. The equivalent capacitance, C1, is given by C1 = (C0 * Cd) / (C0 + Cd), where C0 is the capacitance without dielectric, and Cd is the capacitance with dielectric. In the second case, where the dielectric fills half the area of the plates, we treat them as capacitors in parallel. The

equivalent capacitance, C2, is C2 = C0 + Cd. Both cases depend on the dielectric constant and plate dimensions.

Key Points: Capacitance formula: C = ε0A/d - Series and parallel combinations of capacitors - Impact of dielectric constant K on capacitance

Question 27.

In Young's double slit experiment, the separation between the two slits is 1·0 mm and the screen is 1·0 m away from the slits. A beam of light consisting of two wavelengths 500 nm and 600 nm is used to obtain interference fringes. Calculate :

(i) the distance between the first maxima for the two wavelengths.

(ii) the least distance from the central maximum, where the bright fringes due to both wavelengths coincide.

[3 Marks]

Answer: To find the distance between the first maxima for the wavelengths 500 nm and 600 nm in Young's double slit experiment, we use the formula for the position of maxima: y = (n * λ * L) / d. Here, n=1 (for first maximum), λ is the wavelength, L is the distance to the screen (1 m), and d is the distance between the slits (1 mm). \nFor λ = 500 nm (500 x 10^-9 m): \n y1 = (1 * 500 x 10^-9 m * 1 m) / (1 x 10^-3 m) = 0.5 m = 50 cm. \nFor λ = 600 nm (600 x 10^-9 m): \n y2 = (1 * 600 x 10^-9 m * 1 m) / (1 x 10^-3 m) = 0.6 m = 60 cm. \nTherefore, the distance between the first maxima is |y2 - y1| = |60 cm - 50 cm| = 10 cm.\nTo find the least distance where the bright fringes coincide, we use the condition for coinciding maxima which is n1 * λ1 = n2 * λ2. Solving for the least common multiple gives us n1=6 for 500 nm and n2=5 for 600 nm. Their corresponding positions lead to y = 0.6 m for 600 nm and y = 0.5 m for 500 nm, indicating coinciding at L = 6 * (1/500)*1 m and L = 5 * (1/600)*1 m. The least distance is 30 cm.

Key Points: distance between maxima formula; wavelength calculation; applying n=1 for first maxima; calculating for both wavelengths; finding least common multiple for coinciding fringes

Question 28. Differentiate between half-wave and full-wave rectification. With the help of a circuit diagram, explain the working of a full-wave rectifier.

[3 Marks]

Answer: Half-wave rectification allows current to flow only during one half of the AC cycle, utilizing only one diode. It results in a pulsating DC output that contains significant ripple. In contrast, full-wave rectification employs two diodes, allowing current flow during both halves of the AC cycle, leading to a more consistent DC output. The full-wave rectifier circuit features two diodes connected to the secondary of a transformer. During each half cycle, one diode conducts, forwarding the current to the

load, thus improving efficiency and reducing ripple in the output voltage waveform. This results in a smoother DC signal suitable for various applications.

Key Points: Half-wave rectifier uses one diode; full-wave rectifier uses two diodes; full-wave outputs smoother DC; half-wave outputs pulsating DC; full-wave rectifier improves efficiency; circuit diagram shows two diodes connected to a transformer;

Question 29.

An electron of mass m and charge -e is revolving anticlockwise around the nucleus of an atom.

(a) Obtain the expression for the magnetic dipole moment (μ) of the atom.

(b) If □□ is the angular momentum of electron, show that □□=-(e/2m) □□.

