CBSE EXAMINATION PAPER-2023

PHYSICS

(Solved)

Time allowed : 3 hours Maximum Marks : 86

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **40 questions.** All questions are **compulsory.**
ii. This question paper is divided into **5 sections.**
iii. **Section A** – questions number **1 to 17** are multiple choice questions Each question carries **1 marks.**
iv. **Section B** – questions number **18 to 26** are very short answer Each question carries **2 marks.**
v. **Section C** – questions number **27 to 33** are short answer Each question carries **3 marks.**
vi. **Section D** – questions number **34 to 34** are case based questions
vii. **Section E** – questions number **35 to 40** are long answer Each question carries **5 marks.**
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.

Two charges q1 and q2 are placed at the centres of two spherical conducting shells of radius r1 and r2 respectively. The shells are arranged such that their centres are d [> (r1 + r2)] distance apart. The force on q2 due to q1 is:

[1 Marks]

(A) 1/4πε0 q1q2/d2

(B) Zero

(C) 1/4πε0 q1q2/[d-(r1+r2)]^2

(D) 1/4πε0 q1q2/(d-r1)^2

Explanation:

Given the setup:
- Two point charges q1q1 and q2q2 are placed at the centers of two spherical conducting shells with radii r1r1 and r2r2.
- The distance between the centers of the shells is dd where d>(r1+r2)d>(r1+r2).

Since the distance between the centers dd is greater than the sum of the radii of the two shells, the shells do not overlap and the charges can be treated as point charges with respect to each other. This means we can apply Coulomb's law directly to find the force between them.

Coulomb's Law
The force FF between two point charges q1q1 and q2q2 separated by a distance dd is given by:

1/4πε0 q1q2/d2

Question 2. An electron enters a uniform magnetic field with speed v. It describes a semicircular path and comes out of the field. The final speed of the electron is:

[1 Marks]

(A) Zero

(B) v

(C) 2v

(D) 2v

Explanation: The final speed of the electron is v because the magnetic field exerts a force that changes the direction of the electron but does not change its speed. As it travels through the magnetic field, the kinetic energy remains constant, indicating that the speed remains the same when it exits the field.

Question 3.

The magnetic field lines near a substance are as shown in the figure. The substance is:

[1 Marks]

(A) Iron

(B) Copper

(C) Sodium

(D) Aluminium

Explanation:

To determine the substance based on the magnetic field lines, we need to identify the type of material that exhibits the given magnetic field pattern. The field lines shown indicate that the substance is ferromagnetic, which means it is likely to be iron.

Question 4.

The figure shows variation of current (I) with time (t) in four devices P, Q, R and S. The device in which an alternating current flows is:

[1 Marks]

(A) Q

(B) S

(C) P

(D) R

Explanation:

The device that exhibits a current that varies in both directions over time is identified as an alternating current (AC) device. Usually, this would be represented by a sine wave or a similar varying current pattern, which is characteristic of alternating current. In the options provided, P, whichever displays this characteristic alternating pattern, would be the correct answer.

Question 5. The electromagnetic waves used in radar systems are:

[1 Marks]

(A) Infrared waves

(B) Ultraviolet rays

(C) X-rays

(D) Microwaves

Explanation: The correct answer is Microwaves. Radar systems operate primarily in the microwave range of the electromagnetic spectrum, typically between 1 GHz and 100 GHz, because microwaves are effective for long-range detection and can penetrate atmospheric conditions like rain and fog.

Question 6.

In a Young's double slit experiment, the fringe width is found to be β. If the entire apparatus is immersed in a liquid of refractive index μ, the new fringe width will be:

[1 Marks]

(A) β/μ

(B) β

(C) β/μ^2

(D) $\mu\beta$

Explanation: When the entire apparatus is immersed in a liquid of refractive index μ, the fringe width is adjusted by the refractive index since the speed of light in the medium changes. The new fringe width becomes β/μ because the wavelength of light in the medium is reduced by a factor of μ. Thus, the correct answer is β/μ.

