CBSE EXAMINATION PAPER-2022

PHYSICS

(Solved)

Time allowed : 3 hours | Maximum Marks : 38

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **15 questions.** All questions are **compulsory.**

ii. This question paper is divided into **3 sections.**

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

iv. **Section B** – questions number **2 to 5** are very short answer

v. **Section C** – questions number **6 to 15** are short answer

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

vii. Use of calculator is NOT allowed.

Section A

Question 1.

The British physicist Thomas Young explained the interference of light using the principle of superposition of waves. He observed the interference pattern on the screen, in his experimental set-up - known now as Young's double slit experiment. The two slits S_1 and S_2 were illuminated by light from a slit S. The interference pattern consists of dark and bright bands of light. Such bands are called fringes. The distance between two consecutive bright and dark fringes is called fringe width.

(1)

If the screen is moved closer to the plane of slits S1 and S2, then the fringe width :

(i) will decrease, but the intensity of bright fringe remains the same.

(ii) will increase, but the intensity of bright fringe decreases.

(iii) will decrease, but the intensity of bright fringe increases.

(iv) and the intensity both remain the same.

[1 Marks]

Answer: If the screen is moved closer to the plane of slits S1 and S2, the fringe width will decrease because the distance between the slits and the screen reduces, resulting in closer spacing between the interference fringes. The intensity of the bright fringes will remain the same as it depends on the light source and not the distance to the screen.

Key Points: fringe width decreases-intensity of bright fringe remains the same-closer distance to screen

(2)

What will happen to the pattern on the screen, when the two slits S1 and S2 are replaced by two independent but identical sources ?

(i) The intensity of pattern will increase

(ii) The intensity of pattern will decrease

(iii) The number of fringes will become double

(iv) No pattern will be observed on the screen

[1 Marks]

Answer: When the two slits S1 and S2 are replaced by two independent but identical sources, the interference pattern will still be formed on the screen, resulting in an increase in intensity. This is because two coherent sources will still lead to constructive and destructive interference, maintaining the fringe pattern. Therefore, the correct option is (i) The intensity of pattern will increase.

Key Points: Interference pattern will form-increase in intensity-coherent sources

(3)

Two sources of light are said to be coherent, when both emit light waves of :

(i) same amplitude and have a varying phase difference.

(ii) same wavelength and a constant phase difference.

(iii) different wavelengths and same intensity.

(iv) different wavelengths and a constant phase difference.

[1 Marks]

Answer: Two sources of light are said to be coherent when they emit light waves of the same wavelength and have a constant phase difference. Therefore, option (ii) is the correct answer.

Key Points: coherent light sources-same wavelength-constant phase difference

(4)

The fringe width in a Young's double slit experiment is β . If the whole set-up is immersed in a liquid of refractive index μ , then the new fringe width will be :

(i) β

(ii) βμ

(iii) β/μ

(iv) β/μ^2

[1 Marks]

Answer: The new fringe width when the set-up is immersed in a liquid of refractive index μ will be β/μ (option iii), because the wavelength of light decreases in a medium, leading to a reduction in fringe width.

Key Points: Fringe width definition - Effect of refractive index on wavelength - Relationship between fringe width and wavelength

(5)

The total path difference between two waves meeting at points P1 and P2 on the screen are 3λ/2 and 2λ respectively. Then :

(i) bright fringes are formed at both points.

(ii) dark fringes are formed at both points.

(iii) a bright fringe is formed at P1 and a dark fringe is formed at P2.

(iv) a bright fringe is formed at P2 and a dark fringe is formed at P1.

[1 Marks]

Answer:

At point P, with a path difference of 3λ/2 (which is an odd multiple of λ/2), a dark fringe is formed. At point P2, with a path difference of 2λ (which is an even multiple of λ), a bright fringe is formed. Therefore, a dark fringe is formed at P and a bright fringe at P_1.

Key Points:

Path difference of 3λ/2 leads to dark fringe at P1. Path difference of 2λ leads to bright fringe at P_2

Section B

Question 2. Explain the formation of depletion region in a p-n junction.

[2 Marks]

Answer: The formation of the depletion region in a p-n junction occurs when p-type and n-type semiconductors come into contact. Electrons from the n-side diffuse into the p-side, recombining with holes, which creates a region devoid of charge carriers, known as the depletion region. This region develops an electric field that prevents further movement of charge carriers. The depletion width balances the diffusion and drift processes, establishing equilibrium.

Key Points: Diffusion of carriers-recombination-creation of electric field

Question 3. How is an emf generated by a solar cell due to the three basic processes involved? Explain.

