Sample Question Paper - 24
Physics (042)
Class- XII, Session: 2021-22
TERM II

Time : 2 Hours **Max. Marks : 35**

General Instructions :

(i) There are 12 questions in all. All questions are compulsory.
(ii) This question paper has three sections: Section A, Section B and Section C.
(iii) Section A contains three questions of two marks each, Section B contains eight questions of three marks each, Section C contains one case study-based question of five marks.
(iv) There is no overall choice. However, an internal choice has been provided in one question of two marks and two questions of three marks. You have to attempt only one of the choices in such questions.
(v) You may use log tables if necessary but use of calculator is not allowed.

SECTION - A

1. Distinguish between a metal and an insulator on the basis of energy band diagrams.

2. The density of an electron-hole pair in a pure germanium is 3×10^{16} m^{-3} at room temperature. On doping with aluminium, the hole density increases to 4.5×10^{22} m^{-3}. Find the electron density (in m^{-3}) in doped germanium.

3. How is the radius of a nucleus related to its mass number A?

OR

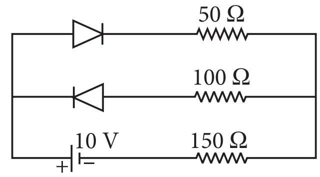
A nucleus at rest splits into two nuclear parts having radii in the ratio 1 : 3. Find the ratio of their velocities.

SECTION - B

4. The radiation corresponding to $3 \rightarrow 2$ transition of hydrogen atom falls on a metal surface to produce photoelectrons. These electrons are made to enter a magnetic field of 3×10^{-4} T. If the radius of the largest circular path followed by these electrons is 10.0 mm, calculate the work function of the metal.

5. A nucleus with mass number 184 initially at rest emits an α-particle. If the Q value of the reaction is 5.5 MeV, calculate the kinetic energy of the α-particle.

6. Assume that each diode shown in the figure has a forward bias resistance of 50 Ω and an infinite reverse bias resistance. Find the current through the resistance 150 Ω.



7. (a) A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65. What is the nature of the lens?

(b) A screen is placed 80 cm from an object. The image of the object on the screen is formed by a convex lens placed between them at two different locations separated by a distance 20 cm. Determine the focal length of the lens.

OR

Draw a labelled ray diagram of an astronomical telescope in the near point adjustment position.

A giant refracting telescope at an observatory has an objective lens of focal length 15 m and an eyepiece of focal length 1.0 cm. If this telescope is used to view the Moon, find the diameter of the image of the Moon formed by the objective lens. The diameter of the Moon is 3.48×10^6 m, and the radius of lunar orbit is 3.8×10^8 m.

8. Sketch the graphs showing variation of stopping potential with frequency of incident radiations for two photosensitive materials A and B having threshold frequencies $\upsilon_A > \upsilon_B$.

(i) In which case is the stopping potential more and why?

(ii) Does the slope of the graph depend on the nature of the material used ? Explain.

9. The electric field part of an electromagnetic wave in a medium is represented by $E_x = 0$,

$E_y = 2.5 \frac{\text{N}}{\text{C}} \cos\left[\left(2\pi \times 10^6 \frac{\text{rad}}{\text{m}}\right)t - \left(\pi \times 10^{-2} \frac{\text{rad}}{\text{s}}\right)x\right]$, $E_z = 0$. Find the frequency of wave.

10. Explain the following, giving reasons:

(i) When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency.

(ii) When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave ?

(iii) In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light?

OR

Answer the following questions :

(a) In a double slit experiment using light of wavelength 600 nm, the angular width of the fringe formed on a distant screen is 0.1°. Find the spacing between the two slits.

(b) Light of wavelength 500 Å propagating in air gets partly reflected from the surface of water. How will the wavelengths and frequencies of the reflected and refracted light be affected?

11. (a) Yellow light ($\lambda = 6000$ Å) illuminates a single slit of width 1×10^{-4} m. Calculate (i) the distance between the two dark lines on either side of the central maximum, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit; (ii) the angular spread of the first diffraction minimum.