Question 7. Photons of energy 3·2 eV are incident on a photosensitive surface. If the stopping potential for the emitted electrons is 1·5 V, the work function for the surface is:

[1 Marks]

(A) 1·5 eV

(B) 4·7 eV

(C) 3·2 eV

(D) 1·7 eV

Explanation: The work function (φ) can be calculated using the equation: φ = Energy of photons - Stopping potential. Here, φ = 3.2 eV - 1.5 V = 1.7 eV. Thus, the correct answer is 1.7 eV.

Question 8.

Which of the following statements is not true for nuclear forces?

[1 Marks]

(A) They are stronger than Coulomb forces.

(B) They saturate as the separation between two nucleons increases.

(C) They are always attractive.

(D) They have about the same magnitude for different pairs of nucleons.

Explanation:

The statement 'They saturate as the separation between two nucleons increases.' is not true for nuclear forces. Nuclear forces do not exhibit saturation with increasing distance between nucleons, meaning they can have significant effects even at larger separations, unlike other forces such as the electromagnetic force, which diminish over distance.

Question 9.

The direction of induced current in the loop abc is:

[1 Marks]

(A) along acb if I increases

(B) along abc if I increases

(C) along abc if I is constant

(D) along abc if I decreases

Explanation: The correct answer is 'along abc if I decreases'. According to Faraday's law of electromagnetic induction, the induced current will flow in a direction that opposes the change in magnetic flux. If the current I decreases, the magnetic field associated with it also decreases, leading to an induced current that flows in the same direction as the original current to oppose the reduction.

Question 10.

An ac voltage v = v0 sinωt is applied to a series combination of a resistor R and an element X. The instantaneous current in the circuit is I = I0 sin (ωt + π/4). Then which of the following is correct?

[1 Marks]

(A) X is a capacitor and XC = R

(B) X is an inductor and XL = R

(C) X is a capacitor and XC = √2R

(D) X is an inductor and XL = √2R

Explanation:

The phase difference between the voltage and current is π/4, indicating that the circuit is inductive; thus, X is an inductor. The relationship between the inductive reactance (XL) and resistance (R) can be derived from the phase angle: tan(π/4) = R / XL, leading to XL = R. Hence, the correct answer is 'X is an inductor and XL = R.'

Question 11.

Assertion (A): When three electric bulbs of power 200 W, 100 W and 50 W are connected in series to a source, the power consumed by the 50 W bulb is maximum.

Reason (R): In a series circuit, current is the same through each bulb, but the potential difference across each bulb is different.

[1 Marks]

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

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

Explanation:

Assertion (A) is true because, in a series circuit, the bulb with the lowest power rating (50 W in this case) actually consumes the least power, not the maximum. Reason (R) is true because, in a series circuit, the current is the same through all components, but the voltage drop across each bulb varies depending on its resistance. Therefore, the correct option is Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Question 12.

Assertion (A): A current carrying square loop made of a wire of length L is placed in a magnetic field. It experiences a torque which is greater than the torque on a circular loop made of the same wire carrying the same current in the same magnetic field.

Reason (R): A square loop occupies more area than a circular loop, both made of wire of the same length.

[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 the correct explanation of the Assertion (A). A square loop does not necessarily experience greater torque than a circular loop just because it occupies more area; the torque depends on the configuration and orientation of the loop in the magnetic field, not merely on the area alone.

Question 13.

A plane wavefront is incident on a concave mirror of radius of curvature R. The radius of the refracted wavefront will be :

[1 Marks]

(A) 2R

(B) R/2

(C) R

(D) R/4

Explanation: When a plane wavefront strikes a concave mirror, it can be treated as if it converges to the focus of the mirror. The radius of curvature R relates to the focal length f of the mirror by the equation $f = R/2$. Therefore, the radius of the refracted wavefront, which is the distance from the focus to the point of reflection (the center of the wavefront), will be equal to 2f. Thus, the radius of the refracted wavefront will be 2R.

Question 14.

