Sample Question Paper - 28
Physics (042)
Class- XII, Session: 2021-22
TERM II

Time : 2 Hours *Max. Marks : 35*

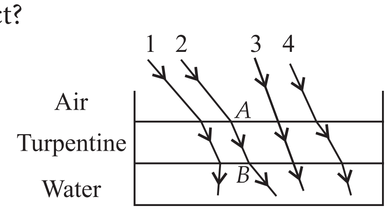
General Instructions :

(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. An electron of mass m and a photon have same energy E. Find the ratio of de-Broglie wavelengths associated with them.

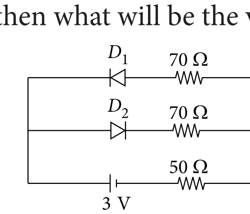
2. The optical density of turpentine is higher than that of water while its mass density is lower. Figure shows a layer of turpentine floating over water in a container. For which one of the four rays incident on turpentine in figure, the path shown is correct?



3. Explain the term 'depletion layer' and 'potential barrier' in a p-n junction diode. How are the (i) width of depletion layer, and (ii) value of potential barrier affected when the p-n junction is forward biased?

OR

The circuit shown in the diagram contains two diodes, each with a forward resistance of 30 Ω and infinite reverse resistance. If the battery is of 3 V, then what will be the voltage drop across 50 Ω resistance?

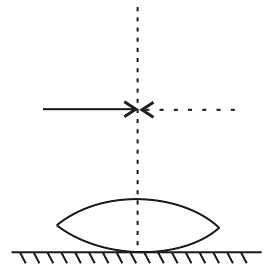


SECTION - B

4. Using Bohr's second postulate of quantization of orbital angular momentum show that the circumference of the electron in the n^{th} orbital state in hydrogen atom is n times the de Broglie wavelength associated with it.

5. An electromagnetic wave of frequency υ = 3.0 MHz passes from vacuum into a dielectric medium with relative permittivity ε = 4.0. Then what will be the wavelength and frequency?

6. A symmetric biconvex lens of radius of curvature R and made of glass of refractive index 1.5, is placed on a layer of liquid placed on top of a plane mirror as shown in the figure. An optical needle with its tip on the principal axis of the lens is moved along the axis until its real, inverted image coincides with the needle itself. The distance of the needle from the lens is measured to be x. On removing the liquid layer and repeating the experiment, the distance is found to be y. Obtain the expression for the refractive index of the liquid in terms of x and y.



7. Write three characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation.

OR

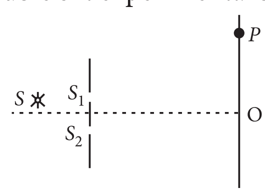
When the light of frequency $2\upsilon_0$ (where υ_0 is threshold frequency), is incident on a metal plate, the maximum velocity of electrons emitted is v_1. When the frequency of the incident radiation is increased to $5\upsilon_0$, the maximum velocity of electrons emitted from the same plate is v_2. Find the ratio of v_1 to v_2?

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

(b) The total magnification produced by a compound microscope is 20. The magnification produced by the eyepiece is 5. The microscope is focussed on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye piece.

9. In a Geiger-Marsden experiment, calculate the distance of closest approach to the nucleus of $Z = 80$, when an α-particle of 8 MeV energy impinges on it before it comes momentarily to rest and reverses its direction. How will the distance of closest approach be affected when the kinetic energy of the α-particle is doubled?

10. The figure shows a modified Young's double slit experimental set-up. Here $SS_2 - SS_1 = \lambda/4$.



(a) Write the condition for constructive interference.

(b) Obtain an expression for the fringe width.

OR

(a) In a single slit diffraction pattern, how does the angular width of the central maximum vary, when
   (i) aperture of slit is increased?
   (ii) distance between the slit and the screen is decreased?

(b) How is the diffraction pattern different from the interference pattern obtained in Young's double slit experiment?