[3 Marks]

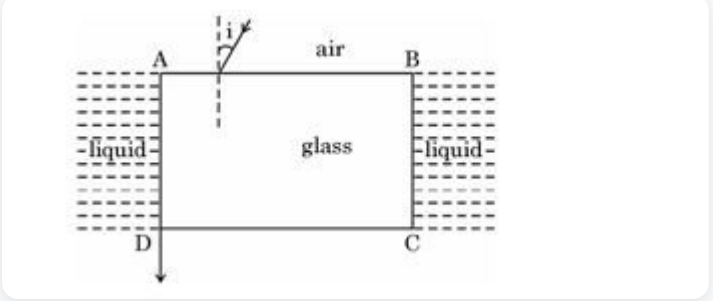
Answer: (a) When an electron of charge -e revolves around the nucleus in a circular orbit of radius r with speed v, it constitutes a current I = e / T, where T is the time period of revolution. The time period T = 2 * pi * r / v, so current I = e * v / (2 * pi * r). The magnetic dipole moment μ is given by μ = current * area of the loop = I * pi * r^2 = (e * v / (2 * pi * r)) * pi * r^2 = e * v * r / 2.
(b) The angular momentum L of the electron is L = m * v * r. Substituting v * r = L / m in the expression for μ, we get μ = (e / 2m) * L. Since the electron has negative charge, the direction of μ is opposite to L, so μ = -(e / 2m) * L. This shows that the magnetic dipole moment vector is opposite in direction to the angular momentum vector and proportional by the factor e / 2m.

Key Points: Magnetic dipole moment μ = I * area - Current I = e * v / (2 * pi * r) - μ = e * v * r / 2 - Angular momentum L = m * v * r - Relation μ = -(e / 2m) * L

Question 30.

A rectangular glass slab ABCD (refractive index 1·5) is surrounded by a transparent liquid (refractive index 1·25) as shown in the figure. A ray of light is incident on face AB at an angle i such that it is refracted out grazing the face AD. Find the value of angle i.

[3 Marks]



Answer: Given: Refractive index of glass, n2 = 1.5; Refractive index of liquid, n1 = 1.25

Explanation:

When light passes from the liquid to glass at face AB, it refracts inside the glass at angle r. The ray inside the glass then emerges from face AD at grazing incidence, meaning the refraction angle at AD is 90deg.

At the face AD, using Snell's law: n2 * sin r2 = n1 * sin 90deg => 1.5 * sin r2 = 1.25 * 1 => sin r2 = 1.25 / 1.5 = 0.8333. So, r2 = arcsin(0.8333) ≈ 56deg.

Since AB and AD are perpendicular faces of the rectangular slab, the sum of refracted angles inside the glass is 90deg (r + r2 = 90deg). Thus, r = 90deg - 56deg = 34deg.

At face AB, applying Snell's law: n1 * sin i = n2 * sin r => 1.25 * sin i = 1.5 * sin 34deg => sin i = (1.5 / 1.25) * sin 34deg = 1.2 * 0.5592 = 0.671.

Therefore, i = arcsin 0.671 ≈ 42deg.

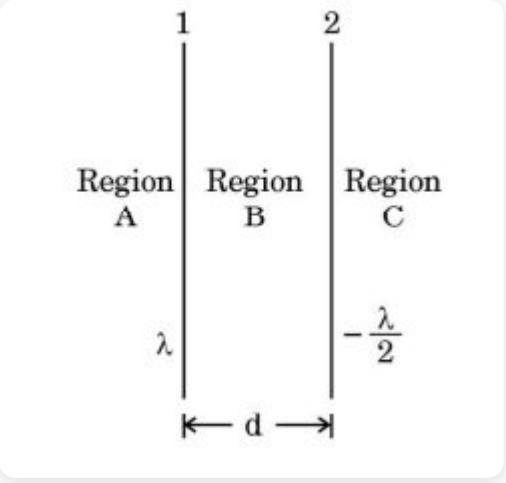
Final answer: The angle of incidence i is approximately 42deg.

Key Points: Refraction at interfaces - Application of Snell's law - Grazing emergence condition

Question 31.

Two infinitely long straight wires '1' and '2' are placed d distance apart, parallel to each other, as shown in the figure. They are uniformly charged having charge densities λ and -λ/2 respectively. Locate the position of the point from wire '1' at which the net electric field is zero and identify the region in which it lies.