A proton and an alpha particle have the same kinetic energy. The ratio of de Broglie wavelengths associated with the proton to that with the alpha particle is :

[1 Marks]

(A) $2\sqrt{2}$

(B) 1

(C) 2

(D) 1/2

Explanation:

The de Broglie wavelength (λ) is given by the formula $\lambda = h/p$, where h is Planck's constant and p is momentum. Since both particles have the same kinetic energy (K.E.), we can derive their momentum using the relation $K.E. = p^2/(2m)$. For the proton (mass m_p) and the alpha particle (mass m_α), we can express the momentum as $p_p = \sqrt{(2m_p * K.E.)}$ and $p_\alpha = \sqrt{(2m_\alpha * K.E.)}$. Therefore, the ratio of their wavelengths is $\lambda_p/\lambda_\alpha = (h/p_p) / (h/p_\alpha) = p_\alpha/p_p = sqrt(m_p/m_\alpha)$. Given that the mass of an alpha particle is four times that of a proton ($m_\alpha = 4m_p$), we find $\lambda_p/\lambda_\alpha = \sqrt{(m_p/(4m_p))} = 1/2$. Thus, the correct option is 1/2.

Question 15.

The potential energy of an electron in the second excited state in hydrogen atom is :

[1 Marks]

(A) - 6.8 eV

(B) -1.51 eV

(C) -3.4 eV

(D) -3.02 eV

Explanation:

The energy levels of an electron in a hydrogen atom are given by the formula $E_n = -13.6$ eV/n^2, where n is the principal quantum number. For the second excited state, n = 3. Therefore, $E_3 = -13.6$ eV / (3^2) = -13.6 eV / 9 = -1.51 eV. Thus, the correct option is -1.51 eV.

Question 16.

The difference in mass of 7X nucleus and total mass of its constituent nucleons is 21·00 u. The binding energy per nucleon for this nucleus is equal to the energy equivalent of :

[1 Marks]

(A) 3u

(B) 3.5u

(C) 7u

(D) 21u

Explanation: The binding energy of a nucleus is given by the mass difference between the nucleons and the nucleus, converted to energy using Einstein's equation E=mc^2. The given mass difference is 21.00 u, and since there are 7 nucleons, the binding energy per nucleon is 21.00 u / 7 = 3.00 u. Therefore, the correct option is 3u.

Question 17.

Assertion (A) : In 'n' type semiconductor, number density of electron is greater than the number density of holes but the crystal maintains an overall charge neutrality.

Reason (R) : The charge of electrons donated by donor atoms is just equal and opposite to that of the ionised donor.

[1 Marks]

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

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

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

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

Explanation: Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A). In 'n' type semiconductors, electrons are added by donor atoms which outnumber the holes, but the overall charge remains balanced due to the equal and opposite charge of the ionized donor atoms.

Section B

Question 18. Two identical dipoles are arranged in the x-y plane as shown in the figure. Find the magnitude and the direction of the net electric field at the origin O.

[2 Marks]

Answer: To find the net electric field at the origin O due to the two identical dipoles, we use the formula for the electric field due to a dipole. Since the dipoles are identical and symmetrically arranged, their fields at point O will have equal magnitude but opposite direction along the dipole axis. Thus, they will cancel each other out completely, resulting in a net electric field of zero at the origin.

Question 19. Write two differences between the emf and terminal potential difference of a cell. What is the most important precaution that one should take while drawing current from a cell?

[2 Marks]

Answer: The electromotive force (emf) of a cell is the maximum potential difference it can provide when no current flows, while the terminal potential difference is the actual voltage available when a current is drawn. The emf remains constant regardless of load, whereas the terminal potential difference decreases with increasing load due to internal resistance. A crucial precaution while drawing current is to avoid drawing excessive current, which can lead to overheating and damage to the cell.

Question 20.

What is a displacement current? How is it different from a conduction current?

[2 Marks]

Answer: Displacement current is a term introduced by Maxwell, representing the change in electric displacement field in a dielectric medium, especially when there is a time-varying electric field. It accounts for the current that flows in a capacitor during charging or discharging, which allows for continuous current flow in the circuit. In contrast, conduction current involves the flow of charge carriers like electrons through a conductor due to an electric field.

Question 21.

a) Obtain an expression for the electrostatic potential energy of a system of three charges q, 2q, and -3q placed at the vertices of an equilateral triangle of side a.

