CBSE EXAMINATION PAPER-2026

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

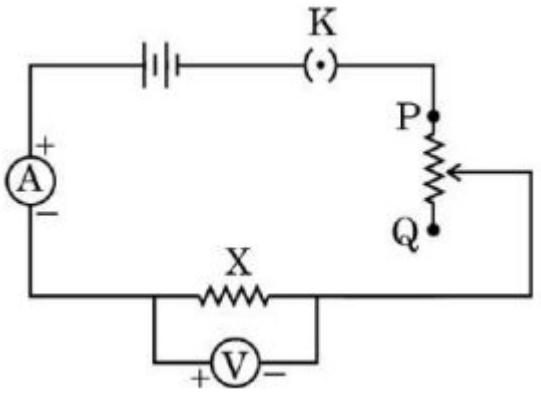
vii. **Section E** – questions number **33 to 38** are long answer

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 student sets up the circuit as shown in the figure to find the value of unknown resistance X and records a set of readings of the voltmeter and the ammeter by using the rheostat.



(1)

Error in the value of X obtained from different sets of voltmeter and ammeter readings, is :

(A) due to error in voltmeter reading only

(B) due to error in ammeter reading only

(C) equal to the sum of error in voltmeter reading and error in ammeter reading

(D) equal to error in voltmeter reading divided by the error in ammeter reading

[1 Marks]

Answer:

Correct Answer is Option (C)

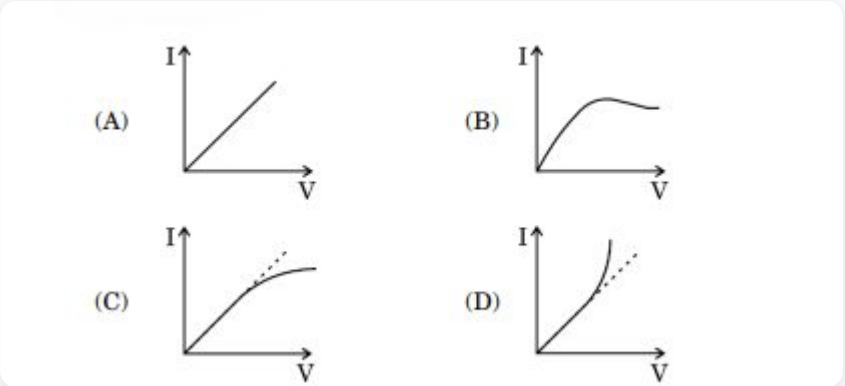
Reason: The resistance is calculated using the formula (X = V/I).

According to the rules of error propagation, the relative or percentage error in a quotient is the sum of the relative errors of the individual quantities.

Therefore, the error depends on the sum of errors from both the voltmeter and the ammeter.

Key Points:

(2) If resistor X were made of manganin and readings for V and I are taken without switching off the circuit, the graph between V and I will be as :



[1 Marks]

Answer:

Correct Answer is Option (A)

Reason: Manganin is an alloy with a negligible temperature coefficient of resistance.

Its resistance remains virtually constant even if the circuit stays on and heats up.

Since resistance stays constant, it strictly obeys Ohm's Law (V = IR), resulting in a straight-line graph passing through the origin.

Key Points:

(3)

If the movable end of rheostat is moved towards P, then :

(A) reading in ammeter decreases and reading in voltmeter increases

(B) readings in both voltmeter and ammeter increase

(C) reading in ammeter increases and reading in voltmeter decreases

(D) readings in both voltmeter and ammeter decrease

[1 Marks]

Answer:

Correct Answer is Option (B)

Reason: Moving the rheostat slider towards P shortens the effective length of the resistance wire in the circuit.

Shorter length reduces the circuit's total resistance.

Lower resistance increases the total current flowing through the circuit, raising the ammeter reading.

Since current increases, the potential difference across resistor X (V = IR) also increases, raising the voltmeter reading

Key Points:

(4)

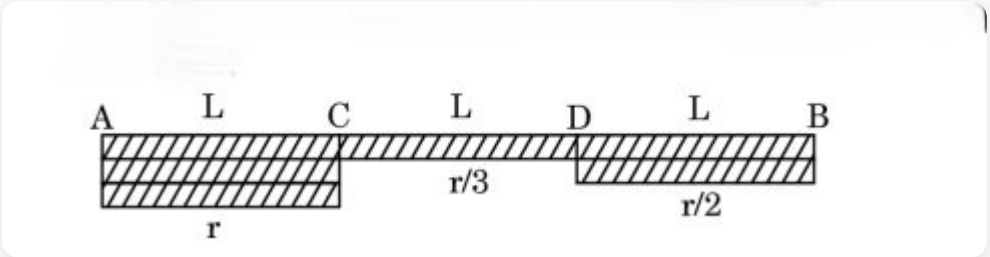
Suppose the unknown resistance X is replaced by a wire made of the same metal. This wire consists of three parts, of the same length L but has radii r, r/3 and r/2 as shown in the figure. For a particular setting of the rheostat, let v_1, v_2 and v_3 be the value of drift velocities in parts AC, CD and DB. Then:

(A) $v_1 > v_2 > v_3$

(B) $v_2 > v_3 > v_1$

(C) $v_3 > v_2 > v_1$

(D) $v_1 = v_2 = v_3$



[1 Marks]

Answer: Since the wire is made of the same metal and has the same length in all three parts, the current is the same in these parts but the radius varies. Drift velocity v is inversely proportional to the cross-sectional area A (which depends on radius squared). Hence, smaller radius means higher drift velocity. Given r, r/3, and r/2, the order of radii is r > r/2 > r/3, so drift velocities are v_2 (smallest radius) > v_3 > v_1 (largest radius). Therefore, the correct option is (B) $v_2 > v_3 > v_1$.

Key Points: Wire parts have same length - Drift velocity inversely proportional to cross-sectional area - Smaller radius means higher drift velocity - Order $v_2 > v_3 > v_1$

(5)

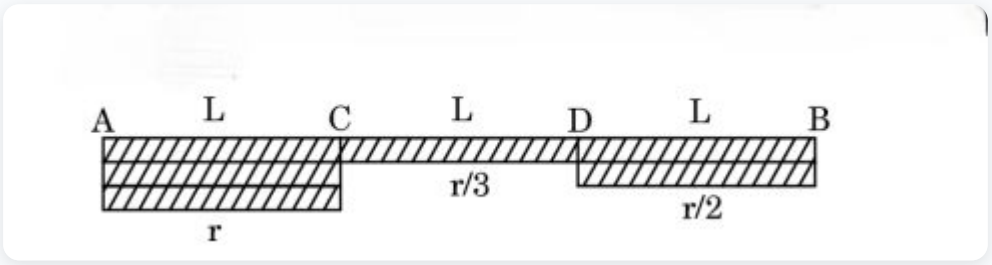
Consider the same wire, as shown in figure in question (iv) (a) connected in place of X. For a particular setting of rheostat, let E1 , E2 and E3 be the value of electric fields in part AC, CD and DB. Then :

(A) $E_1 = E_2 = E_3$

(B) $E_3 > E_2 > E_1$

(C) $E_2 > E_3 > E_1$

(D) $E_1 > E_2 > E_3$



[1 Marks]

Answer:

Correct Answer is Option (B)

Reason: For a wire carrying a uniform current in series, the electric field is given by ($E = I / \sigma.A$),where σ is the conductivity.

This means the electric field is inversely proportional to the cross-sectional area, and thus inversely proportional to the square of the radius ($E \propto 1/r^2$)

Since the smallest radius is at CD (r/3) and the largest is at AC (r), the electric field strength follows the reverse order: (E_2 > E_3 > E_1).