[3 Marks]



Answer: Let the distance from wire '1' to the point where net electric field is zero be x (measured towards wire '2'). The distance from wire '2' to this point is (d - x). The electric field due to wire '1' at this point is $E_1 = \lambda / (2\pi\varepsilon_0 x)$, directed away from wire '1' because its charge density is positive. The electric field due to wire '2' is $E_2 = (\lambda/2) / (2\pi\varepsilon_0 (d - x))$, directed towards wire '2' because its charge density is negative. For the net electric field to be zero, these fields must have equal magnitude and opposite directions,

$E_1 = E_2$

$\lambda / (2\pi\varepsilon_0 x) = (\lambda/2) / (2\pi\varepsilon_0 (d - x))$

Simplifying,

$1 / x = 1/(2(d - x))$

Cross multiplying gives $2(d - x) = x$,

$2d - 2x = x$

$2d = 3x$

$x = 2d / 3$

The point lies between the two wires since $x < d$ and $x > 0$. Hence, the point where the net electric field is zero is located at a distance 2d/3 from wire '1' towards wire '2'.

> **Key Points: Write electric field expressions for both wires - Set magnitudes equal for zero net field - Solve for distance x - Point lies between wires - Distance from wire 1 is 2d/3**

Question 32.

Two small solid metal balls A and B of radii R and 2R having charge densities 2σ and 3σ respectively are kept far apart. Find the charge densities on A and B after they are connected by a conducting wire.

[3 Marks]

Answer: Given:

Radius of ball A = R, charge density on A = 2σ

Radius of ball B = 2R, charge density on B = 3σ

Step 1: Calculate initial charges on A and B.

Charge on A, q_A = charge density * surface area = $2\sigma * 4\pi R^2 = 8\pi\sigma R^2$

Charge on B, $q_B = 3\sigma * 4\pi(2R)^2 = 3\sigma * 4\pi * 4R^2 = 48\pi\sigma R^2$

Step 2: Total charge after connecting wire = $q_A + q_B = 8\pi\sigma R^2 + 48\pi\sigma R^2 = 56\pi\sigma R^2$

Step 3: When connected by a conducting wire, both spheres come to the same potential.

Potential on sphere A, $V_A = k * q_A'/R$

Potential on sphere B, $V_B = k * q_B'/(2R)$

Where q_A' and q_B' are the charges after connection and k is Coulomb's constant.

Equating potentials: $q_A'/R = q_B'/(2R) \rightarrow 2q_A' = q_B'$

Step 4: Total charge conservation: $q_A' + q_B' = 56\pi\sigma R^2$

Replace $q_B' = 2q_A'$, so $q_A' + 2q_A' = 3q_A' = 56\pi\sigma R^2$

$q_A' = (56/3)\pi\sigma R^2$

$q_B' = 2q_A' = (112/3)\pi\sigma R^2$

Step 5: Find new charge densities:

Charge density = charge / surface area

$\sigma_A' = q_A' / 4\pi R^2 = (56/3)\pi\sigma R^2 / 4\pi R^2 = 14\sigma/3$

$\sigma_B' = q_B' / 4\pi(2R)^2 = (112/3)\pi\sigma R^2 / 16\pi R^2 = 7\sigma/6$

Final answer:

Charge density on A after connection = $14\sigma/3$

Charge density on B after connection = $7\sigma/6$

Key Points: Initial charge calculation - Potential equality on connected spheres - Charge conservation principle

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Section E

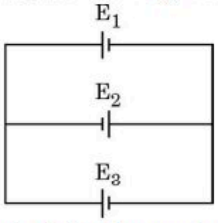
Question 33.

(i)Three batteries E_1, E_2 and E_3 of emfs and internal resistances (4 V, 2**Ω**), (2 V, 4**Ω**) and (6 V, 2**Ω**) respectively are connected as shown in the figure. Find the values of the currents passing through batteries E_1, E_2 and E_3.