11. Monochromatic light of wavelength 5000 Å is used in YDSE, with slit width, $d = 1$ mm, distance between screen slits $D = 1$ m, If intensities at the two slits are $I_1 = 4I_0$ and $I_2 = I_0$, Find :

(i) fringe width b;

(ii) distance of 5th minimum from the central maxima on the screen;

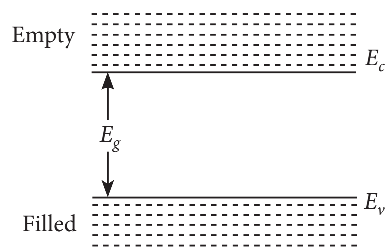
(iii) intensity at $y = \frac{1}{3}$ mm;

(iv) distance of the 1000th maxima.

SECTION - C

12. CASE STUDY : ENERGY BAND GAP

From Bohr's atomic model, we know that the electrons have well defined energy levels in an isolated atom. But due to interatomic interactions in a crystal, the electrons of the outer shells are forced to have energies different from those in isolated atoms. Each energy level splits into a number of energy levels forming a continuous band. The gap between top of valence band and bottom of the conduction band in which no allowed energy levels for electrons can exist is called energy gap.



(i) In an insulator, energy band gap is
(a) $E_g = 0$ (b) $E_g < 3$ eV (c) $E_g > 3$ eV (d) none of the above.

(ii) In a semiconductor, separation between conduction and valence band is of the order of
(a) 0 eV (b) 1 eV (c) 10 eV (d) 50 eV

(iii) Based on the band theory of conductors, insulators and semiconductors, the forbidden gap is smallest in
(a) conductors (b) insulators (c) semiconductors (d) all of these.

(iv) Carbon, silicon and germanium have four valence electrons each. At room temperature which one of the following statements is most appropriate ?
(a) The number of free electrons for conduction is significant only in Si and Ge but small in C.
(b) The number of free conduction electrons is significant in C but small in Si and Ge.
(c) The number of free conduction electrons is negligibly small in all the three.
(d) The number of free electrons for conduction is significant in all the three.

(v) Solids having highest energy level partially filled with electrons are
(a) semiconductor (b) conductor (c) insulator (d) none of these.

Solution

PHYSICS - 042

Class 12 - Physics

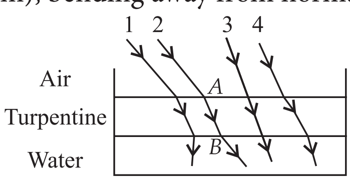
1. For electron of energy E,

de-Broglie wavelength, $\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$

For photon of energy, $E = h\upsilon = \frac{hc}{\lambda_p} \Rightarrow \lambda_p = \frac{hc}{E}$

$$\therefore \frac{\lambda_e}{\lambda_p} = \frac{h}{\sqrt{2mE}} \times \frac{E}{hc} = \frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$$

2. In the figure, the path shown for the ray 2 is correct. The ray suffers two refractions : At A, ray goes from air to turpentine, bending towards normal. At B, ray goes from turpentine to water (*i.e.*, from denser to rarer medium), bending away from normal.



3. Depletion layer : The small region in the vicinity of the junction which is depleted of free charge carriers and has only immobile ions is called the depletion layer.

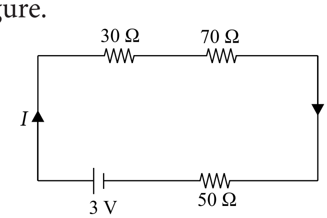
Barrier potential : Due to accumulation of negative charges in the p-region and positive charges in the n-region sets up a potential difference across the junction sets up. This acts as a barrier and is called potential barrier V_B which opposes the further diffusion of electrons and holes across the junction.

(i) When there is an increase in doping concentration, the applied potential difference causes an electric field which acts opposite to the potential barrier. This results in reducing the potential barrier and hence the width of depletion layer decreases.

(ii) In forward biasing the width of depletion layer reduced and the external applied field is able to overcome the strong electric field of depletion layer. In reverse biasing the width of depletion layer increases and the electric field of depletion layer become more stronger.