(b) How can be the resolving power of a telescope increase?

SECTION - C

12. CASE STUDY : REFRACTION THROUGH SPHERICAL SURFACES

Refraction of light is the change in the path of light as it passes obliquely from one transparent medium to another medium. According to law of refraction $\frac{\sin i}{\sin r} = {}^1\mu_2$, where ${}^1\mu_2$ is called refractive index of second medium with respect to first medium. From refraction at a convex spherical surface, we have

$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$. Similarly from refraction at a concave spherical surface when object lies in the rarer medium, we have $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ and when object lies in the denser medium, we have $\frac{\mu_1}{v} - \frac{\mu_2}{u} = \frac{\mu_1 - \mu_2}{R}$.

(i) Refractive index of a medium depends upon
(a) nature of the medium
(b) wavelength of the light used
(c) temperature
(d) all of these

(ii) A ray of light of frequency 5×10^{14} Hz is passed through a liquid. The wavelength of light measured inside the liquid is found to be 450×10^{-9} m. The refractive index of the liquid is
(a) 1.33
(b) 2.52
(c) 2.22
(d) 0.75

(iii) A ray of light is incident at an angle of 60° on one face of a rectangular glass slab of refractive index 1.5. The angle of refraction is
(a) $\sin^{-1}(0.95)$
(b) $\sin^{-1}(0.58)$
(c) $\sin^{-1}(0.79)$
(d) $\sin^{-1}(0.86)$

(iv) A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of the virtual image from the surface of sphere is
(a) 2 cm
(b) 4 cm
(c) 6 cm
(d) 12 cm

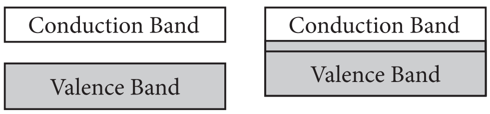
(v) In refraction, light waves are bent on passing from one medium to the second medium because in the second medium
(a) the frequency is different
(b) the co-efficient of elasticity is different
(c) the speed is different
(d) the amplitude is smaller.

Solution

PHYSICS - 042

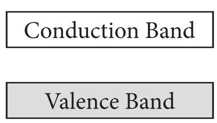
Class 12 - Physics

1. Metals : For metals, the valence band is completely filled and the conduction band can have two possibilities-either it is partially filled with an extremely small energy gap between the valence and conduction bands or it is empty, with the two bands overlapping each other as shown in the figure.



On applying even an small electric field, metals can conduct electricity.

Insulators : For insulators, the energy gap between the conduction and valence bands is very large. Also, the conduction band is practically empty, as shown in the figure.



When an electric field is applied across such a solid, the electrons find it difficult to acquire such a large amount of energy to reach the conduction band. Thus, the conduction band continues to be empty. That is why no current flows through insulators.

2. In pure germanium, $n_i = n_e = n_h = 3 \times 10^{16}\ \text{m}^{-3}$

In doped germanium, $n_i^2 = n_e n_h$

$$\therefore\ n_e = \frac{n_i^2}{n_h} = \frac{(3\times10^{16}\,\text{m}^{-3})^2}{4.5\times10^{22}\,\text{m}^{-3}} = \frac{9\times10^{32}}{4.5\times10^{22}}\ \text{m}^{-3}$$

$$= 2 \times 10^{10}\ \text{m}^{-3}$$

Thus, the electron density in doped germanium will be $2 \times 10^{10}\ \text{m}^{-3}$.