Key Points:

Question 2. An astronomical telescope consists of two converging lenses. One of them of large aperture and large focal length is called objective lens and the other one, of smaller focal length and smaller aperture is called the eyepiece. It is used to see distant objects which are not seen clearly with naked eyes. The image formed by the objective lens acts as an object for the eyepiece and the final image produced by eyepiece is magnified.

(1)

The images formed by the objective lens and the eyepiece are respectively:

(A) virtual, real

(B) real, virtual

(C) virtual, virtual

(D) real, real

[1 Marks]

Answer: The objective lens of an astronomical telescope forms a real image of the distant object. This real image then acts as the object for the eyepiece, which forms a virtual, magnified image for the observer. Therefore, the images formed by the objective lens and the eyepiece are real and virtual respectively, which corresponds to option (B).

Key Points: objective lens forms real image - eyepiece forms virtual image - correct option is (B)

(2)

The magnification produced by the telescope does not depend upon the:

(A) colour of light

(B) focal length of objective lens

(C) focal length of eyepiece

(D) apertures of objective lens and eyepiece

[1 Marks]

Answer:

Correct Answer is Option (D)

The magnifying power of a telescope depends purely on the focal lengths of the lenses and the color (wavelength) of light. The aperture (diameter) of the lenses only determines the light-gathering capacity and brightness of the image, not its geometric magnification.

Key Points:

(3)

Which of the following statements is not correct for this telescope?

(A) The focal length of objective lens (f_o) is larger than the focal length of eyepiece (f_e)

(B) Its magnifying power can be increased by increasing the focal length of objective lens (f_o)

(C) The distance between two lenses is more than ($f_o + f_e$)

(D) The magnifying power can be decreased by increasing the focal length of eyepiece

[1 Marks]

Answer: Option C is not correct. For an astronomical telescope, the distance between the objective lens and the eyepiece is equal to the sum of their focal lengths ($f_o + f_e$), not more. This arrangement forms a clear image as explained in the case passage.

Key Points: Focal length of objective is larger than eyepiece - Magnifying power increases with larger f_o - Distance between lenses equals $f_o + f_e$

(4)

An astronomical telescope has objective lens and eyepiece of focal lengths 80 cm and 4 cm respectively. To view the image in normal adjustment, the lenses must be separated by a distance of :

(A) 84 cm

(B) 76 cm

(C) 20 cm

(D) 320 cm

[1 Marks]

Answer: For normal adjustment, the distance between the objective and eyepiece lenses is equal to the sum of their focal lengths. Here, focal length of objective = 80 cm and focal length of eyepiece = 4 cm. So, distance = 80 cm + 4 cm = 84 cm. Hence, the correct answer is (A) 84 cm.

Key Points: Distance between lenses = sum of focal lengths - Objective focal length = 80 cm - Eyepiece focal length = 4 cm - Distance = 84 cm

(5)

Consider the telescope described in question (iv) (a). Its magnifying power in normal adjustment will be :

(A) 320

(B) 84

(C) 76

(D) 20

[1 Marks]

Answer:

Correct Answer is Option (D)

The formula for the magnifying power of an astronomical telescope in normal adjustment is:

Magnification = fo / fe

Magnification = 80 / 4 = 20

Key Points:

Section B

Question 3.

Two wires of same length and same area of cross-section but made of different material of resistivities ρ_1 and ρ_2 are connected in series. The equivalent resistivity of the combination is:

[1 Marks]

(A) $\rho_1 + \rho_2$

(B) $\sqrt{(\rho_1\rho_2)}$

(C) $2(\rho_1 + \rho_2)$

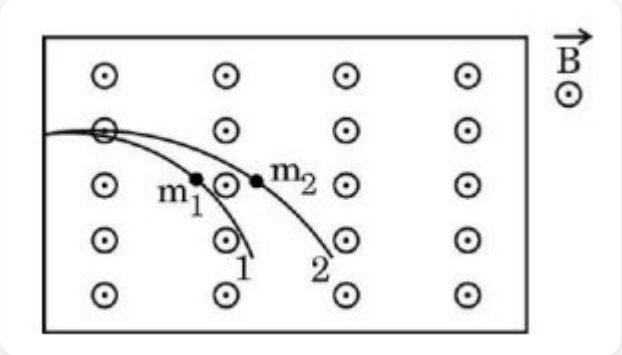
(D) $1/2(\rho_1 + \rho_2)$

Explanation: The resistance R of a wire is given by $R = \rho \times (l / A)$, where ρ is the resistivity of the material, l is the length, and A is the area of cross-section. When two wires of the same length and cross-sectional area are connected in series, the total resistance R_{total} is $R_1 + R_2 = \rho_1 \times (l / A) + \rho_2 \times (l / A) = (\rho_1 + \rho_2) \times (l / A)$. The equivalent resistivity ρ_{eq} for a wire of length l and area A that has the same resistance is given by $R_{total} = \rho_{eq} \times (l / A)$. Comparing both expressions, $\rho_{eq} = \rho_1 + \rho_2$.

Question 4.

Two particles of masses m_1 and m_2 having charges q_1 and q_2 respectively are projected with the same velocity in a region of uniform magnetic field □□ pointing vertically upward. If they describe circular paths as shown in the figure, one may conclude that:

[1 Marks]



(A) $m_1/m_2 > q_2/q_1$

(B) $m_1/m_2 > q_1/q_2$

(C) $m_1/m_2 < q_1/q_2$

(D) $m_1/m_2 < q_2/q_1$

Explanation: When charged particles move in a magnetic field with the same velocity, they experience a magnetic force that causes them to move in circular paths. The radius r of the circular path is given by $r = mv/(qB)$. Since both particles have the same velocity v and magnetic field B, the radius depends on the ratio m/q. If the radius of the particle with mass m_1 and charge q_1 is larger than that of the particle with mass m_2 and charge q_2, then $m_1/q_1 > m_2/q_2$, implying $m_1/m_2 > q_1/q_2$. Therefore, the correct conclusion is that $m_1/m_2 > q_1/q_2$.

Question 5.

An electron moves around the nucleus in a circular orbit of radius r and makes n revolutions per second. The value of equivalent current in the orbit is:

[1 Marks]

(A) ne/r

(B) e/nr

(C) ne

(D) e/n

Explanation:

Current is defined as charge passing through a point per unit time. Here, the electron (charge e) completes n revolutions per second, so the charge passes the same point n times in one second. Therefore, the equivalent current I = n × e = ne.

Question 6.

The dimensions of the rate of change of magnetic flux are:

[1 Marks]

(A) $[M L^2 T^{-3} A^{-2}]$

(B) $[M L^2 T^{-3} A^{-1}]$

(C) $[M L T^{-3} A]$

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

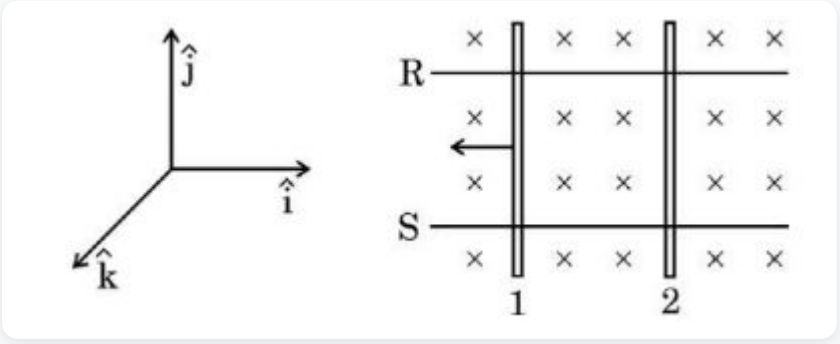
Explanation:

Magnetic flux (φ_B) has dimensions [M L^2 T^-2 A^-1]. The rate of change of magnetic flux with respect to time introduces an extra factor of T^-1, as rate of change with time involves dividing by time. Therefore, the dimensions of the rate of change of magnetic flux are [M L^2 T^-3 A^-1].

