# 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 **14 questions.** All questions are **compulsory.**
ii. This question paper is divided into **2 sections.**
iii. **Section A** – questions number **1 to 4** are very short answer Each question carries **2 marks.**
iv. **Section B** – questions number **5 to 14** are short answer Each question carries **3 marks.**
v. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.
vi. Use of calculator is NOT allowed.

## Section A

**Question 1.** 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.

**Question 2.** 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.

**Question 3.**

(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.

**Question 4.**

(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.

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## Section B

**Question 5.**

(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.

**Question 6.**

(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.

**Question 7.**

(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.

**Question 8.**

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.

**Question 9.**

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.

**Question 10.**

(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.

**Question 11.**

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 λ = h / (mv), so ratio λ_alpha / λ_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 λ = h / (m v) = h / (m sqrt(2K/m)) = h / sqrt(2Km).
Ratio λ_alpha / λ_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) $\lambda_{alpha} / \lambda_{proton} = 1/2$

**Question 12.**

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.

**Question 13.**

(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.

Question 14.

(b) A plane wavefront of light of wavelength '$\lambda$' 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 $\lambda$ 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 $\theta=0$ and several secondary maxima on both sides with decreasing intensity. The intensity falls to zero (minima) at angles $\theta$ where $a \sin \theta = m \lambda$, for $m = \pm 1, \pm 2, \ldots$ The central maximum is the widest and brightest.

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