3. The volume of the nucleus is directly proportional to the number of nucleons (mass number) constituting the nucleus.

$\frac{4}{3}\pi R^3 \propto A$ Where $R \rightarrow$ radius

$R \propto A^{1/3}$ $A \rightarrow$ Mass number

$R = R_0 A^{1/3}$

OR

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} \text{ or } \frac{A_1}{A_2} = \left(\frac{R_1}{R_2}\right)^3$$

$$\therefore\ \frac{A_1}{A_2} = \left(\frac{1}{3}\right)^3 = \frac{1}{27}$$

Hence the ratio of their masses is $\frac{m_1}{m_2} = \frac{1}{27}$

According to law of conservation of linear momentum magnitude of p_1 = magnitude of p_2

i.e., $m_1 v_1 = m_2 v_2$ or $\frac{v_1}{v_2} = \frac{m_2}{m_1} = \frac{27}{1}$

4. Radius of a charged particle moving in a constant magnetic field is given by

$$R = \frac{mv}{qB} \text{ or } R^2 = \frac{m^2v^2}{q^2B^2} = \frac{2m\left(\frac{1}{2}mv^2\right)}{q^2B^2} = \frac{2m(\text{K.E.})}{q^2B^2}$$

$$\Rightarrow\ \text{K.E.} = \frac{q^2B^2R^2}{2m} \qquad \therefore\ \text{K.E}_{\text{max}} = \frac{q^2B^2R^2{}_{\text{max}}}{2m} = 0.80\ \text{eV}$$

Energy of photon corresponding transition from orbit $3 \rightarrow 2$ in hydrogen atom.

$$E = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 1.89\ \text{eV}$$

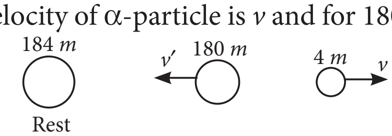
Using Einstein photoelectric equation,

$E = \text{K.E.}_{\text{max}} + \phi \ \Rightarrow\ 1.89 = 0.8 + \phi \ \Rightarrow\ \phi = 1.09 \approx 1.1\ \text{eV}$

5. Mass number, $A = 184$

$Q_{\text{value}} = 5.5$ MeV

Let the velocity of α-particle is v and for $180\,m$, it is v'.



Use conservation of momentum,

$184\,m \times 0 = 180\,mv' - 4mv$

$$v' = \frac{4v}{180} \qquad \text{...(i)}$$

Now using conservation of energy,

$$\frac{1}{2}(4m)v^2 + \frac{1}{2}(180m)v'^2 = 5.5\ \text{MeV}$$

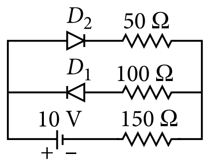
$$\frac{1}{2}\cdot 4mv^2\left[1 + 45\times\left(\frac{4}{180}\right)^2\right] = 5.5\ \text{MeV} \ \ \text{(Using (i))}$$

Here $\text{K}\cdot\text{E}_\alpha = \frac{1}{2}(4mv^2)$

$$\text{K}\cdot\text{E}_\alpha\left(1 + 45\times\left(\frac{4}{180}\right)^2\right) = 5.5\ \text{MeV}$$

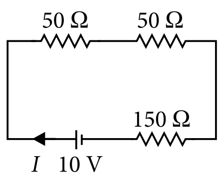
$$\text{K}\cdot\text{E}_\alpha = \frac{5.5}{1 + 45\left(\frac{4}{180}\right)^2} = 5.38\ \text{MeV}$$

6. In the circuit, diode D_1 is reverse biased and offers infinite resistance, diode D_2 is forward biased and offers 50 Ω resistance. The equivalent circuit is shown in the figure.



Total resistance of the circuit,

R = 50 Ω + 50 Ω + 150 Ω = 250 Ω



The current in the circuit,

$$I = \frac{V}{R} = \frac{10\text{ V}}{250\ \Omega} = 0.04\text{ A}$$

So, current through the resistance 150 Ω is 0.04 A.