Question 7.

Two identical conductors 1 and 2 are placed on two frictionless conducting rails R and S in a uniform magnetic field directed vertically downward into the plane of the page. If conductor 1 is moved with a constant velocity in the direction as shown in figure, the force on conductor 2 will be along:

[1 Marks]



(A) $-\hat{i}$

(B) $\hat{k}$

(C) $\hat{j}$

(D) $-\hat{j}$

Explanation: When conductor 1 moves with a constant velocity in a magnetic field directed vertically downward, it causes a change in magnetic flux, which induces a current in the circuit formed by the rails and the conductors. This induced current in conductor 2 interacts with the magnetic field, resulting in a force. Using the right-hand rule, the direction of the force on conductor 2 is opposite to the direction of the $\hat{j}$ axis, i.e., along $-\hat{j}$.

Question 8.

An ac voltage is given as V = 14 sin (314t) V. The average and the effective value of the voltage (in V) over a cycle are respectively:

[1 Marks]

(A) 10 and 0

(B) 10 and 14

(C) 14 and 7

(D) 0 and 10

Explanation:

For an AC voltage V = Vmax sin(ωt), the average voltage over one complete cycle is zero because the positive and negative halves cancel out. The effective or RMS value is Vmax / √2. Given Vmax = 14 V, the RMS voltage is 14/√2 ≈ 10 V. Hence, the average is 0 V and the effective value is 10 V.

Question 9.

The ratio of amplitude of electric field to the amplitude of the magnetic field associated with an electromagnetic wave propagating in glass (n = 1.5) is:

[1 Marks]

(A) 5×10^{-9} m s^{-1}

(B) 3.3×10^{-9} m s^{-1}

(C) 3×10^{8} m s^{-1}

(D) 2×10^8 m s^{-1}

Explanation: The ratio of the amplitude of the electric field (E) to the amplitude of the magnetic field (B) in an electromagnetic wave propagating in a medium is equal to the speed of light in that medium (v). The speed of light in a medium is given by v = c/n, where c = 3 × 10^8 m/s is the speed of light in vacuum and n is the refractive index of the medium. For glass with n = 1.5, v = (3 × 10^8 m/s) / 1.5 = 2 × 10^8 m/s. Therefore, the ratio E/B = v = 2 × 10^8 m/s.

Question 10.

While studying photoelectric emission from a given surface, the wavelength of the incident radiation is changed from 600 nm to 400 nm, keeping the intensity of radiation the same. Then:

[1 Marks]

(A) cut-off potential will increase

(B) cut-off potential will decrease

(C) saturation current will increase

(D) saturation current will decrease

Explanation:

The cut-off potential (or stopping potential) depends on the frequency (or wavelength) of the incident radiation and is related to the maximum kinetic energy of emitted electrons. When the wavelength decreases from 600 nm to 400 nm, the frequency increases, leading to greater kinetic energy of photoelectrons. Thus, the cut-off potential increases. Since intensity is kept constant, the saturation current, which depends on the intensity, remains unchanged. Hence, the correct answer is that the cut-off potential will increase.

Question 11.

Radiation of wavelength 331 nm irradiates the following metals: Which of the following statements is correct?

[1 Marks]

Metal	Work Function (eV)
Na	1·92
K	2·15
Ca	3·20
Mo	4·17

(A) Only Na and K show photoelectric emission

(B) All of the given metals show photoelectric emission

(C) None of them show photoelectric emission

(D) Only Mo will not show photoelectric emission

Explanation:

According to the context, alkali metals such as sodium (Na) and potassium (K) can show photoelectric emission even with visible light due to their low work function. Radiation with wavelength 331 nm (which is in the ultraviolet region) has higher energy and can thus eject photoelectrons from metals with moderate work functions. Molybdenum (Mo), being a transition metal, has a higher work function and may not exhibit photoelectric emission at this wavelength. Therefore, only Mo will not show photoelectric emission under 331 nm radiation.

Question 12.

The kinetic energy of a charged particle is increased to four times of its initial value. The de Broglie wavelength associated with the particle will:

[1 Marks]

(A) increase by 100% of its initial value

(B) decrease by 25% of its initial value

(C) decrease by 50% of its initial value

(D) increase by 50% of its initial value

Explanation:

The de Broglie wavelength λ is related to the momentum p of a particle by λ = h / p, where h is Planck's constant. Momentum p is related to kinetic energy KE by p = sqrt(2mKE). When the kinetic energy is increased to four times, KE becomes 4KE. Therefore, the momentum becomes p' = sqrt(2m × 4KE) = 2 × sqrt(2mKE) = 2p. Since λ' = h / p' = h / (2p) = λ / 2, the de Broglie wavelength decreases to half (50%) of its initial value.

Question 13. Paschen series in spectrum of hydrogen atom lies in:

[1 Marks]

(A) infrared region

(B) visible region

(C) ultraviolet region

(D) partly in ultraviolet region and partly in visible region

Explanation: The Paschen series corresponds to electron transitions ending at the third energy level (n=3) in the hydrogen atom. The wavelengths of these spectral lines range from approximately 820 nm to 1875 nm, which fall in the infrared region of the electromagnetic spectrum. Infrared light has longer wavelengths than visible light and is not visible to the human eye. Therefore, the Paschen series lies in the infrared region.

Question 14.

In a reversed-biased p-n junction diode, the applied voltage mostly drops across:

[1 Marks]

(A) p-region only

(B) n-region only

(C) the diode

(D) depletion region

Explanation:

In a reverse biased p-n junction diode, the positive terminal of the battery is connected to the n-region and the negative terminal to the p-region. This widens the depletion region, which has very high resistance compared to the p-region and n-region. As a result, most of the applied voltage drops across the depletion region, while the voltage drop across the p-region and n-region is negligible.

Question 15. Assertion (A): The work done, in taking a unit charge around a closed loop of an electric circuit involving cells and resistors in the loop, is zero. Reason (R): The potential at a point depends

on the location of the point in the loop. After completing one round, the charge comes back to the point of start.

[1 Marks]

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

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

Explanation: The work done in moving a unit charge around a closed loop involving cells and resistors is zero because electric potential is a scalar quantity that depends on the location of the point. Since the charge returns to the starting point after completing the loop, the total change in potential is zero, making the net work done zero. This matches the loop rule which states that the algebraic sum of potential changes in a closed circuit is zero. Hence, both the assertion and reason are true, and the reason correctly explains the assertion.

Question 16.

Assertion (A): When a ferromagnetic substance is heated to high temperature it becomes paramagnetic in nature. Reason (R): The disappearance of magnetisation of a ferromagnet is abrupt and not gradual.

[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) 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 false

Explanation:

The assertion is correct because a ferromagnetic substance becomes paramagnetic when heated to a sufficiently high temperature (called the Curie temperature). However, the reason is incorrect because the disappearance of magnetisation in a ferromagnet with increase in temperature is gradual, not abrupt. The domain structure disintegrates gradually with temperature leading to a gradual loss of magnetisation.

Question 17.

Assertion (A): When a convex lens made of glass is immersed in water, its converging power increases. Reason (R): The focal length of a lens depends only on the radii of curvature of its two faces.

[1 Marks]

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

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

Explanation:

When a convex lens made of glass is immersed in water, its focal length increases because the refractive index difference between the lens and the surrounding medium decreases. Hence, the converging power (which is inversely proportional to focal length) actually decreases, not increases. Therefore, the assertion that converging power increases is false. Also, the focal length of the lens depends not only on the radii of curvature of its faces but also on the refractive indices of the lens material and the surrounding medium. So, the reason given is false.