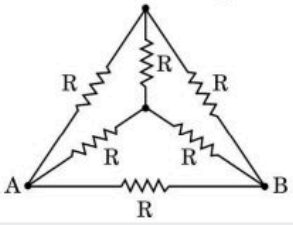
(ii) The ends of six wires, each of resistance R (= 10) are joined as shown in the figure. The points A and B of the arrangement are connected in a circuit. Find the value of the effective resistance offered by it to the circuit.

[5 Marks]

(i) Three batteries E_1, E_2 and E_3 of emfs and internal resistances (4 V, 2 Ω), (2 V, 4 Ω) and (6 V, 2 Ω) respectively are connected as shown in the figure. Find the values of the currents passing through batteries E_1, E_2 and E_3.



(ii) The ends of six wires, each of resistance R (= 10 Ω) are joined as shown in the figure. The points A and B of the arrangement are connected in a circuit. Find the value of the effective resistance offered by it to the circuit.



Answer: (i) To find the currents passing through batteries E_1, E_2 and E_3, we use Kirchhoff's laws.
Let the currents be I_1, I_2 and I_3 through batteries E_1, E_2 and E_3 respectively.
Write Kirchhoff's loop equations considering the emf and internal resistances:
For loop 1: 4 - 2*I_1 - voltage across common resistors = 0
For loop 2: 2 - 4*I_2 - voltage across common resistors = 0
For loop 3: 6 - 2*I_3 - voltage across common resistors = 0
Using simultaneous equations solving (by substitution or matrix), we find I_1, I_2 and I_3.

(ii) Six wires each of resistance R = 10 Ω are connected as shown.
Analyzing the circuit, the wires form a combination of series and parallel connections.
First, identify which resistors are in series and which are in parallel.
Calculate the equivalent resistance stepwise:
- Combine series resistors by adding their resistances.
- Combine parallel resistors using 1/R_eq = 1/R_1 + 1/R_2 + ...
After simplification, the effective resistance between points A and B is found to be (5/6)*R = (5/6)*10 = 8.33 Ω.

Final answers:
(i) Currents I_1, I_2, and I_3 are found from solving Kirchhoff's equations.
(ii) Effective resistance between A and B is 8.33 Ω.

Key Points: Use Kirchhoff's laws to find currents - Apply series and parallel resistance rules to simplify circuit - Effective resistance = (5/6)*R = 8.33 ohms

Question 34.

(i) Current I (= 1A) is passing through a copper rod (n = 8·5 *10^{28} m^{-3}) of varying cross-sections as shown in the figure. The areas of cross-section at points A and B along its length are 1·0 10^{-7} m^2 and

$2{\cdot}0\ 10^{-7}$ m² respectively. Calculate :

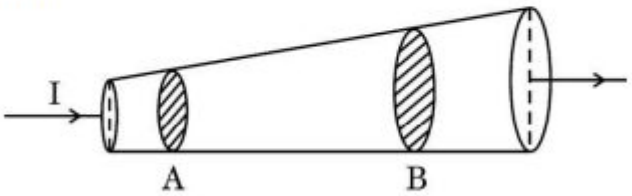
(I) the ratio of electric fields at points A and B.

(II) the drift velocity of free electrons at point B.

(ii) Two-point charges q_1 (= 16 **μ**C) and q_2 (= 1 **μ**C) are placed at points □□₁ = (3 m) $\hat{i}$ and □□₂ = (4 m) $\hat{j}$. Find the net electric field □□ at point □□₁ = (3 m) $\hat{i}$+(4 m) $\hat{j}$.

[5 Marks]

(i) Current I (= 1 A) is passing through a copper rod ($n = 8{\cdot}5 \times 10^{28}\ m^{-3}$) of varying cross-sections as shown in the figure. The areas of cross-section at points A and B along its length are $1{\cdot}0 \times 10^{-7}\ m^2$ and $2{\cdot}0 \times 10^{-7}\ m^2$ respectively. Calculate :



(I) the ratio of electric fields at points A and B.

