CBSE EXAMINATION PAPER-2022

PHYSICS

(Solved)

Time allowed : 3 hours | Maximum Marks : 33

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 **3 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 12** are short answer Each question carries **3 marks.**
v. **Section C** – questions number **13 to 13** are case based questions
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.

What is meant by energy band gap in a solid? Draw the energy band diagrams for a conductor, an insulator and a semiconductor.

[2 Marks]

Answer: The energy band gap in a solid refers to the energy difference between the valence band (where electrons are bound to atoms) and the conduction band (where electrons can move freely). In conductors, this gap is negligible, allowing easy electron flow. Insulators have a large band gap, preventing electron movement. Semiconductors possess a small band gap, enabling controlled conductivity. The diagrams illustrate these differences in band structure among the three types of materials.

Question 2.

Name the spectral series for a hydrogen atom which lies in the visible region. Find the ratio of the maximum to the minimum wavelengths of this series.

[2 Marks]

Answer: The spectral series for a hydrogen atom that lies in the visible region is called the Balmer series. It consists of transitions where electrons drop from higher energy levels ($n > 2$) to the second energy level ($n = 2$). The wavelengths of the Balmer series range from 410 nm to 656 nm. To calculate the ratio of the maximum wavelength (656 nm) to the minimum wavelength (410 nm), we find the ratio as 656:410, which simplifies to approximately 1.6:1.

Question 3. Name the device which converts electrical energy into light energy. Write three advantages of the device.

[2 Marks]

Answer: The device that converts electrical energy into light energy is called a Light Emitting Diode (LED). Three advantages of LEDs are: 1) Energy Efficiency: LEDs consume less electricity compared to traditional bulbs, leading to lower energy bills. 2) Longevity: LEDs have a longer lifespan, often lasting up to 25,000 hours or more, reducing the need for frequent replacements. 3) Environmentally Friendly: LEDs do not contain harmful substances like mercury, making them safer for the environment.

Question 4.

What are matter waves? A proton and an alpha particle are accelerated through the same potential difference. Find the ratio of the de Broglie wavelength associated with the proton to that with the alpha particle.

[2 Marks]

Answer: Matter waves, or de Broglie waves, are the waves associated with moving material particles, illustrating the wave-particle duality. The de Broglie wavelength is inversely proportional to the momentum of the particle, given by $\lambda = h/p$, where h is Planck's constant and p is momentum. For a proton (mass m_p) and an alpha particle (mass m_α), accelerated through the same potential difference, their wavelengths can be found, leading to a ratio $\lambda_p/\lambda_\alpha = m_\alpha/m_p$.

Section B

Question 5.

(a) Differentiate between nuclear fission and nuclear fusion.

(b) Deuterium undergoes fusion as per the reaction:

Find the duration for which an electric bulb of 500 W can be kept glowing by the fusion of 100 g of deuterium.

[3 Marks]

Answer: Nuclear fission and nuclear fusion are two distinct nuclear reactions. Fission involves the splitting of a heavy nucleus into lighter nuclei, releasing energy. This process is used in nuclear reactors and atomic bombs. Fusion, on the other hand, is the merging of two light nuclei to form a heavier nucleus, releasing even more energy than fission. An example of fusion is the reaction of deuterium (hydrogen isotope) to form helium. The energy from 100 g of deuterium can be calculated as follows: 1 g of deuterium releases about 3.2 x 10^14 J of energy. Therefore, 100 g would release 3.2 x 10^16 J. A 500 W bulb uses 500 J per second, so the duration is 3.2 x 10^16 J / 500 J/s = 6.4 x 10^13 seconds, which is approximately 2.03 million years.

Question 6.

(a) The resistance of a p-n junction is low when it is forward biased and is high when it is reversed biased.

(b) Doping of intrinsic semiconductors is a necessity for making electronic devices.

(c) Photodiodes are operated in reverse bias.

[3 Marks]

Answer: The behavior of a p-n junction depends significantly on its biasing. When forward-biased, a p-n junction exhibits low resistance because the majority charge carriers can easily move across the junction, allowing a larger current to flow. In contrast, when reverse-biased, the junction's resistance increases drastically due to the widening of the depletion region, preventing current. Doping intrinsic semiconductors introduces impurities that create additional charge carriers, essential for semiconductor functionality in devices. Lastly, photodiodes operate in reverse bias to enhance their sensitivity to light, enabling them to convert light into electrical signals effectively.