Question 18. Assertion (A): The conductivity of an n-type semiconductor is higher than that of a p-type semiconductor at a given temperature. Reason (R): The electrons being in the conduction band in n-type semiconductor are more mobile than the holes in the valence band in p-type semiconductor.

[1 Marks]

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

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

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

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

Explanation: n-type semiconductors have electrons as majority carriers in the conduction band, while p-type semiconductors have holes as majority carriers in the valence band. Electrons generally have higher mobility than holes because they are lighter and move more easily through the lattice. Therefore, the conductivity of an n-type semiconductor is higher than that of a p-type semiconductor at the same temperature. The reason given correctly explains the assertion.

Section C

Question 19.

An electric dipole consists of two point charges +1 μC and –1 μC, held 10 cm apart. It is subjected to a uniform electric field of 100 N/C. Calculate the amount of work done in turning the dipole from its position of stable equilibrium to the position of unstable equilibrium, in the field.

[2 Marks]

Answer: Given: charge q = 1 μC = 1 * 10^-6 C, distance d = 10 cm = 0.1 m, electric field E = 100 N/C.
The dipole moment p = q * d = 1 * 10^-6 * 0.1 = 1 * 10^-7 C m.
The work done W in rotating the dipole from stable equilibrium (θ = 0 deg) to unstable equilibrium (θ = 180 deg) is W = pE(cos θ_initial - cos θ_final).
Therefore, W = 1 * 10^-7 * 100 * (cos 0 deg - cos 180 deg) = 1 * 10^-5 * (1 - (-1)) = 2 * 10^-5 Joules.
Answer: The work done is 2 * 10^-5 Joules.

Key Points: Calculate dipole moment using charge and distance - Use formula W = pE(cos θ_initial - cos θ_final) for work done - Substitute values and calculate final work done

Question 20.

State Huygens principle. How did Huygens justify the absence of the backward wave on a spherical wavefront?

[2 Marks]

Answer: (a) **Huygens principle:** Every point on a given wavefront acts as a source of secondary wavelets, which spread out in all directions with the speed of the wave. The new wavefront at any later time is the envelope of these secondary wavelets.
(b) **Justification for absence of backward wave:** Huygens assumed that the amplitude of these secondary wavelets is maximum in the forward direction and zero in the backward direction. This ad hoc assumption explained why the backward wave is not observed. Although this assumption is not fully satisfactory, the absence of the backward wave is properly justified by more rigorous wave theories.

Key Points: Huygens principle definition - Secondary wavelets concept - Ad hoc assumption of zero amplitude backward wavelet

Question 21.

In a single-slit diffraction experiment, light of wavelength λ illuminates the slit of width ‘a’. The diffraction pattern is observed on a screen kept at distance D from the slits.

(i) Depict variation in intensity in the fringe pattern with the angular position of the fringes.
(ii) How is the linear width of central maximum affected when separation between the slit and the screen is decreased?

[2 Marks]

Answer: (i) In single slit diffraction, the intensity of light varies with the angle θ. The pattern shows a bright central maximum with the highest intensity at θ = 0 and successive dark and bright fringes on either side. Intensity falls to zero at angles θ where a sin θ = mλ (m = ±1, ±2, ...). Between these minima, weaker secondary maxima occur with decreasing intensity.
(ii) The linear width of the central maximum on the screen is given by 2Dλ/a. When the distance D between the slit and screen decreases, the linear width of the central maximum decreases proportionally because it is directly proportional to D.

Key Points: Single slit diffraction pattern intensity varies with angle - Intensity is maximum at centre and zero at minima a sin θ = mλ - Linear width of central maximum is 2Dλ/a - Decreasing screen distance D decreases central maximum width

Question 22.

A small bulb is placed at the bottom of a tank, containing a transparent liquid of refractive index √2, to a depth of 1 m. Calculate the area of the surface of the liquid through which light from the bulb emerges.

[2 Marks]

Answer: Given: Refractive index of liquid, n = sqrt(2), Depth, d = 1 m.
Step 1: The critical angle, C = $\sin^{-1}(1/n) = \sin^{-1}(1/\sqrt{2}) = 45$ deg.
Step 2: Light rays inside the liquid make a cone with half angle C at the bulb.
Step 3: Radius of the circular area on the surface, R = d * tan C = 1 * tan 45 = 1 m.
Step 4: Area of the surface, A = pi * $R^2 = 3.14 * 1^2 = 3.14$ m^2.
Answer: The area of the surface of the liquid through which light emerges is 3.14 m^2.

Key Points: Refractive index used to find critical angle - Critical angle determines maximum emergence angle - Area of surface calculated using radius from depth and tan of critical angle

Question 23.

Draw the graph showing the variation of number of scattered alpha particles (N) detected with scattering angle (θ) in Geiger–Marsden experiment. Infer two conclusions from the graph.

[2 Marks]

Answer: (a) The graph plots scattering angle θ (degrees) on horizontal axis from 0 to 180 and number of scattered alpha particles (N) on vertical axis with logarithmic scale.
(b) Most alpha particles scatter at very small angles close to 0°, with N very high near 0°.
(c) Number of scattered particles decreases drastically as θ increases and very few particles are scattered at angles near 180°.
(d) **Conclusions:**
1. Most alpha particles pass through the foil undeflected meaning atoms are mostly empty space.
2. A small number of alpha particles scatter at large angles, indicating presence of a small dense positively charged nucleus inside atom.

Key Points: Number of scattered particles is highest at small angles - Number decreases rapidly with increase in scattering angle - Few alpha particles scatter at large angles indicating dense nucleus

Question 24.

The hole concentration in an intrinsic semiconductor is $5 \times 10^{8}\ m^{-3}$. When it is doped with certain impurity, the electron concentration becomes $4 \times 10^{12}\ m^{-3}$. Find the new value of the hole concentration. Also identify the type of new semiconductor formed after doping.

[2 Marks]

Answer: Given: Hole concentration in intrinsic semiconductor $p_i = 5 * 10^{8}\ m^{-3}$, Electron concentration after doping $n = 4 * 10^{12}\ m^{-3}$.
Step 1: In intrinsic semiconductor, $n_i = p_i = 5 * 10^{8}\ m^{-3}$.
Step 2: For doped semiconductor, $n * p = n_i^2$. So, $p = n_i^2 / n = (5 * 10^{8})^2 / (4 * 10^{12}) = 25 * 10^{16} / 4 * 10^{12} = 6.25 * 10^{4}\ m^{-3}$.
Step 3: Since electron concentration is much greater than hole concentration, majority carriers are electrons. So, the semiconductor is n-type after doping.

Key Points: Using n * p = n_i squared - Calculating hole concentration from electron concentration - Identifying n-type semiconductor due to majority electrons

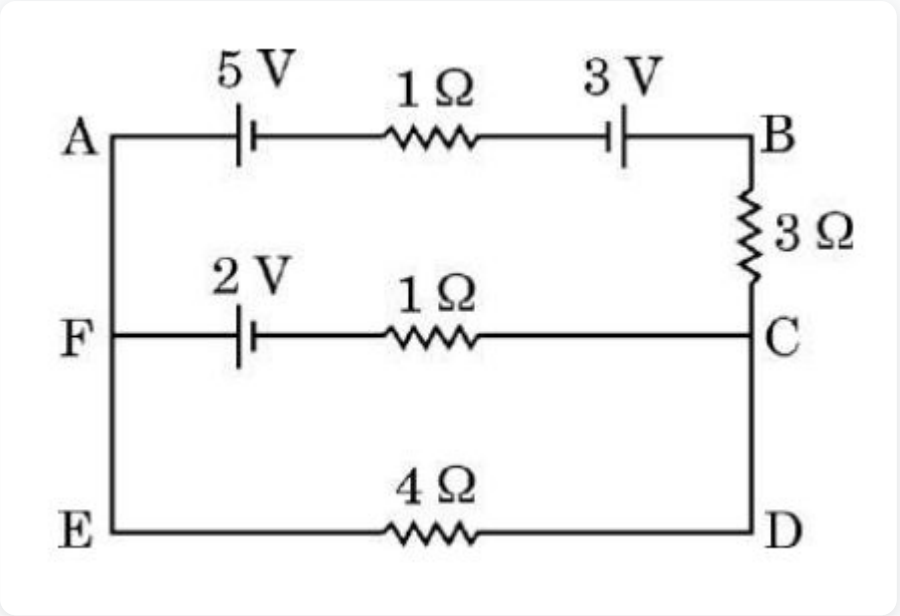
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Section D

Question 25.