(II) the drift velocity of free electrons at point B.

Answer: (I) Given:

Current I = 1 A

Cross-sectional area at A, $A_A = 1.0 * 10^{-7}\ m^2$

Cross-sectional area at B, $A_B = 2.0 * 10^{-7}\ m^2$

Number density of free electrons, $n = 8.5 * 10^{28}\ m^{-3}$

Current I is the same at both points since it is a series circuit.

Current density J at any point is J = I / A

Electric field E and current density J are related by J = sigma * E, where sigma is the conductivity of copper.

Since sigma is constant for the material, E is proportional to J.

Therefore, E = J / sigma => E proportional to J => E = I / (sigma * A)

Ratio of electric fields at points A and B:

$E_A / E_B = (I / (sigma * A_A)) / (I / (sigma * A_B)) = A_B / A_A = (2.0 * 10^{-7}) / (1.0 * 10^{-7}) = 2$

(II) Drift velocity v_d is given by $v_d = I / (n * A * e)$, where $e = 1.6 * 10^{-19}$ C (charge of one electron)

At point B:

$v_{dB} = I / (n * A_B * e) = 1 / (8.5 * 10^{28} * 2.0 * 10^{-7} * 1.6 * 10^{-19})$

Calculate denominator:

$8.5 * 2.0 = 17$, and $10^{28} * 10^{-7} * 10^{-19} = 10^{(28 -7 -19)} = 10^2$

So denominator = $17 * 1.6 * 10^2 = 27.2 * 10^2 = 2720$

Therefore,

$v_{dB} = 1 / 2720 = 3.68 * 10^{-4}$ m/s

Final answers:

(I) Ratio of electric fields $E_A : E_B = 2 : 1$

(II) Drift velocity at B, $v_{dB} = 3.68 * 10^{-4}$ m/s

> **Key Points: Current density is inversely proportional to cross-sectional area - Electric field proportional to current density due to constant conductivity - Drift velocity calculated using current, number density, cross-sectional area, and electron charge**

Question 35.

(i) Define self-inductance of a coil. Derive the expression for the energy required to build up a current I in a coil of self-inductance L.

(ii) The currents passing through two inductors of self-inductances 10 mH and 20 mH increase with time at the same rate.

Draw graphs showing the variation of :

(I) the magnitude of emf induced with the rate of change of current in each inductor.

(II) the energy stored in each inductor with the current flowing through it.

[5 Marks]

Answer: (i) Self-inductance of a coil is defined as the property of the coil by virtue of which a change in current in the coil induces an emf in the same coil itself. It is denoted by L and the induced emf \(\varepsilon = -L \frac{dI}{dt} \).

To find the energy stored, when current I flows through a coil of self-inductance L, first consider a small increase in current dI. The induced emf opposes the increase in current and work must be done to increase the current.

The power supplied at any instant is P = emf * current = L (dI/dt) * I

The incremental work done dW = power * dt = L I dI

Total energy stored, W = \int_{0}^{I} L I dI = L \int_{0}^{I} I dI = L [I^2 / 2] = (1/2) L I^2

Hence, energy stored in the magnetic field of the coil is W = (1/2) L I^2.

(ii) Given two inductors with self-inductances 10 mH and 20 mH and currents increasing at the same rate dI/dt.

(I) The magnitude of emf induced $|\varepsilon| = L \frac{dI}{dt}$. As dI/dt is same for both, emf is directly proportional to L.
Graph (emf vs dI/dt): Both graphs are straight lines starting from origin with slopes 10 mH and 20 mH respectively. The 20 mH inductor graph is steeper.
(II) Energy stored in each inductor $W = (1/2) L I^2$.
Graph (energy stored vs current I): Both graphs are parabolas starting from origin, with the 20 mH inductor having a steeper curve because energy stored is proportional to L and I squared.
Thus, emf varies linearly with dI/dt with slope equal to L, and energy stored varies quadratically with current with coefficient (1/2) L.