Question 7.

(a) In Geiger-Marsden experiment, calculate the distance of closest approach for an alpha particle with energy 2.56×10^{-12} J. Consider that the particle approaches gold nucleus (Z = 79) in head-on position.

(b) If the above experiment is repeated with a proton of the same energy, then what will be the value of the distance of closest approach?

[3 Marks]

Answer: To calculate the distance of closest approach (d) for an alpha particle, we use the formula: d = (Z_1 * Z_2 * e^2) / (4 * π * $ε_0$ * E), where Z_1 is the atomic number of the alpha particle ($Z_1 = 2$), Z_2 is for gold ($Z_2 = 79$), e is the charge of the electron (1.6×10^{-19} C), $ε_0$ is the permittivity of free space (8.85×10^{-12} $C^2/N{\cdot}m^2$), and E is the energy (2.56×10^{-12} J). Plugging in these values, we get $d \approx 2.05 \times 10^{-14}$ m for the alpha particle. For the proton ($Z_1 = 1$), the distance of closest approach is calculated similarly and results in approximately 4.1×10^{-14} m.

Question 8.

Briefly explain how bright and dark fringes are formed on the screen in Young's double slit experiment. Hence, derive the expression for the fringe width.

[3 Marks]

Answer: In Young's double slit experiment, coherent light passes through two narrow slits, causing the light waves from each slit to overlap and interfere. When the waves are in phase, they reinforce each other, producing bright fringes (constructive interference). Conversely, when the waves are out of phase, they cancel each other out, resulting in dark fringes (destructive interference). The condition for bright fringes is given by $d \sin θ = nλ$ and for dark fringes by $d \sin θ = (n + 0.5)λ$, where d is the slit separation, θ is the angle of the fringe from the center, n is an integer, and λ is the wavelength of light. The fringe width (β) is the distance between two successive bright or dark fringes on the screen, which is derived as $β = λD/d$, where D is the distance from the slits to the screen.

Question 9.

a) (i) Draw a labelled ray diagram showing the formation of the image at infinity by an astronomical telescope.

(ii) A telescope consists of an objective of focal length 150 cm and an eyepiece of focal length 6.0 cm. If the final image is formed at infinity, then calculate:

(I) the length of the tube in this adjustment, and

(II) the magnification produced.

[3 Marks]

Answer: To draw the ray diagram for an astronomical telescope, depict the objective lens (focal length 150 cm) facing the distant object and the eyepiece (focal length 6.0 cm) positioned such that the final image is at infinity. The rays from the object converge at the focus of the objective, creating a virtual image that the eyepiece then magnifies.

Calculating the tube length, $L = f0 + fe = 150\ cm + 6\ cm = 156\ cm$. The total magnification can be found using the formula $m = (L/f0)(L/fe)$. Hence, $m = (156/150)(156/6) = 13.00$.

Question 10.

(a) Use Einstein photoelectric equation to depict the variation of the maximum kinetic energy (E_k) of electrons emitted with the frequency (v) of the incident radiation.

(b) A photosensitive surface is illuminated with a beam of (i) yellow light, and (ii) red light, both of the same intensity. In which case will

(I) photoelectrons have more E_k?

(II) more numbers of electrons be emitted?

Justify your answer in each case.

[3 Marks]

Answer: According to Einstein's photoelectric equation, $E_k = hf - \Phi$, where E_k is the maximum kinetic energy, h is Planck's constant, f is the frequency of the incident radiation, and Φ is the work function of the material. As the frequency (f) increases, the kinetic energy (E_k) of the emitted electrons increases linearly. For yellow light (higher frequency) compared to red light (lower frequency), the emitted photoelectrons from yellow light will have higher E_k due to the greater energy supplied. However, the number of emitted electrons mainly depends on the intensity. Since both lights have the same intensity, the results in terms of emitted electrons being equal, but the E_k will be greater for yellow light.

Question 11. A ray of light is incident on a prism at an angle of 45° and passes symmetrically as shown in the figure. Calculate the (a) angle of minimum deviation, (b) refractive index of the prism material, and (c) angle of refraction at point P.

[3 Marks]

Answer: To find the required values, we start with the geometry of the prism. Since the ray passes symmetrically through the prism, the angle of minimum deviation (D) is equal to the angle of incidence (i) minus the angle of refraction (r) at point P. For a prism, the relationship between the angle of deviation (D), angle of incidence (i), angle of refraction (r), and the refractive index (n) of the material can be derived. For a prism, the refractive index $n = \sin((A + D)/2) / \sin(A/2)$. Assuming a prism angle A could be obtained, we can substitute our known values to find n. Finally, if A is known as 60°, calculations yield D, n, and r accordingly, using appropriate trigonometric identities.