State Kirchhoff's rules. Using these rules, find the current flowing through branch FC in the given circuit.

[3 Marks]



Answer: (a) Kirchhoff's Rules:

Kirchhoff's First Rule (Junction Rule): The algebraic sum of currents meeting at a junction is zero. This means the sum of currents entering a junction equals the sum of currents leaving it.

Kirchhoff's Second Rule (Loop Rule): The algebraic sum of the products of currents and resistances and the emf's in any closed loop of a circuit is zero.

(b) Finding Current through Branch FC:

1. Assign current variables to each branch including branch FC.
2. Apply Kirchhoff's junction rule at suitable nodes to express currents relation.
3. Apply Kirchhoff's loop rule to the independent loops involving branch FC to form equations with currents.
4. Solve the simultaneous equations obtained to find the current through branch FC.
5. The direction of current assumed initially is considered positive if the final value is positive; if negative, the current flows opposite.

Thus, by systematically applying Kirchhoff's rules and solving the equations, the current in branch FC can be determined accurately.

Key Points: Kirchhoff's junction rule - Kirchhoff's loop rule - Systematic equation solving for current

Question 26.

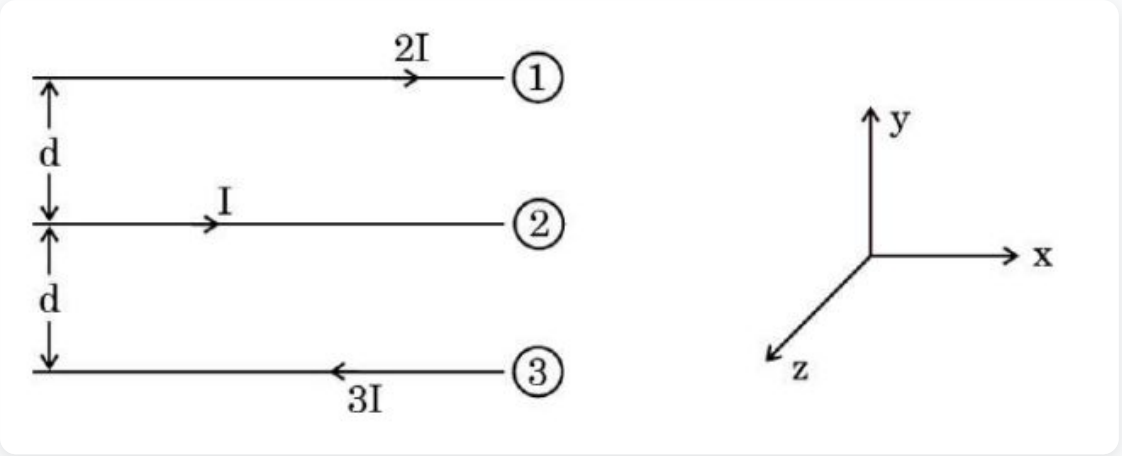
The figure given below shows three straight long parallel conductors ①, ② and ③ kept in x-y plane, carrying currents 2I, I and 3I respectively as shown in figure.

Find the magnitude and direction of:

(i) net magnetic field at a point on conductor ① and

(ii) net magnetic force acting on unit length of conductor ①, due to conductors ② and ③.

[3 Marks]



Answer: (i) To find the net magnetic field at conductor ① due to conductors ② and ③, we use the formula for magnetic field due to a long straight conductor: $B = (mu_0 * I) / (2 * pi * r)$. Let the distances from conductor ① to ② and ③ be r_{12} and r_{13} respectively.

Magnetic field due to conductor ② at ①: $B_2 = (mu_0 * I) / (2 * pi * r_{12})$, direction given by right-hand rule.

Magnetic field due to conductor ③ at ①: $B_3 = (mu_0 * 3I) / (2 * pi * r_{13})$, direction also by right-hand rule.

The directions of B_2 and B_3 depend on current directions; sum vectorially to get net B.

(ii) The force per unit length on conductor ① due to conductor ② is $F_{12}/L = (mu_0 * 2I * I) / (2 * pi * r_{12})$, attractive or repulsive depending on current directions.

Similarly, force per unit length on ① due to ③ is $F_{13}/L = (mu_0 * 2I * 3I) / (2 * pi * r_{13})$.

Net force per unit length on ① is vector sum of F_{12}/L and F_{13}/L. Direction is along line joining the conductors, given by attraction if currents are in same direction, repulsion if opposite.

Thus, by calculating individual magnetic fields and forces using the formula and summing vectorially considering directions, we get the required net magnetic field and force on conductor ①.

Key Points: Formula for magnetic field due to a long conductor - Use of right hand rule for field direction - Calculation of force per unit length between parallel currents

Question 27.

A rectangular loop of sides l and b and resistance 'R' is kept in a region in which the magnetic field varies as $B = B_0 \sin \omega t$.
(i) Derive the expression for the emf induced in the loop.
(ii) Find the effective value of current that flows in the loop.

[3 Marks]

Answer: (i) Expression for emf induced:
The magnetic flux Φ through the rectangular loop is given by $\Phi = B A$, where $A = l * b$ is the area of the loop.
Given, $B = B_0 \sin \omega t$, so $\Phi = B_0 \sin \omega t * l * b$.
According to Faraday's law of electromagnetic induction, emf $\varepsilon = - d\Phi/dt$.
Calculating derivative, $d\Phi/dt = B_0 l b \omega \cos \omega t$.
So, emf, $\varepsilon = - B_0 l b \omega \cos \omega t$.

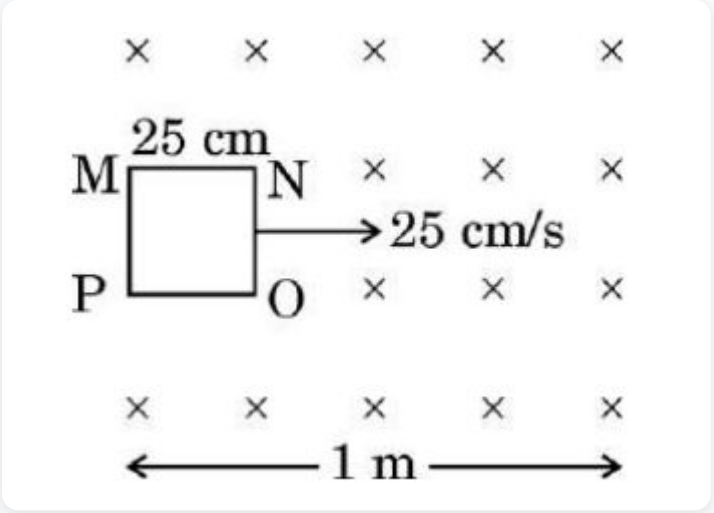
(ii) Effective value of current:
The induced current I = emf / R = $(- B_0 l b \omega \cos \omega t) / R$.
The effective value or RMS value of current I_{eff} is obtained by taking RMS of cos ωt which is 1 / sqrt(2).
Hence, $I_{eff} = (B_0 l b \omega) / (R \sqrt{2})$.