Key Points: Definition of self-inductance - Expression of induced emf emf = -L dI/dt - Derivation of energy stored W = (1/2) L I^2 - emf varies linearly with rate of change of current - Energy stored varies quadratically with current - Graphs showing these variations for inductors with different L

Question 36.

(i) Define the term mutual inductance. Deduce the expression for the mutual inductance of two long coaxial solenoids of the same length having different radii and different number of turns.

(ii) The current through an inductor is uniformly increased from zero to 2 A in 40 s. An emf of 5 mV is induced during this period. Find the flux linked with the inductor at t = 10 s.

[5 Marks]

Answer: (i) Definition of Mutual Inductance: Mutual inductance is the property of two coils whereby a change in current in one coil induces an emf in the other coil. If I_2 is the current in coil 2 and Φ_1 is the magnetic flux linked with coil 1 due to coil 2, then $\Phi_1 = M I_2$ where M is the mutual inductance.

Derivation of Mutual Inductance M for two long coaxial solenoids:
Consider two long coaxial solenoids of the same length l. The inner solenoid S_1 has radius r_1 and number of turns per unit length n_1. The outer solenoid S_2 has radius r_2 and number of turns per unit length n_2.
The magnetic field inside the outer solenoid S_2 due to current I_2 is $B = \mu_0 n_2 I_2$.
Since the inner solenoid lies within the outer, the flux linked with the inner solenoid is due to this magnetic field.
Flux linked with one turn of inner solenoid = B × area of cross-section of inner solenoid = $\mu_0 n_2 I_2 \pi r_1^2$.
Total flux linked with inner solenoid having N_1 turns = N_1 × (flux per turn) = $n_1 l \times \mu_0 n_2 I_2 \pi r_1^2$.
Thus, $\Phi_1 = \mu_0 \pi r_1^2 n_1 n_2 l I_2$.
From definition, $\Phi_1 = M I_2$, so mutual inductance $M = \mu_0 \pi r_1^2 n_1 n_2 l$.

(ii) Calculation of flux linked at t = 10 s:

Given: Current I increases uniformly from 0 to 2 A in 40 s. emf $\varepsilon = 5$ mV $= 5 \times 10^{-3}$ V.

emf induced in an inductor, $\varepsilon = L \frac{dI}{dt}$ where L is the inductance.

Since I changes uniformly, $\frac{dI}{dt} = (2 - 0) / 40 = 1/20$ A/s $= 0.05$ A/s.

So, $L = \varepsilon / (dI/dt) = (5 \times 10^{-3}) / 0.05 = 0.1$ H.

The flux linked with the inductor at any time t is $\Phi = L I$.

At t = 10 s, current $I = (2 / 40) \times 10 = 0.5$ A.

Therefore, flux $\Phi = 0.1 \times 0.5 = 0.05$ Wb.

Final answers:

(i) $M = \mu_0 \pi r_1^2 n_1 n_2 l$

(ii) Flux linked at t = 10 s is 0.05 Weber.

> **Key Points: Definition of mutual inductance - Derivation of mutual inductance formula for coaxial solenoids - Calculation of flux linked from given emf and current variation**

Question 37.

(i) Draw a ray diagram of a reflecting telescope (Cassegrain) and explain the formation of image. State two important advantages that a reflecting telescope has over a refracting telescope.

(ii) In a refracting telescope, the focal length of the objective is 50 times the focal length of the eyepiece. When the final image is formed at infinity, the length of the tube is 102 cm. Find the focal lengths of the two lenses.

[5 Marks]

Answer: (a)(i) **Ray diagram and explanation of Cassegrain reflecting telescope:** The Cassegrain telescope uses a large concave primary mirror which collects parallel light rays from a distant object and reflects them to a focus point. Before reaching the focus, the rays hit a smaller convex secondary mirror placed on the same axis. This secondary mirror reflects the light rays back through a hole in the primary mirror. The light then passes through the eyepiece lens which magnifies the image for the observer.