[2 Marks]

Answer: The generation of emf in a solar cell occurs through three basic processes: absorption of light, excitation of electrons, and separation of charge carriers. When sunlight hits the solar cell, photons are absorbed, exciting electrons to higher energy states. This creates electron-hole pairs. The built-in electric field in the solar cell then separates these charge carriers, allowing electrons to flow through an external circuit, thus generating electromotive force (emf) that can be harnessed for electricity.

Key Points: absorption of light-excitation of electrons-separation of charge carriers

Question 4.

(a) (i) Define the terms : ' impact parameter' and 'distance of closest approach' for an α -particle in Geiger-Marsden scattering experiment.

(ii) What will be the value of the impact parameter for scattering angle (I) θ= 0 degree and (II) θ= 180 degree?

[2 Marks]

Answer: The 'impact parameter' in the Geiger-Marsden experiment refers to the perpendicular distance from the center of the nucleus to the trajectory of an α-particle. The 'distance of closest approach' is the minimum distance between the nucleus and the α-particle. For scattering angles, when θ = 0 degrees, the impact parameter is infinite as particles are not deflected. When θ = 180 degrees, the impact parameter is equal to the distance of closest approach.

Key Points: impact parameter definition; distance of closest approach definition; impact parameter at θ=0 degrees; impact parameter at θ=180 degrees

Question 5.

(b) Photoelectric emission occurs when a surface is irradiated with the radiation of frequency (i) v1, and (ii) v2. The maximum kinetic energy of the electrons emitted in the two cases are K and 2K respectively. Obtain the expression for the threshold frequency for the surface.

[2 Marks]

Answer: In the photoelectric effect, the maximum kinetic energy (K.E.) of emitted electrons is given by K.E. = hv - $Ø_0$, where h is Planck's constant and $Ø_0$ is the work function. For frequency v1, the K.E. is K, thus K = hv1 - $Ø_0$. For frequency v2, K.E. is 2K, thus 2K = hv2 - $Ø_0$. Equating these, we find the work function: $Ø_0$ = hv1 - K, $Ø_0$ = hv2 - 2K. By equating the two expressions, we can derive the threshold frequency v_0 as v_0 = $Ø_0$/h.

Key Points: Photoelectric effect; K.E.=hv-$Ø_0$; K.E. for v1 and v2; derive from given K and 2K; expression for threshold frequency.

Section C

Question 6.

(a) (i) Depict a plane electromagnetic wave propagating along the x-axis. Write the expressions for its oscillating electric and magnetic fields.

(ii) Write three characteristics of electromagnetic waves.

[3 Marks]

Answer: A plane electromagnetic wave propagating along the x-axis can be visualized as electric (E) and magnetic (B) fields oscillating perpendicular to each other and the direction of propagation. The general expressions for the electric and magnetic fields are given by $E(x, t) = E_0 \sin(kx - \omega t)$ and $B(x, t) = B_0 \sin(kx - \omega t)$, respectively, where E_0 and B_0 are the amplitudes, k is the wave number, and ω is the angular frequency. Characteristics of electromagnetic waves include: they travel at the speed of light in a vacuum (approximately 3 × 10^8 m/s), they can propagate through a vacuum without a medium, and they exhibit both wave-like and particle-like properties.

> **Key Points: Plane electromagnetic wave; $E = E_0 \sin(kx - \omega t)$; $B = B_0 \sin(kx - \omega t)$; Speed of light; Propagation through vacuum; Wave-particle duality**

Question 7.

(a) State the conditions for total internal reflection to take place.

(b) A tank is filled with a transparent liquid to height 'H'. A coin suspended by a thread in the liquid is gradually lowered till it touches the bottom. The apparent depth is determined corresponding to different positions of the coin.

(i) Plot a graph showing variation of the apparent depth with the real depth of the coin.

(ii) What is the physical significance of the slope of the graph ?

[3 Marks]

Answer: Total internal reflection occurs under two primary conditions: firstly, the light must be passing from a denser medium to a rarer medium, such as from water to air. Secondly, the angle of incidence must exceed the critical angle specific to the pair of media in contact. For example, if light moves from water (n = 1.33) to air (n = 1.00), the critical angle can be calculated using Snell's law. In a graph of apparent depth versus real depth, the slope indicates the refractive index of the liquid. A steeper slope reflects a higher refractive index, while a shallower slope suggests a lower refractive index. This graph illustrates how light travels differently in various media, crucial for understanding optical phenomena.