[2 Marks]

Answer: The electrostatic potential energy (U) of a system of point charges is given by the formula U = k * Σ(qi * qj / rij), summing over all unique pairs of charges. For three charges q, 2q, and -3q at vertices of an equilateral triangle with side a, U becomes $U = k * [(q * 2q / a) + (q * -3q / a) + (2q * -3q / a)]$. After substitution and simplification, we find $U = k * (2q^2 / a - 3q^2 / a - 6q^2 / a) = -7kq^2 / a$.

Question 22.

A small magnetised needle P is placed at the origin of x-y plane with its magnetic moment pointing along the y-axis. Another identical magnetised needle Q is placed in two positions, one by one.

Case 1 : at (a, 0) with its magnetic moment pointing along x-axis.

Case 2 : at (0, a) with its magnetic moment pointing along y-axis.

(a) In which case is the potential energy of P and Q minimum ?

(b) In which case is P and Q not in equilibrium ?

Justify your answers.

[2 Marks]

Answer: The potential energy is minimum in Case 1 when Q is placed at (a, 0) with its moment along the x-axis, as the moment of Q is perpendicular to P, leading to stable equilibrium. In Case 2, when Q is at (0, a), both P and Q have their moments aligned, resulting in maximum potential energy and instability. Hence, P and Q are not in equilibrium in Case 2.

Question 23.

The figure shows v^2_m versus $1/\lambda$ graph for photoelectrons emitted from a surface where Vm is the maximum speed of electrons and λ is the wavelength of incident radiation. Using this graph and Einstein's photoelectric equation, obtain the expression for Planck's constant and work function of the surface.

[2 Marks]

Answer: From Einstein's photoelectric equation, we have $E = h\nu = \phi + \frac{1}{2}mVM^2$, where E is the energy of photons, ϕ is the work function, and VM is the maximum speed. The graph of v^2_m versus $1/\lambda$ is linear, suggesting $v^2_m = m(h/\lambda - \phi)$. The slope of this line gives m(h) and the intercept provides ϕ. Thus, Planck's constant h and work function ϕ can be derived from the slope and intercept respectively.

Question 24.

Draw the graph showing the variation of binding energy per nucleon with mass number A of nuclei ($2 < A < 170$). Use this graph to explain the release of energy in nuclear fission.

[2 Marks]

Answer: The graph of binding energy per nucleon versus mass number A shows a rising trend up to iron ($A \approx 56$), where the binding energy is maximized. As A increases past iron, the binding energy per nucleon begins to decrease. This indicates that elements heavier than iron, when split (nuclear fission), release energy because their binding energy per nucleon is lower compared to the products formed. Thus, energy is released during fission.

Question 25.

Write any two characteristics of an electromagnetic wave. Why are microwaves used in radar systems?

[2 Marks]

Answer: Two characteristics of electromagnetic waves include their ability to travel at the speed of light and their capacity to carry energy across distances. Microwaves, which are a type of electromagnetic wave with short wavelengths, are used in radar systems because they can efficiently interact with materials and are suitable for precise measurements, such as aircraft navigation and speed detection for various objects. Their short wavelength allows for better resolution in radar technology.

Question 26.

b) Two small conducting balls A and B of radius r1 and r2 have charges q1 and q2 respectively. They are connected by a wire. Obtain the expression for charges on A and B in equilibrium.

[2 Marks]

Answer: When two conducting balls A and B with radii r1 and r2, having initial charges q1 and q2, are connected by a wire, charges will redistribute until they reach the same electric potential. The potential V of a sphere is given by $V = k * Q/r$, where k is a constant. In equilibrium, VA = VB, which leads to $k*q1/r1 = k*q2/r2$. Hence, the charges are given by $q1 = (r1/(r1+r2)) * (q1 + q2)$ and $q2 = (r2/(r1+r2)) * (q1 + q2)$.

Section C

Question 27. Two circular loops A and B, each of radius 3 m, are placed coaxially at a distance of 4 m. They carry currents of 3 A and 2 A in opposite directions respectively. Find the net magnetic field at the centre of loop A.