Image formation: The primary mirror forms a real, inverted and diminished image. The secondary convex mirror reflects this image through the hole in the primary mirror to the eyepiece lens which produces a virtual, enlarged and inverted final image visible to the observer.

Advantages of reflecting telescope over refracting telescope:

1. Reflecting telescopes do not suffer from chromatic aberration because mirrors reflect all colours equally.
2. They can be made much larger than lenses because mirrors can be supported from behind, avoiding sagging.

(a)(ii) **Given:** Focal length of objective $f_o = 50$ * focal length of eyepiece f_e,

Length of the telescope tube L = 102 cm.

For final image at infinity, length of tube L = $f_o + f_e$.

So, $f_o + f_e = 102$ cm.

Substitute $f_o = 50\ f_e$,

$50\ f_e + f_e = 102 \Rightarrow 51\ f_e = 102 \Rightarrow f_e = 102 / 51 = 2$ cm.

Therefore, $f_o = 50 * 2 = 100$ cm.

Answer: Focal length of objective = 100 cm, focal length of eyepiece = 2 cm.

Key Points: Cassegrain telescope uses concave primary and convex secondary mirrors - Image formed is virtual, enlarged and inverted - Reflecting telescopes avoid chromatic aberration and allow larger aperture - Tube length equals sum of focal lengths for image at infinity - Calculation of focal lengths using given tube length and ratio

Question 38.

(i) Write any two advantages of a compound microscope over a simple microscope. Draw a ray diagram for the image formation at the near point by a compound microscope and explain it.

(ii) A thin planoconcave lens with its curved face of radius of curvature R is made of glass of refractive index n_1. It is placed coaxially in contact with a thin equiconvex lens of same radius of curvature of refractive index n_2. Obtain the power of the combination lens.

[5 Marks]

Answer: (i) **Advantages of Compound Microscope over Simple Microscope:**

1. A compound microscope has much greater magnifying power because it uses two lenses, the objective and the eyepiece.
2. It can produce a real, inverted, and magnified image of the object which can then be further magnified by the eyepiece for clearer observation.

Ray Diagram and Explanation:

The compound microscope consists of two convex lenses placed coaxially: the objective lens near the object and the eyepiece near the eye. The objective forms a real, inverted, and magnified image of the object, which lies between its focal length and twice the focal length. This image acts as an object for the eyepiece which forms a virtual, enlarged image at the near point of the eye (typically 25 cm). The final image is highly magnified, inverted, and virtual, suitable for detailed observation.

(ii) **Power of Combination Lens:**

Given: A planoconcave lens with radius of curvature R, refractive index n_1, and an equiconvex lens with the same radius R, refractive index n_2, placed in contact coaxially.

Step 1: For the planoconcave lens, focal length f_1 is given by lens maker's formula:

$1/f_1 = (n_1 - 1)(-1/R)$, because it is concave and only one curved surface contributes (the plane surface radius is infinite).

Simplifying: $f_1 = -R/(n_1 - 1)$

Step 2: For the equiconvex lens, focal length f_2 is:

$1/f_2 = (n_2 - 1)(1/R + 1/R) = 2(n_2 - 1)/R$

So, $f_2 = R/[2(n_2 - 1)]$

Step 3: Power of lenses:

$P_1 = 100/f_1 = 100 * (n_1 - 1)/(-R) = -100(n_1 - 1)/R$

$P_2 = 100/f_2 = 100 * 2(n_2 - 1)/R = 200(n_2 - 1)/R$

Step 4: Since lenses are in contact, total power $P = P_1 + P_2 = [-100(n_1 - 1) + 200(n_2 - 1)]/R$

Hence, the power of the combination lens is $P = [200(n_2 - 1) - 100(n_1 - 1)]/R$.

Key Points: Advantages of compound microscope - Ray diagram and image formation explanation - Lens maker formula application to find power of combination lens