OR

Here, diode D_1 is reverse biased and diode D_2 is forward biased. Equivalent circuit can be drawn as shown in figure.



Net resistance of the circuit, $R_N = 30\ \Omega + 70\ \Omega + 50\ \Omega = 150\ \Omega$

$\therefore$ Current in the circuit, $I = \frac{V}{R_N} = \frac{3\text{ V}}{150\ \Omega} = \frac{1}{50}$ A

So, voltage drop across 50 Ω resistance,

$$V_{50\Omega} = IR = \frac{1}{50}\text{ A} \times 50\ \Omega = 1\text{ V}$$

4. According to Bohr's second postulate quantization of angular momentum

$$mv_n r_n = n\frac{h}{2\pi} \quad \text{or} \quad r_n = \frac{nh}{2\pi m v_n} \qquad \text{...(i)}$$

where h is the Planck's constant

Circumference of the electron in the n^{th} orbital state in hydrogen atom,

$$2\pi r_n = 2\pi \frac{nh}{2\pi m v_n} \qquad \text{(Using (i))}$$

$$2\pi r_n = n\frac{h}{mv_n} \qquad \text{...(ii)}$$

But de Broglie wavelength of the electron

$$\lambda = \frac{h}{mv_n} \qquad \text{...(iii)}$$

From (ii) and (iii), we get

$\therefore \quad 2\pi r_n = n\lambda$

5. Frequency of electromagnetic wave does not change with change in medium but wavelength and velocity of wave changes with change in medium.

Velocity of electromagnetic wave in vacuum

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \upsilon \lambda_{\text{vacuum}} \qquad \text{...(i)}$$

Velocity of electromagnetic wave in the medium

$$v_{\text{medium}} = \frac{1}{\sqrt{\mu_0\,\mu_r \varepsilon_0 \varepsilon_r}} = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$$

where μ_r and ε_r be relative permeability and relative permittivity of the medium.

For dielectric medium, $\mu_r = 1$

$$\therefore \quad v_{\text{medium}} = \frac{c}{\sqrt{\varepsilon_r}}$$

Here, $\varepsilon_r = 4.0$

$$\therefore \quad v_{\text{medium}} = \frac{c}{\sqrt{4}} = \frac{c}{2} \qquad \text{...(ii)}$$

Wavelength of the wave in medium

$$\lambda_{\text{vaccum}} = \frac{c}{\upsilon} = \frac{3\times10^8}{3\times10^6} = 100$$

$$\lambda_{\text{medium}} = \frac{v_{\text{medium}}}{\upsilon} = \frac{c}{2\upsilon} = \frac{\lambda_{\text{vacuum}}}{2} = \frac{100}{2} = 50 \text{ m}$$

(Using (i) and (ii))

6. Clearly, equivalent focal length of equiconvex lens and water lens, $f = x$

Focal length of equiconvex lens $f_1 = y$

Focal length f_2 of water lens is given by

$$\frac{1}{f_2} = \frac{1}{f} - \frac{1}{f_1} = \frac{1}{x} - \frac{1}{y} = \frac{y-x}{xy}$$

or $f_2 = \dfrac{xy}{y-x}$

The water lens formed between the plane mirror and the equiconvex lens is a planoconcave lens. For this lens,

$R_1 = -R$ and $R_2 = \infty$

Using lens maker's formula, $\dfrac{1}{f_2} = (\mu - 1)\left[\dfrac{1}{R_1} - \dfrac{1}{R_2}\right]$

or $\dfrac{y-x}{xy} = (\mu - 1)\left[\dfrac{1}{-R} - \dfrac{1}{\infty}\right]$

or $\mu - 1 = \dfrac{(x-y)R}{xy}$ or $\mu = 1 + \dfrac{(x-y)R}{xy}$.

7. Einstein's photoelectric equation is given below.

$$h\upsilon = \frac{1}{2}mv_{\max}^2 + W_0$$

where υ = frequency of incident radiation

$\frac{1}{2}mv_{\max}^2$ = maximum kinetic energy of an emitted electron

W_0 = work function of the target metal

Three salient features observed are

(i) Below threshold frequency υ_0 corresponding to W_0, no emission of photoelectrons takes place.