[3 Marks]

Answer: To calculate the net magnetic field at the center of loop A, we will first calculate the field produced by each loop using the formula for the magnetic field due to a loop at its center: B = (μ_0 * I) / (2 * R). For loop A, I = 3 A and R = 3 m, thus BA = (4π × 10^-7 T m/A * 3 A) / (2 * 3 m) = 2 × 10^-7 T. For loop B, which is 1 m away (distance = 4 m - 3 m), I = 2 A, thus BB = (4π × 10^-7 * 2 A) / (2 * 4 m) = 1.57 × 10^-7 T. Both currents are in opposite directions, so the net field is BA - BB = 2 × 10^-7 - 1.57 × 10^-7 = 0.43 × 10^-7 T. Hence, the net magnetic field at the center of loop A is 0.43 × 10^-7 T in the direction of the current in loop A.

Question 28. Briefly explain the Geiger-Marsden experiment. Show the variation of the number of particles scattered (N) with scattering angle (θ) in this experiment. What is the main conclusion that can be inferred from this plot?

[3 Marks]

Answer: The Geiger-Marsden experiment, conducted in 1909, aimed to probe the structure of the atom. In this experiment, a beam of alpha particles was directed at a thin gold foil, and detectors recorded the scattering of these particles. Most alpha particles passed through the foil with little deflection, but some were deflected at large angles. The variation of the number of particles scattered (N) with scattering angle (θ) shows that as θ increases, N decreases sharply, indicating that most of the mass of the atom is concentrated in a small nucleus. The key conclusion is that the atom consists of a dense, positively charged nucleus surrounded by a cloud of electrons, challenging the previous plum pudding model.

Question 29.

(a) The figure shows the variation of induced emf as a function of rate of change of current for two identical solenoids X and Y. One is air cored and the other is iron cored. Which one of them is iron cored ? Why ?

(b) Obtain an expression for self-inductance of a long solenoid of length L and cross-sectional area A having N turns.

[3 Marks]

Answer: To determine which solenoid, X or Y, is iron cored, we look at the variation of induced emf with the rate of change of current. The iron cored solenoid has a higher induced emf for the same rate of change of current compared to the air cored solenoid. This is due to the higher magnetic permeability of iron, which enhances the magnetic field and hence the induced emf. For part (b), the self-inductance L of a long solenoid can be expressed with the formula $L = (\mu_0 N^2 A)/L$, where μ_0 is the permeability of free space, N is the number of turns, A is the cross-sectional area, and L is the length of the solenoid.

Question 30.

(a) A resistor of 30 ohm and a capacitor of $250/\pi$ μF are connected in series to a 200 V, 50 Hz ac source. Calculate (i) the current in the circuit, and (ii) voltage drops across the resistor and the capacitor. (iii) Is the algebraic sum of these voltages more than the source voltage ? If yes, solve the paradox.

[3 Marks]

Answer: For part (a), we first find the capacitive reactance ($Xc = 1/(2\pi fC)$). Given $C = 250/\pi$ μF and f = 50 Hz, we calculate $Xc \approx 12.73$ ohms. The total impedance (Z) in the circuit is $Z = \sqrt{(R^2 + Xc^2)} = \sqrt{(30^2 + 12.73^2)} \approx 33.15$ ohms. The current (I) can be calculated using Ohm's law: $I = V/Z = 200/33.15 \approx 6.02$ A. The voltage drop across the resistor ($Vr = I*R \approx 180.6$ V) and capacitor ($Vc = I*Xc \approx 76.63$ V). Algebraically, $Vr + Vc \neq V\_source$, indicating a phase difference rather than a paradox.

Question 31.

(b) (i) In a Young's double-slit experiment $SS2-SS1 = \lambda/4$, where S1 and S2 are the two slits as shown in the figure. Find the path difference (S2P -S1P) for constructive and destructive interference at P.

(ii) What is the effect on the interference fringes in a Young's double-slit experiment, if the monochromatic source S is replaced by a source of white light ?

[3 Marks]

Answer: In diffraction, the phase difference (φ) determines the nature of the fringe formed. A phase difference of 5π corresponds to an odd multiple of π, implying destructive interference occurs. Thus, a dark fringe will be observed at the specified point on the screen. For obtaining eight maxima of double-slit patterns within a single-slit central maximum, the slit width 'a' should be designed to allow those maxima while considering both central maximum dispersal and fringe shifts. The calculation involves careful assessment of the relationships between 'a', 'd', and the number of expected maxima.

Question 32.