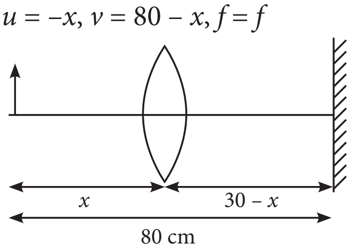
7. (a) : Focal length of a concave lens is negative. Using lens maker's formula,

$$\frac{1}{f} = \left(\frac{\mu_l}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Here, $\mu_l = 1.5$, $\mu_m = 1.65$

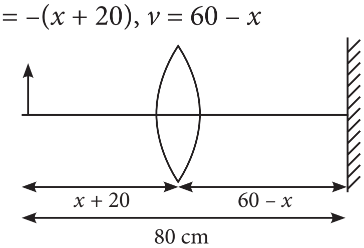
Also, $\frac{\mu_l}{\mu_m} < 1$, so $\left(\frac{\mu_l}{\mu_m} - 1\right)$ is negative and focal length of the given lens becomes positive. Hence, it behaves as a convex lens.

(b) Case I : $u = -x$, $v = 80 - x$, $f = f$



$$\therefore\ \frac{1}{f} = \frac{1}{V} - \frac{1}{u} = \frac{1}{80 - x} + \frac{1}{x} \qquad \text{...(i)}$$

Case II : $u = -(x + 20)$, $v = 60 - x$



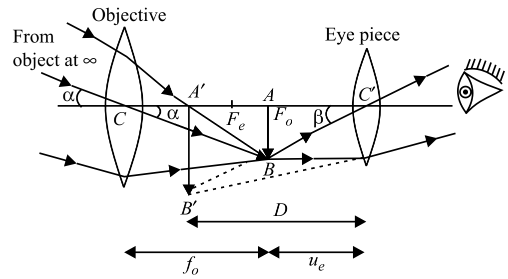
$$\frac{1}{f} = \frac{1}{60 - x} + \frac{1}{x + 20} \qquad \text{...(ii)}$$

From (i) and (ii)

$$\frac{1}{80 - x} + \frac{1}{x} = \frac{1}{60 - x} + \frac{1}{x + 20} \Rightarrow x = 30\text{ cm}$$

$$\therefore\ \frac{1}{f} = \frac{1}{80 - 30} + \frac{1}{30} \Rightarrow f = 18.75\text{ cm}$$

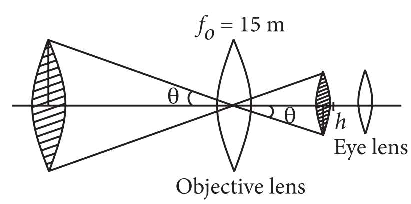
OR



Here, f_o = 15 m = 1500 cm and f_e = 1.0 cm Angular magnification by the telescope in normal adjustment

$$m = \frac{f_o}{f_e} = \frac{1500\text{ cm}}{1.0\text{ cm}} = 1500$$

The image of the moon by the objective lens is formed on its focus only as the moon is nearly at infinite distance as compared to focal length.



i.e., Radius of moon $R_m = \frac{3.48}{2} \times 10^6$ m

$R_m = 1.74 \times 10^6$ m

Distance of object = Radius of lunar orbit

$R_0 = 3.8 \times 10^8$ cm

Distance of image for objective lens is the focal length of objective lens, f_0 = 15 m

Radius of image of moon by objective lens can be calculated.

$$\tan\theta = \frac{R_m}{R_0} = \frac{h}{f_o}$$

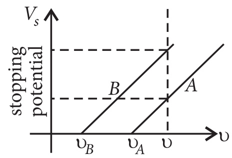
$$h = \frac{R_m \times f_o}{R_0} = \frac{1.74 \times 10^6 \times 15}{3.8 \times 10^8} = 6.87 \times 10^{-2}\text{ m.}$$

Diameter of the image of the moon,

$= 2h = 13.74 \times 10^{-2}$ m = 13.74 cm

8. We know,

$K_{max} = eV_s = h(\upsilon - \upsilon_0)$



or, $V_s = \frac{h}{e}\upsilon - \frac{h}{e}\upsilon_0$

(i) From the graph for the same value of υ, stopping potential is more for material *B*.

as $V_s = \frac{h}{e}(\upsilon - \upsilon_0)$

$\therefore$ V_s is higher for lower value of υ_0. Here $\upsilon_B < \upsilon_A$ so $V_{SB} > V_{SA}$.