Key Points: Conditions for total internal reflection: 1. Light must pass from a denser to a rarer medium 2. Angle of incidence > critical angle; Graph: x-axis (real depth), y-axis (apparent depth); Slope: Represents refractive index; Steeper slope = higher refractive index.

Question 8.

(a) Draw a labelled ray diagram showing the formation of an image by an astronomical refracting telescope in normal adjustment. Hence, obtain the expression for its magnifying power.

[3 Marks]

Answer: An astronomical refracting telescope consists of two convex lenses: the objective lens and the eyepiece. In normal adjustment, the image formed by the objective lens is at the focus of the eyepiece. For drawing the ray diagram, depict the parallel rays coming from a distant object entering the objective lens, converging to form a real, inverted image at its focus. This image acts as the virtual object for the eyepiece, producing a larger image viewed by the eye. The magnifying power 'M' of the telescope can be derived as M = (D/f_e) + (f_o/f_e), where 'D' is the distance of distinct vision, 'f_e' is the focal length of the eyepiece, and 'f_o' is the focal length of the objective. Thus, the telescope amplifies the image size, allowing clearer distant observations.

Key Points: 1. Structure of an astronomical refracting telescope with two lenses 2. Ray diagram showing incident rays, formation of image by objective 3. Image from the objective lens as object for eyepiece 4. Magnifying power formula: M = (D/f_e) + (f_o/f_e)

Question 9.

A converging lens made of glass (μ= 1·5) has its spherical faces of radii of curvature 10 cm and 20 cm. Find its focal length

(a) in air, and

(b) when it is immersed in a liquid of refractive index 1·25.

[3 Marks]

Answer: To find the focal length of the converging lens, we use the lens maker's formula: $\frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$. For air, the radii of curvature are positive and negative; $R_1 = 10$ cm and $R_2 = -20$ cm. Substituting the values, we find the focal length in air is 15 cm. In the liquid, the effective refractive index is $\frac{1.5}{1.25} = 1.2$. The focal length in liquid is calculated similarly, yielding approximately 30 cm.

Key Points: Use lens maker's formula; Air refractive index; Calculate R1 and R2; Effect of liquid refractive index

Question 10.

The energy of a hydrogen atom in the first excited state is -3.4 eV. Find :

(a) the radius of this orbit. (Take Bohr radius = 0·53 Å)

(b) the angular momentum of the electron in the orbit.

(c) the kinetic and potential energy of the electron in the orbit.

[3 Marks]

Answer: To find the radius of the orbit for a hydrogen atom in the first excited state (n=2), we use the formula for the radius in the Bohr model: r_n = n^2 * r_0, where r_0 is the Bohr radius (0.53 Å). Thus, r_2 = 2^2 * 0.53 Å = 4 * 0.53 Å = 2.12 Å. The angular momentum is given by L = n * h / (2π); for n=2, L = 2 * h / (2π) = h / π. The kinetic energy (KE) is equal to -E/2 = 1.7 eV and potential energy (PE) is equal to 2 * KE = -3.4 eV.

Key Points: Bohr model formula; r_n = n^2 * r_0; n=2; r_2 calculation; angular momentum; KE and PE relationship; values of energies

Question 11.

(a) Depict the variation of the potential energy of a pair of nucleons with the separation between them.

(b) Imagine the fission of a 56 /26Fe into two equal fragments of 28 /13 Al nucleus. Is the fission energetically possible ? Justify your answer

by working out Q value of the process.

Given : m 56 /26 Fe = 55·93494 u, m 28/ 13 Al = 27·98191 u.

[3 Marks]

Answer: The potential energy of a pair of nucleons varies with their separation in a unique manner. Initially, as nucleons come closer, the potential energy decreases due to the strong nuclear force. However, at very short distances, the energy increases due to repulsive forces. This can be represented as a potential energy curve with a minimum point corresponding to the stable configuration. For the fission of 56Fe into two 28Al nuclei, we calculate the Q value: Q = (mass of 56Fe - 2 * mass of 28Al) * c^2. Substituting values yields a positive Q value, indicating that the fission is energetically favorable and thus possible.

Key Points: Potential energy decreases initially with decreasing separation; minimum energy corresponds to stable state; fission process involves mass-energy calculations; Q value indicates energetics of the reaction; substitution of values shows positive Q value.

Question 12.

Find the ratio of the de Broglie wavelengths associated with an alpha particle and a proton, if both

(a) have the same speeds,

(b) have the same kinetic energy,

(c) are accelerated through the same potential difference.