Key Points: Magnetic flux expression as $\Phi = B A$ - Application of Faraday's law: emf = $- d\Phi/dt$ - Calculation of RMS current $I_{eff} = emf_{max} / (R \sqrt{2})$

Question 28.

The figure given below shows a square-shaped loop MNOP of side 25 cm placed horizontally in a uniform magnetic field B(vector) directed vertically downward. The position of the loop at t = 0 s is as shown in figure. The loop is pulled with a constant velocity of 25 cm/s till it goes out of the field.
(a) What will be the direction of the induced current in the loop as it goes out of the field? For how long would the current in the loop persist?
(b) Plot graphs showing the variation of magnetic flux and magnitude of induced emf as a function of time.

[3 Marks]



Answer: (a) As the loop moves out of the magnetic field directed vertically downward, the magnetic flux through the loop decreases. By Lenz's law, the induced current will flow in a direction to oppose this decrease. Since the field is downward, the induced current will produce a downward magnetic field inside the loop. By the right-hand rule, the induced current flows in the anticlockwise direction when viewed from above.

The current persists only while the loop is partially in the magnetic field, i.e., while the flux changes. The loop side is 25 cm and velocity is 25 cm/s, so it takes time t = side/velocity = 25 cm / 25 cm/s = 1 second. Thus, the induced current will last for 1 second.

(b) The magnetic flux decreases linearly from its initial value to zero in 1 second as the loop moves out. So, the flux vs time graph is a straight line decreasing from maximum flux at t=0 to zero at t=1 s. The magnitude of induced emf is the rate of change of flux, which is constant because flux decreases uniformly. Hence, the emf vs time graph is a constant horizontal line during the 1 second and zero afterwards.

The graphs are:

- Magnetic flux vs time: straight line decreasing from maximum flux to zero over 1 second
- Induced emf vs time: constant nonzero value for 1 second, then zero

This shows the induced current exists only during the time flux changes due to the loop moving out of the field.

Key Points: Induced current direction anticlockwise due to Lenz's law - Current persists for 1 second while loop exits the field - Flux decreases linearly as loop moves out - Induced emf is constant during 1 second - Graphs show linear flux decrease and constant emf during that time

Question 29.

What are infrared waves ? Why are these waves referred to as ‘heat waves’ ? Give any two uses of these waves.

[3 Marks]

Answer:

(a) Infrared waves are electromagnetic waves with frequencies lower than visible light and lie adjacent to the visible spectrum's low-frequency or long-wavelength end. They are produced by hot bodies and molecules.

(b) These waves are called ‘heat waves’ because many molecules, especially water molecules in materials, absorb infrared waves easily. This absorption increases the thermal motion of molecules, raising the temperature of the substance and its surroundings.

(c) Two uses of infrared waves are:

1. Infrared lamps are used in physical therapy to provide heat to injured muscles and tissues.

2. They are used in night vision devices to detect heat emitted by objects in darkness.

Key Points: Infrared waves are electromagnetic waves with lower frequency than visible light - Called heat waves because they increase thermal motion when absorbed - Used in physical therapy and night vision devices

Question 30.

(a) Explain how the dual aspect of matter is evident in the de Broglie relation.
(b) Radiation of wavelength λ is incident on a photosensitive surface. Find the de Broglie wavelength of electrons emitted from the surface. Assume that the work function of the surface is negligible.

[3 Marks]

Answer: (a) The dual aspect of matter is evident in the de Broglie relation given by $\lambda = h / p = h / mv$, where λ is the wavelength (a wave property) and $p = mv$ is the momentum (a particle property) of a particle. This equation shows that matter exhibits both wave and particle characteristics simultaneously. Planck's constant h links these two aspects, confirming the wave-particle duality of matter.

(b) Given radiation of wavelength λ incident on a photosensitive surface with negligible work function, the energy of the incident photon is $E = hc / \lambda$. Since work function is negligible, this photon energy converts entirely into kinetic energy of the emitted electron.
Therefore, K.E. = $E = hc / \lambda = (1 / 2) m v^2$
Momentum of electron $p = m v = \text{sqrt}(2 m \text{K.E.}) = \text{sqrt}(2 m (hc / \lambda))$
De Broglie wavelength of emitted electron $\lambda_e = h / p = h / \text{sqrt}(2 m hc / \lambda) = \text{sqrt}(\lambda h / 2 m c)$
This is the expression for the de Broglie wavelength of electrons emitted when radiation of wavelength λ falls on a surface with negligible work function.

Key Points: De Broglie relation shows wave and particle properties - λ is wave aspect, p is particle aspect - Planck's constant relates wave and particle - Photon energy converts

to kinetic energy - Kinetic energy relates to momentum - De Broglie wavelength of electron depends on incident radiation wavelength

Question 31.

In the nuclear reaction:
$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{A}_{2}X + ^{1}_{0}n$
(a) Find the value of A.
(b) Calculate the amount of energy released in the reaction.
Given: m($^{2}_{1}H$) = 2.014102 u, m($^{A}_{2}X$) = 3.016049 u,
m($^{1}_{0}n$) = 1.008665 u, 1 u = 931.5 MeV/c^2

[3 Marks]

Answer: (a) In the reaction $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{A}_{2}X + ^{1}_{0}n$, the total mass number before the reaction is 2 + 2 = 4. After the reaction, the mass number is A + 1 (for the neutron). Therefore, 4 = A + 1 implies A = 3. So the product nucleus is $^{3}_{2}X$.
(b) To calculate the energy released, first find the mass defect: mass defect = mass of reactants - mass of products = (2.014102 + 2.014102) u - (3.016049 + 1.008665) u = 4.028204 u - 4.024714 u = 0.00349 u.
Energy released, E = mass defect * 931.5 MeV/u = 0.00349 * 931.5 = 3.25 MeV.
Final answers: (a) A = 3
(b) Energy released = 3.25 MeV

Key Points: Mass number conservation - Calculation of mass defect - Energy released calculation using mass defect and conversion factor

Question 32.

With the help of a circuit diagram, explain the working of a full wave rectifier. Depict the input and output waveforms.

[3 Marks]

Answer: A full-wave rectifier converts the entire AC input signal into pulsating DC output.
(a) Circuit Diagram: It consists of a center-tapped transformer and two diodes connected such that each diode conducts during alternate half cycles of the AC input.
(b) Working: During the positive half cycle of AC, diode D1 conducts and D2 is reverse biased, allowing current through the load in one direction.
During the negative half cycle, diode D2 conducts and D1 is reverse biased, again allowing current in the same direction through the load.
This way, both half cycles produce current in the same direction.
(c) Waveforms: The input waveform is a sinusoidal AC voltage.
The output voltage across the load is a series of positive pulses corresponding to both half cycles,

producing a pulsating DC voltage.
This pulsating DC can be filtered to get smooth DC voltage.