(b) A series LCR circuit with R = 20 ohm , L = 2 H and C = 50 μF is connected to a 200 volts ac source of variable frequency. What is (i) the amplitude of the current, and (ii) the average power transferred to the circuit in one complete cycle, at resonance ? (iii) Calculate the potential drop across the capacitor.

[3 Marks]

Answer: To find the amplitude of the current at resonance, we use the formula $I = V/R$, where V = 200 V and R = 20 ohm. Thus, the amplitude of the current $I = 200/20 = 10$ A. The average power at resonance is given by $P = V * I = 200 * 10 = 2000$ W. The potential drop across the capacitor is calculated using Vc = I * Xc, where Xc = 1/(ωC). First, we find the resonant frequency: ω = 1/√(LC) = 10 rad/s, giving Xc = 2 ohm. Therefore, Vc = 10 * 2 = 20 V.

Question 33.

(a) (i) In diffraction due to a single slit, the phase difference between light waves reaching a point on the screen is 5π . Explain whether a bright or a dark fringe will be formed at the point.

(ii) What should the width (a) of each slit be to obtain eight maxima of two double-slit patterns (slit separation d) within the central maximum of the single slit pattern ?

(iii) Draw the plot of intensity distribution in a diffraction pattern due to a single slit.

[3 Marks]

Answer: (i) The phase difference of 5π corresponds to an odd multiple of π, which indicates destructive interference. Thus, a dark fringe will be formed at the point on the screen. (ii) To obtain eight maxima of two double-slit patterns within the central maximum of the single-slit diffraction pattern, the width (a) of each slit can be calculated using the formula: a = λN/d, where λ is the wavelength, N is the number of required maxima, and d is the distance between the slits. This ensures that the maxima fit within the central maximum of the diffraction pattern. (iii) The plot of intensity distribution for a single slit diffraction shows a central bright maximum that decreases in intensity as one moves away from the center, with alternating dark and bright fringes.

Section D

Question 34.

The lens maker's formula is useful to design lenses of desired focal lengths using surfaces of suitable radii of curvature. The focal length also depends on the refractive index of the material of the lens and the surrounding medium. The refractive index depends on the wavelength of the light used. The power of a lens is related to its focal length.

Answer the following questions based on the above :

> **(1) The radius of curvature of two surfaces of a convex lens is R each. For what value of its material will its focal length become equal to R?**
>
> [1 Marks]
>
> **Answer:** To find the value of the refractive index (n) of the material of a convex lens for which its focal length (f) is equal to the radius of curvature (R), we can use the lens maker's formula. The formula is given by 1/f = (n - 1)(1/R1 - 1/R2). Since R1 = R and R2 = -

R for a convex lens, substituting these values gives us 1/f = (n - 1)(1/R + 1/R) or 1/f = (n - 1)(2/R). For f = R, substituting this into the equation gives: 1/R = (n - 1)(2/R). Simplifying this results in n - 1 = 1/2, leading to n = 3/2. Thus, the required refractive index is n = 1.5.

Key Points: Use lens maker's formula-Set f = R-Calculate refractive index(n)

(2)

The focal length of a concave lens of μ = 1.5 is 20 cm in air. It is completely immersed in water of μ = 4/3. Calculate its focal length in water.

[2 Marks]

Answer: To calculate the focal length of the concave lens in water, we can use the lens maker's formula: 1/f = (n2 - n1)/n1 (1/R1 - 1/R2). First, we need to determine the effective focal length in water. Given that the focal length in air (f_1) is -20 cm (negative for concave lenses), we have: n1 (air) = 1, n2 (water) = 4/3. Therefore, we can calculate the new focal length (f_2) in water: f_2 = f_1 * (n2/n1) = -20 cm * (4/3) = -26.67 cm. Thus, the focal length of the lens in water is approximately -26.67 cm.

Key Points: Use lens maker's formula; consider change in medium's refractive index; calculate new focal length using ratio of refractive indices.

(3)

How will the power of a lens be affected with an increase of wavelength of light?

[1 Marks]

Answer: With an increase in the wavelength of light, the refractive index of the material typically decreases, leading to an increase in the focal length of the lens. Consequently, since power is inversely related to focal length (P = 1/f), the power of the lens would decrease.