[3 Marks]

Answer: Answer:
(a) When both have the same speed v,
de Broglie wavelength $\lambda = h / (mv)$, so ratio $\lambda_{alpha} / \lambda_{proton} = m_{proton} / m_{alpha}$.
Given $m_{alpha} = 4\, m_{proton}$,
ratio = 1 / 4.

(b) When both have the same kinetic energy K,
$K = (1/2)\, m\, v^2$, so $v = \sqrt{2K/m}$.
Therefore $\lambda = h / (m\, v) = h / (m \sqrt{2K/m}) = h / \sqrt{2Km}$.
Ratio $\lambda_{alpha} / \lambda_{proton} = \sqrt{m_{proton} / m_{alpha}} = \sqrt{1/4} = 1/2$.

(c) When both are accelerated through the same potential difference V,
kinetic energy gained $K = q\, V$.
Both have charge magnitude q, so $K_{alpha} = K_{proton}$.
Thus same as part (b), ratio $\lambda_{alpha} / \lambda_{proton} = 1/2$.

Summary:
(a) $\lambda_{alpha} / \lambda_{proton} = 1/4$
(b) $\lambda_{alpha} / \lambda_{proton} = 1/2$
(c) $\lambda_{alpha} / \lambda_{proton} = 1/2$

> **Key Points: de Broglie wavelength depends on momentum - mass of alpha particle is 4 times proton - kinetic energy relation to speed - effect of same potential difference on kinetic energy**

Question 13.

With the help of a circuit diagram, explain the working of a p-n junction diode as a full-wave rectifier. Also draw its input and output waveforms.

[3 Marks]

Answer: A p-n junction diode can be used as a full-wave rectifier by using two diodes connected in a bridge configuration. In this setup, the input AC voltage is applied across the bridge, and during the

positive half-cycle, two diodes conduct, allowing current to flow in one direction. During the negative half-cycle, the other two diodes conduct, again allowing current to flow in the same direction through the load. The output waveform is a pulsating DC signal that is the full-wave rectified version of the input AC signal. The circuit diagram displays the arrangement of the diodes and the load across which the output is measured. The input waveform is a sine wave, while the output waveform is a series of positive peaks, eliminating the negative cycle of the original input.

> **Key Points: Circuit diagram with bridge rectifier configuration - Explanation of positive and negative half-cycle conduction - Output waveform characteristics**

Question 14.

(b) Name the electromagnetic waves which are produced by the following :

(i) Radioactive decays of nucleus

(ii) Welding arcs

(iii) Hot bodies

Write one use each of these waves.

[3 Marks]

Answer: The electromagnetic waves produced by the radioactive decays of a nucleus are gamma rays. These high-energy photons are emitted during gamma decay and are utilized in the medical field for cancer treatment by targeting and destroying cancer cells. The welding arcs produce infrared waves, which are critical for providing heat in welding processes. Lastly, hot bodies emit thermal radiation, commonly referred to as infrared radiation, used in various applications including heat sensing and thermal imaging.

> **Key Points: Gamma rays from radioactive decay used in cancer treatment-Infrared waves from welding arcs for heat application-Thermal radiation from hot bodies in thermal imaging**

Question 15.

(b) A plane wavefront of light of wavelength 'λ' is incident normally on a narrow slit of width 'a' and a diffraction pattern is observed on a screen at a distance 'D' from the slit.

(i) Depict the intensity distribution in the pattern observed.

(ii) Obtain the expression for the first maximum from the central maximum.

[3 Marks]

Answer: (i) When a plane wavefront of wavelength λ passes normally through a narrow slit of width a, a diffraction pattern is formed on the screen at distance D. The intensity distribution shows a central bright maximum at θ=0 and several secondary maxima on both sides with decreasing intensity. The intensity falls to zero (minima) at angles θ where a sin θ = m λ, for m = ±1, ±2, ... The central maximum is the widest and brightest.

(ii) The positions of minima are given by a sin θ = m λ. The secondary maxima lie between these minima approximately at angles θ satisfying a sin θ = (m + 0.5) λ, where m = 1, 2, ... The first maximum from the central maximum occurs approximately at sin θ = 3 λ / 2a, but for small angles the exact position requires solving dI/dθ = 0. However, approximately, the first maximum occurs near θ where a sin θ = 3 λ / 2. This gives the position of the first secondary maximum from the central peak.

Key Points: Diffraction pattern consists of central and secondary maxima - Intensity minima at angles a sin θ = m λ - First secondary maximum approx. at a sin θ = (m+0.5) λ