Key Points: Center-tap transformer and two diodes - Both half cycles used to produce DC - Output is pulsating DC voltage

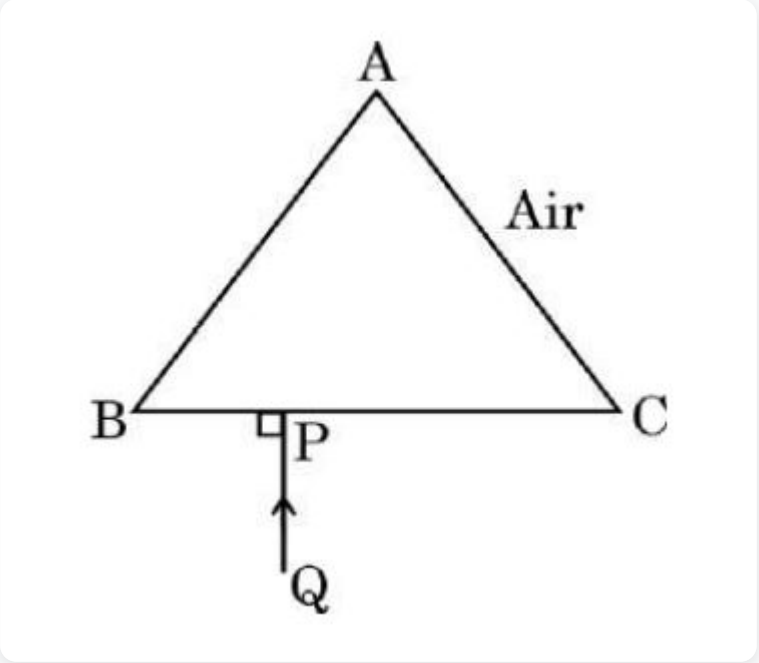
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Section E

Question 33.

(i) Define refractive index of a medium in terms of speed of light.
(ii) Derive the relation for the refractive index (μ) of a prism in terms of angle of minimum deviation (δ_m) and angle of prism (A).
(iii) A ray of light QP is incident normally on the face BC of a triangular prism ABC of refractive index 1.5 kept in air, as shown in the figure. Trace the path of the ray as it passes through the prism and give relevant explanation.

[5 Marks]



Answer: (a) The refractive index (μ) of a medium is defined as the ratio of the speed of light in vacuum (c) to the speed of light in that medium (v). Mathematically, $\mu = c / v$.

(b) Derivation of refractive index of prism: Let A be the angle of the prism and δ_m be the angle of minimum deviation. When light passes through the prism at minimum deviation, the angle of incidence (i) is equal to the angle of emergence (e) and the refracted angles inside the prism are equal (r). Using geometry of prism, the angle $A = r_1 + r_2 = 2r$ and the total deviation $\delta_m = (i + e) - A$, but at minimum deviation $i = e$, so $\delta_m = 2i - A$ or $i = (A + \delta_m) / 2$. Using Snell's law at the first face air to prism,

sin i = μ sin r. Therefore, μ = sin i / sin r = sin((A + δ_m) / 2) / sin(A / 2). This is the required formula relating μ, A and δ_m.

(c) When a ray of light QP is incident normally on the face BC of the triangular prism ABC, it enters the prism without deviation since incidence is normal. Inside the prism, the ray bends at the other face AC because the light passes from denser medium (glass) to rarer medium (air). Due to refraction, the ray bends away from the normal at face AC and emerges out of the prism at some angle, causing the emergent ray RS to deviate from the original incident ray PQ. The overall deviation depends on the refractive index and angles of the prism. This explains the path of light through the prism when incident normally on one face.

Key Points: Definition of refractive index in terms of speed of light - Derivation of refractive index formula μ = sin((A + δ_m) / 2) / sin(A / 2) - Explanation of light path inside prism with normal incidence on one face

Question 34.

(i) What is the difference between a ray and a wavefront ?

(ii) A plane wave is incident on a reflecting surface. Using Huygens principle, show how it is reflected from the surface. Hence, verify the law of reflection.

(iii) Depict refraction of a plane wave by a convex lens.

[5 Marks]

Answer: (i) Difference between a ray and a wavefront:
A wavefront is an imaginary line or surface joining all points of a wave that vibrate in phase. Rays are straight lines drawn perpendicular to the wavefronts showing the direction of wave propagation.

(ii) Reflection of a plane wave using Huygens principle and verification of law of reflection:
When a plane wave is incident on a reflecting surface, every point on the wavefront acts as a source of secondary wavelets according to Huygens principle. These wavelets spread out in the forward direction. The reflected wavefront is the envelope of these secondary wavelets. The angle of incidence (angle between incident ray and normal to the surface) i equals the angle of reflection r (angle between reflected ray and normal), which verifies the law of reflection: i = r.

(iii) Refraction of a plane wave by a convex lens:
When a plane wave is incident on a convex lens, the lens makes the wavefronts bend due to change in speed of light in the lens material. The convex lens converges the parallel incident wavefronts towards its principal focus, changing the direction of rays to converge. This bending of wavefronts is refraction, causing the rays to meet at the focal point of the lens.

Key Points: Wavefront is a line joining points in same phase - Rays are perpendicular to wavefronts showing direction of wave travel - Huygens principle explains reflection by secondary wavelets - Angle of incidence equals angle of reflection - Convex lens converges plane wavefronts causing refraction

Question 35.

(i) Define the terms (I) resonant frequency, and (II) power factor of a series LCR circuit. For what value of the power factor will the power dissipated in the circuit be maximum?
(ii) An inductor of 5/π H, a capacitor of 50/π μF and a resistor of 400 Ω are connected in series across an ac voltage v = 140 sin (100πt) V. Calculate:
(I) impedance of the circuit, and
(II) rms value of current that flows in the circuit.
(Take √2 = 1.4)

[5 Marks]

Answer: (i) (I) **Resonant frequency** is the frequency at which the inductive reactance equals the capacitive reactance in a series LCR circuit. At this frequency, the circuit's impedance is minimum and the current is maximum. Mathematically, resonant angular frequency $\omega_0 = 1 / \text{sqrt}(LC)$, and resonant frequency $f_0 = \omega_0 / 2\pi$.
(II) **Power factor** of a series LCR circuit is the cosine of the phase angle between the voltage and current. It is given by $\cos\phi = R / Z$, where R is resistance and Z is impedance of the circuit.
The power dissipated in the circuit is maximum when the power factor is 1, which occurs at the resonant frequency when Z = R and the phase angle $\phi = 0$.
(ii) Given:
Inductance, $L = 5 / \pi$ H, Capacitance, $C = 50 / \pi$ μF $= (50 / \pi) * 10^{-6}$ F, Resistance, R = 400 Ω, Voltage, $v = 140 \sin(100\pi t)$ V. Angular frequency, $\omega = 100\pi$ rad/s.
(I) Calculate inductive reactance, $X_L = \omega L = 100\pi * (5 / \pi) = 500$ Ω.
Calculate capacitive reactance, $X_C = 1 / (\omega C) = 1 / (100\pi * 50 / \pi * 10^{-6}) = 1 / (100 * 50 * 10^{-6}) = 1 / 0.005 = 200$ Ω.
Impedance, $Z = \text{sqrt}(R^2 + (X_L - X_C)^2) = \text{sqrt}(400^2 + (500 - 200)^2) = \text{sqrt}(160000 + 90000) = \text{sqrt}(250000) = 500$ Ω.
(II) Calculate rms voltage, $V_{rms} = V_{max} / \text{sqrt}(2) = 140 / 1.4 = 100$ V.
Rms current, $I_{rms} = V_{rms} / Z = 100 / 500 = 0.2$ A.
Final answers: (I) Impedance of the circuit, Z = 500 Ω.
(II) Rms current in the circuit, $I_{rms} = 0.2$ A.

Key Points: Definition of resonant frequency - Definition of power factor - Power factor value for maximum power - Formulas for reactance and impedance - Calculation of impedance - Calculation of rms current

Question 36.

(i) Draw a labelled diagram of a step-up transformer. Obtain the ratio of secondary voltage to primary voltage in terms of number of turns in the two coils.
(ii) The number of turns in the primary and the secondary coil of an ideal transformer are 100 and 5000 respectively. If 3.3 kW power is supplied to the transformer at 220 V, find
(I) current in the primary coil, and (II) output voltage.

[5 Marks]

Answer: (i) A step-up transformer consists of two coils: primary coil with fewer turns (N_p) and secondary coil with more turns (N_s) wound on a common iron core. The primary coil is connected to the input AC supply while the secondary coil gives the output voltage. The labelled diagram shows the primary and secondary coils on the iron core.