Key Points: Power is inversely related to focal length - Increase in wavelength affects refractive index - Decrease in power with increase in wavelength

(4)

An object is placed in front of a lens which forms its erect image of magnification 3. The power of the lens is 5 D. Calculate the distance of the object and the image from the lens.

[2 Marks]

Answer: To find the distances of the object (u) and the image (v) from the lens, we can use the formula for the power of the lens: P = 1/f. Given that the power (P) is 5 D, we have f = 1/P = 1/5 = 0.2 m (or 20 cm). Since the magnification (m) is given as 3, we know that m = v/u. Thus, v = 3u. Using the lens formula: 1/f = 1/v - 1/u, we can substitute f, v, and u: 1/0.2 = 1/(3u) - 1/u. Solving this equation gives us u = 10 cm and v = 30 cm. Therefore, the distances of the object and the image from the lens are 10 cm and 30 cm, respectively.

Key Points: Use of power of a lens formula; Relation between magnification and distances; Application of lens formula

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Section E

Question 35.

a) (i) Define mobility of electrons. Give its SI units.

(ii) A steady current flows through a wire AB, as shown in the figure. What happens to the electric field and the drift velocity along the wire? Justify your answer.

(iii) Consider the circuit shown in the figure. Find the effective resistance of the circuit and the current drawn from the battery.

[5 Marks]

Answer: The mobility of electrons, denoted by μ, is defined as the ability of charge carriers, such as electrons, to move through a conductor in response to an electric field. It represents the drift velocity (Vd) per unit electric field (E), mathematically expressed as μ = |Vd| / E. The SI unit of mobility is m^2/Vs, which reflects how the drift of electrons varies with the strength of the electric field. In steady conditions, the electric field inside a conductor remains constant, while the drift velocity of electrons also stabilizes, allowing continuous current flow. Total effective resistance in an electrical circuit can be determined by using Ohm's Law (R = V/I) alongside series and parallel resistance formulas, based on the configuration of the circuit.

Question 36.

(a) (i) Draw a ray diagram to show how the final image is formed at infinity in an astronomical refracting telescope. Obtain an expression for its magnifying power.

(ii) Two thin lenses L_1 and L_2, L_1 being a convex lens of focal length 24 cm and L_2 a concave lens of focal length 18 cm are placed coaxially at a separation of 45 cm. A 1 cm tall object is placed in front of the lens L_1 at a distance of 36 cm. Find the location and height of the image formed by the combination.

[5 Marks]

Answer: To illustrate the formation of an image at infinity with an astronomical refracting telescope, we begin with the objective lens (L_1) and eyepiece lens (L_2). The telescope uses a convex lens as the objective, focusing parallel rays from a distant object to a point called the focal point, forming a real and inverted image. This image acts as a virtual object for the eyepiece, which is a concave lens, allowing the final image to be formed at infinity, enhancing magnification. The magnifying power is given by the formula m = (L/f_0)(L/f_e), where L is the length of the telescope, f_0 is the focal length of the objective lens, and f_e is the focal length of the eyepiece lens. \n\nFor the second part, with lenses L_1 (focal length 24 cm) and L_2 (focal length -18 cm) arranged at 45 cm distance: First, we find the image formed by L_1. The object distance is u_1 = -36 cm. Using the lens formula 1/f = 1/v + 1/u, we calculate v_1. The first image distance v_1 from L_1 would be 72 cm, forming a real image. This image acts as the object for L_2, and we can find the height of the final image using magnification.

Question 37.

a) (i) A germanium crystal is doped with antimony. With the help of an energy-band diagram, explain how the conductivity of the doped crystal is affected.

(ii) Briefly explain the two processes involved in the formation of a p-n junction.

(iii) What will the effect of (1) forward biasing, and (2) reverse biasing be on the width of depletion layer in a p-n junction diode?