(ii) Slope of the graph is given by $\frac{h}{e}$ which is constant for all the materials. Hence slope of the graph does not depend on the nature of the material used.

9. $E_y = 2.5\frac{\text{N}}{\text{C}} \times \cos\left[\left(2\pi \times 10^6 \frac{\text{rad}}{\text{m}}\right)t - \left(\pi \times 10^{-2}\frac{\text{rad}}{\text{s}}\right)x\right]$

$E_z = 0, E_x = 0$

The wave is moving in the positive direction of *x*.

This is in the form $E_y = E_0\cos(\omega t - kx)$

$\omega = 2\pi \times 10^6$

$2\pi\upsilon = 2\pi \times 10^6 \Rightarrow \upsilon = 10^6$ Hz

10. (i) Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence frequency remains unchanged.

(ii) Energy carried by a wave depends on the frequency of the wave, not on the speed of wave propagation.

(iii) For a given frequency, intensity of light in the photon picture is determined by

$$I = \frac{\text{Energy of photons}}{\text{area} \times \text{time}} = \frac{n \times h\upsilon}{A \times t}$$

Where *n* is the number of photons incident normally on crossing area *A* in time *t*.

OR

(a) Angular width, $\theta = \frac{\lambda}{d}$ or $d = \frac{\lambda}{\theta}$

Here, $\lambda = 600$ nm $= 6 \times 10^{-7}$ m

$\theta = 0.1° = \frac{0.1 \times \pi}{180}$ rad $= \frac{\pi}{1800}$ rad, $d = ?$

$\therefore$ $d = \frac{6 \times 10^{-7} \times 1800}{\pi} = 3.44 \times 10^{-4}$ m

(b) Frequency of a light depends on its source only. So, the frequencies of reflected and refracted light will be same as that of incident light.

Reflected light is in the same medium (air) so its wavelength remains same as 500 Å.

Wavelength of refracted light, $\lambda_r = \frac{\lambda}{\mu_w}$

μ_w = refractive index of water.

So, wavelength of refracted wave will be decreased.

11. (a) (i) Here $a = 1 \times 10^{-4}$ m, $D = 1.5$ m

$\lambda = 6000$ Å $= 6000 \times 10^{-10}$ m

The distance between the two dark bands on each side of central band is equal to width of the central bright band, *i.e.*, $\frac{2D\lambda}{a}$

$= \frac{2 \times 1.5 \times 6000 \times 10^{-10}}{1 \times 10^{-4}} = 18$ mm

(ii) Angular spread $= \frac{\lambda}{a} = \frac{6000 \times 10^{-10}}{1 \times 10^{-4}}$

$= 6 \times 10^{-3}$ m $= 6$ mm

(b) Resolving power $= \frac{d}{1.22\lambda}$, where *d* is the diameter of the objective lens.

12. (i) **(d):** Refractive index of a medium depends upon nature and temperature of the medium, wavelength of light.

(ii) **(a) :** Here $\nu = 5 \times 10^{14}$ Hz; $\lambda = 450 \times 10^{-9}$m

$c = 3 \times 10^8$ m s^{-1}

Refractive index of the liquid,

$\mu = \frac{c}{v} = \frac{c}{\nu\lambda} = \frac{3 \times 10^8}{5 \times 10^{14} \times 450 \times 10^{-9}}$

$\mu = 1.33$

(iii) **(b) :** Here $i = 60°$; $\mu = 1.5$

By snell's law, $\mu = \frac{\sin i}{\sin r}$

$\sin r = \frac{\sin i}{\mu} = \frac{\sin 60°}{1.5} = \frac{0.866}{1.5}$

$\sin r = 0.5773$ or $r = \sin^{-1}(0.58)$

(iv) **(c) :** As object is at the centre of the sphere, the image must be at the centre only.

$\therefore$ Distance of virtual image from centre of sphere = 6 cm.

(v) **(c) :** Speed of light in second medium is different than that in first medium