The ratio of secondary voltage (V_s) to primary voltage (V_p) is equal to the ratio of the number of turns in the secondary coil to that in the primary coil, i.e.,
$V_s/V_p = N_s/N_p$
This means if $N_s > N_p$, the output voltage is stepped up.

(ii)(I) Given: Power input P = 3.3 kW = 3300 W, Primary voltage V_p = 220 V, Number of turns N_p = 100, Number of turns N_s = 5000.
Current in primary coil I_p = Power / Voltage = 3300 / 220 = 15 A.

(II) Using transformer relation, $V_s/V_p = N_s/N_p$, so
$V_s = V_p * (N_s/N_p) = 220 * (5000 / 100) = 220 * 50 = 11000$ V.

Therefore, the output voltage is 11000 V and the current in the primary coil is 15 A. This shows the transformer steps up the voltage from 220 V to 11000 V while the power remains the same in an ideal transformer.

Key Points: Labelled diagram of step-up transformer - Voltage ratio V_s/V_p = N_s/N_p - Calculation of current in primary coil I_p = P / V_p - Calculation of output voltage V_s = V_p * (N_s / N_p) - Understanding of step-up transformer operation

Question 37.

(i) Explain the following statements giving reason:
(a) An equipotential surface through a point is normal to the electric field at that point.
(b) When a dielectric is placed in an external electric field, the electric field inside the dielectric is less than that outside it.
(c) The potential difference between the plates of a charged parallel plate capacitor decreases when

its plates are brought closer.
(ii) Obtain an expression for the work done to dissociate the system of three charges q, –4q and 2q placed at the vertices A, B and C respectively of an equilateral triangle of side ‘a’.

[5 Marks]

Answer: (i) (a) An equipotential surface is a surface on which the electric potential is constant everywhere. The electric field is defined as the negative gradient of potential and points in the direction of maximum decrease of potential. Since potential does not change on an equipotential surface, its gradient is perpendicular to the surface. Hence, the electric field at any point on an equipotential surface is normal (perpendicular) to that surface.

(b) When a dielectric material is placed in an external electric field, its molecules get polarized, creating induced charges on the surfaces of the dielectric. This induced field inside the dielectric opposes the external field, reducing the net electric field inside the dielectric compared to the outside.

(c) The potential difference V between the plates of a capacitor is given by V = Q/C, where Q is charge and C is capacitance. Capacitance of a parallel plate capacitor is C = ε$_0$ A/d, where d is the separation between plates. When the plates are brought closer (d decreases), capacitance C increases and since Q is constant, the potential difference V = Q/C decreases.

(ii) Charges at vertices A, B, C of equilateral triangle with side a are q, –4q and 2q respectively.
Work done to assemble the system = Electrostatic potential energy U of system
U = Sum of potential energies of all pairs = k * [q * (–4q)/a + q * 2q/a + (–4q) * 2q/a], where k = $1/(4\pi\varepsilon_0)$
= k * [$(-4q^2)/a + 2q^2/a - 8q^2/a$] = k * $(-10q^2/a)$ = – 10k q^2/a
Since work done to dissociate means separating charges to infinite distance, we need to do work equal to magnitude of potential energy. So, work done = 10k q^2/a.

Where k = $1/(4\pi\varepsilon_0)$.

Key Points: Equipotential surface is perpendicular to electric field - Dielectric reduces internal electric field due to polarization - Potential difference decreases when plate separation decreases due to increased capacitance - Work done equals system's electrostatic potential energy - Electrostatic energy calculated by summing pairwise interactions in the triangle

Question 38.

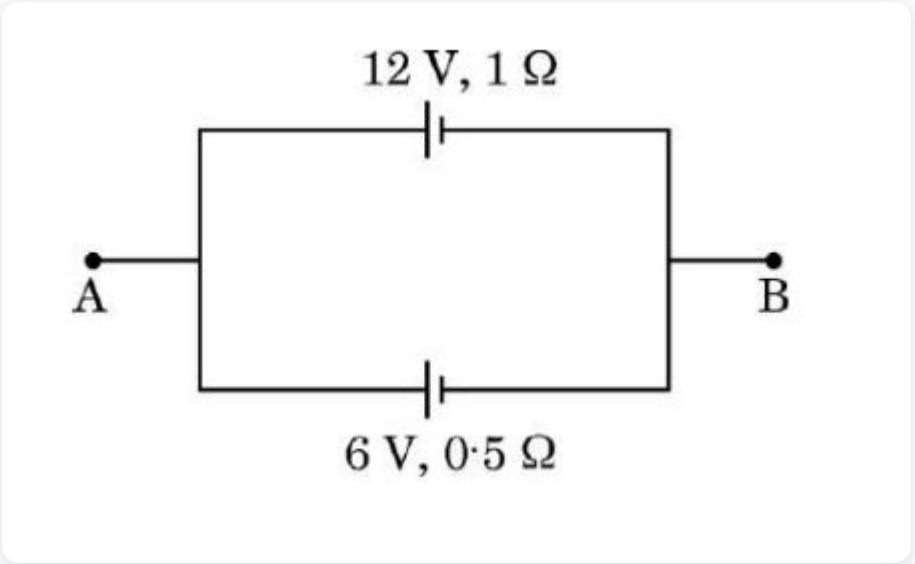
(i) Answer the following giving reason:
(I) The electron drift speed is estimated to be only a few mm/s for currents in the range of a few amperes. How, then, is the current established almost the instant a circuit is closed?
(II) A low voltage supply from which one needs high currents must have very low internal resistance.

Why?

(III) The assertion that V = IR is a statement of Ohm's law is not true. Why?

(ii) Two cells of emfs 12 V and 6 V are connected in parallel as shown in the figure. Their internal resistances are 1 Ω and 0.5 Ω respectively. Calculate the emf and internal resistance of the equivalent cell between points A and B.

[5 Marks]



Answer: (i) (I) Even though the electron drift speed is very slow, the electric field that causes the electrons to move propagates through the conductor almost instantly at nearly the speed of light. This causes all electrons along the circuit to start moving simultaneously, establishing the current almost immediately when the circuit is closed.

(II) A low voltage supply supplying high current needs very low internal resistance because internal resistance reduces the terminal voltage and wastes power as heat inside the source. Low internal resistance ensures maximum voltage is available to the external circuit and minimizes power loss.

(III) Ohm's law states that V = IR is valid only for ohmic conductors where resistance remains constant. The assertion that it is a universal law is not true because many materials do not obey this linear relation; their resistance depends on factors like temperature, voltage, and current.

(ii) Given two cells connected in parallel:
Emf of cell 1, E_1 = 12 V, internal resistance r_1 = 1 Ω
Emf of cell 2, E_2 = 6 V, internal resistance r_2 = 0.5 Ω

The emf of the equivalent cell (E) is given by:
$E = (E_1/r_1 + E_2/r_2) / (1/r_1 + 1/r_2)$
$= (12/1 + 6/0.5) / (1/1 + 1/0.5)$
$= (12 + 12) / (1 + 2) = 24 / 3 = 8$ V

The internal resistance of equivalent cell (r) is:

$r = 1 / (1/r_1 + 1/r_2) = 1 / (1 + 2) = 1/3\ \Omega = 0.333\ \Omega$

Therefore, the equivalent cell between points A and B has an emf of 8 V and internal resistance 0.333 Ω.

Key Points: electron drift speed is slow but current established instantly due to fast electric field propagation - low internal resistance needed for high current to minimize voltage drop and power loss - V=IR true only for ohmic conductors, not universally valid - emf of parallel cells found by weighted average based on internal resistances - internal resistance of parallel cells is reciprocal of sum of reciprocals

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