[5 Marks]

Answer: When a germanium crystal is doped with antimony, it introduces extra electrons, making it an n-type semiconductor. The energy-band diagram shows that the conduction band of germanium shifts upwards due to the additional energy levels from antimony, reducing the energy gap between the conduction and valence bands and increasing conductivity. In a p-n junction, formed by bringing p-type and n-type materials together, holes and electrons recombine, creating a depletion region. Forward biasing narrows the depletion layer, allowing current to flow easily, while reverse biasing widens the depletion layer, restricting current flow. The full-wave rectifier converts both halves of AC input into DC using two diodes, allowing current during both cycles. Diode V-I characteristics show a forward voltage drop and a high resistance in reverse, making them effective for rectification. Silicon behaves as a semiconductor due to its four valence electrons, allowing controlled conduction, whereas carbon's bonding leads to insulating behavior due to its distinct orbital overlap.

Question 38.

(b) (i) Define electrical conductivity of a wire. Give its SI unit.

(ii) High current is to be drawn safely from (1) a low-voltage battery, and (2) a high-voltage battery. What can you say about the internal resistance of the two batteries ?

(iii) Calculate the total energy supplied by the batteries to the circuit shown in the figure, in one minute.

[5 Marks]

Answer: Electrical conductivity is a measure of a material's ability to conduct electric current. It is defined as the ratio of the current density to the electric field strength in the material, indicating how easily the charge carriers move through the conductor. The SI unit of electrical conductivity is siemens per meter (S/m). \nFor a low-voltage battery, the internal resistance tends to be lower to facilitate high current flow, ensuring efficiency. Conversely, a high-voltage battery generally has a higher internal resistance to manage the increased voltage without risking short circuits, which may limit the current.\nTo calculate the total energy supplied by the batteries, we use the formula Energy (E) = Power (P) × Time (t), where Power can be calculated using P = Voltage (V) × Current (I). Assuming a voltage and current are specified, and time is one minute (60 seconds), we can find the overall energy output successfully.

Question 39.

(b) (i) Explain the working principle of an optical fibre with the help of a diagram. Mention one use of a light pipe.

(ii) A ray of light is incident at an angle of 60 degree on one face of a prism with the prism angle A = 60 degree. The ray passes symmetrically through the prism. Find the angle of minimum deviation (δm) and refractive index of the material of the prism. If the prism is immersed in water, how will δm be affected ? Justify your answer.

[5 Marks]

Answer: An optical fibre operates on the principle of total internal reflection. It consists of a core (higher refractive index) surrounded by a cladding (lower refractive index). When light enters the core at an angle greater than the critical angle, it reflects internally, allowing light to travel through bends without loss. A diagram would show the light's path reflecting along the core. One common use of a light pipe is in medical instruments, such as endoscopes, which enable visualization inside the body without invasive procedures. \n\nFor the prism, when a ray of light incident at 60° hits a prism with A = 60°, it will pass symmetrically through it. The minimum deviation δ_m can be calculated using the formula $\delta_m = i + e - A$, where i is the angle of incidence and e is the angle of emergence, both equal in this case, resulting in $\delta_m = 60^\circ + 60^\circ - 60^\circ = 60^\circ$. The refractive index n is given by $n = \frac{\sin((A+\delta_m)/2)}{\sin(A/2)}$, resulting in an n value around 1.732. When the prism is immersed in water, the refractive index decreases, leading to an increase in δ_m due to the reduced light bending ability.

Question 40.

(b) (i) With the help of a circuit diagram, briefly explain the working of a full-wave rectifier using p-n junction diodes.

(ii) Draw V- I characteristics of a p-n junction diode. Explain how these characteristics make a diode suitable for rectification.

(iii) Carbon and silicon have the same lattice structure. Then why is carbon an insulator but silicon a semiconductor ?

[5 Marks]

Answer: A full-wave rectifier converts alternating current (AC) to direct current (DC) using two p-n junction diodes arranged in a bridge configuration. During the positive half-cycle of AC, diodes D1 and D2 conduct, allowing current to pass through the load. During the negative half-cycle, diodes D3 and D4 conduct, again allowing current to flow in the same direction through the load. Hence, both halves of the AC waveform contribute to output DC. The V-I characteristics of a p-n junction diode show it conducts when forward-biased (positive voltage) and blocks reverse current (negative voltage). This behavior is essential for rectification. Silicon, despite having a similar lattice structure to carbon, acts as a semiconductor because of its ability to conduct electricity under certain conditions, particularly when doped, while carbon remains an insulator due to its limited free charge carriers.