Question 12.

(i) Draw a labelled ray diagram showing the formation of the image at least distance of distinct vision by a compound microscope.

(ii) A small object is placed at a distance of 3.0 cm from a magnifier of focal length 4.0 cm.

Find:

(I) the position of the image formed, and

(II) the linear magnification produced.

[3 Marks]

Answer: To draw the ray diagram for a compound microscope, start with the objective lens, focusing on a small object placed at its focal length. Rays from the object converge to form a real, inverted image at a distance greater than the focal length of the eyepiece. The eyepiece then forms an enlarged virtual image at the least distance of distinct vision (25 cm). For the second part of the question, using the lens formula $1/f = 1/v - 1/u$, we find the image position and linear magnification ($M = v/u$). Given $u = -3$ cm and $f = 4$ cm, we find $v = 12$ cm and $M = 4$. Thus, the image is formed 12 cm from the lens, and the magnification is 4.

Section C

Question 13. Two transparent media of refractive indices n_1 and n_2 are separated by a spherical transparent surface. The rays of light incident on the surface get refracted into the medium on the other side. The laws of refraction are valid at each point of the spherical surface. A lens is a transparent optical medium bounded by two surfaces, at least one of which should be spherical. The focal length of a lens is determined by the radii of curvature (R_1 and R_2) of its two surfaces and the refractive index (n) of the medium of the lens with respect to the surrounding medium. Depending on R_1 and R_2, a lens behaves as a diverging or a converging lens. The ability of a lens to diverge or converge a beam of light incident on it defines its power.

> **(1)**
>
> **An object is placed at the point B as shown in the figure. The object distance (u) and the image distance (v) are related as**
>
> [1 Marks]

Answer: The object distance (u) and the image distance (v) are related by the lens formula, which is given by 1/f = 1/v - 1/u, where f represents the focal length of the lens.

Key Points: Lens formula; u and v relationship; focal length

(2)

A point object is placed in air at a distance 'R' in front of a convex spherical refracting surface of radius of curvature R. If the medium on the other side of the surface is glass, then the image is : (i) real and formed in glass.

(ii) real and formed in air.

(iii) virtual and formed in glass.

(iv) virtual and formed in air.

[1 Marks]

Answer: The correct answer is (i) real and formed in glass. When a point object is placed in air in front of a convex lens, the rays of light converge after refraction through the lens, resulting in a real image formed in the glass medium.

Key Points: Refraction occurs at spherical surface-Convex lens converges light rays-Formed image depends on lens type and object distance

(3)

An object is kept at 2F in front of an equiconvex lens. The image formed is :

(i) real and of the size of the object.

(ii) virtual and of the size of the object.

(iii) real and enlarged.

(iv) virtual and diminished.

[1 Marks]

Answer: The correct answer is (i) real and of the size of the object. When an object is placed at a distance of 2F from an equiconvex lens, the image formed is real, inverted, and of the same size as the object.

Key Points: object at 2F-forms image at 2F-real image-same size

(4)

A thin converging lens of focal length 10 cm and a thin diverging lens of focal length 20 cm are placed coaxially in contact. The power of the combination is :

(i) -5 D

(ii) + 5 D

(iii) + 15 D

(iv) -15 D

[1 Marks]

Answer: The power of a lens is given by the formula P = 1/focal length (in meters). The power of the converging lens is P1 = 1/0.1 = +10 D, and the power of the diverging lens is P2 = 1/(-0.2) = -5 D. The total power of the combination is P = P1 + P2 = +10 D - 5 D = +5 D.

Key Points: Power of lens formula - Equivalent power calculation - Positive and negative powers

(5)

An equiconcave lens of focal length 'f' is cut into two identical parts along the dotted line as shown in the figure. The focal length of each part will be :

(i) f

(ii) f/4

(iii) f/2

(iv) 2f

[1 Marks]

Answer: When an equiconcave lens with focal length 'f' is cut into two identical parts, each part behaves like a new lens with a focal length that is half of the original.

Therefore, the focal length of each part will be f/2.

Key Points: focal length of original lens is f-focal length of each part will be f/2-cutting lens changes focal length.