(ii) As energy of a photon depends on the frequency of light, so the maximum kinetic energy with which photoelectron is emitted depends only on the energy of photon or on the frequency of incident radiation.

(iii) For a given frequency of incident radiation, intensity of light depends on the number of photons per unit area per unit time and one photon liberates one photoelectron, so number of photoelectrons emitted depend only on its intensity.

OR

According to the Einstein's photoelectric equation, $E = W_0 + \frac{1}{2}mv^2$

When frequency of incident light is $2\upsilon_0$.

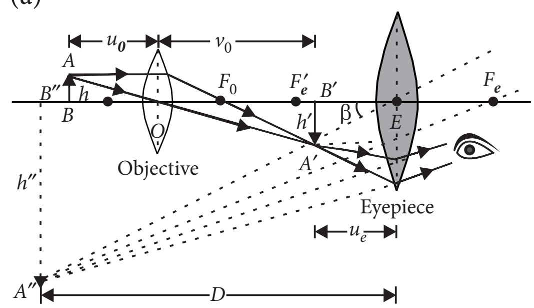
$$h(2\upsilon_0) = h\upsilon_0 + \frac{1}{2}mv_1^2 \Rightarrow h\upsilon_0 = \frac{1}{2}mv_1^2 \quad \text{...(i)}$$

When frequency of incident light is $5\upsilon_0$

$$h(5\upsilon_0) = h\upsilon_0 + \frac{1}{2}mv_2^2 \Rightarrow 4h\upsilon_0 = \frac{1}{2}mv_2^2 \quad \text{...(ii)}$$

Dividing (i) by (ii), $\dfrac{1}{4} = \dfrac{v_1^2}{v_2^2}$ or $\dfrac{v_1}{v_2} = \dfrac{1}{2}$.

8. (a)



(b) Separation between eye-piece and the objective, $L = 14$ cm,

$m = -20$, $m_e = 5$, $D = 20$ cm, $f_o = ?$, $f_e = ?$

Magnification of eye-piece when image is formed at the least distance for clear vision

$$m_e = \left(1 + \frac{D}{f_e}\right) \Rightarrow 5 = \left(1 + \frac{20}{f_e}\right)$$

$$\Rightarrow 4 = \frac{20}{f_e} \Rightarrow f_e = 5 \text{ cm}$$

Net magnification of the compound microscope when image is formed at the least distance for clear vision

$$m = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) \Rightarrow -20 = -\frac{14}{f_o}\left(1 + \frac{20}{5}\right)$$

$$\Rightarrow 10 = \frac{7}{f_o}(5) \Rightarrow f_o = \frac{35}{10} = 3.5 \text{ cm}$$

9. $\dfrac{(Ze)(2e)}{4\pi\varepsilon_0(r_0)} = \text{K.E.}$

$\therefore \quad r_0 = \dfrac{2Ze^2}{4\pi\varepsilon_0(K.E.)} \qquad (\because Z = 80, K.E. = 8 \text{ MeV})$

$$r_0 = \frac{9\times10^9 \times 2\times80\times(1.6\times10^{-19})^2}{8\times10^6\times(1.6\times10^{-19})} \text{ m}$$

$$r_0 = \frac{18\times1.6\times10^{-10}\times80}{8\times10^6} = 2.88 \times 10^{-14} \text{ m}$$

$\because \quad r_0 \propto \dfrac{1}{\text{K.E.}}$

If K.E. becomes twice then $r_0' = \dfrac{r_0}{2}$

i.e. distance of closest approach becomes half.

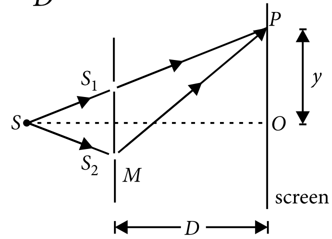
10. (a) Given : $SS_2 - SS_1 = \dfrac{\lambda}{4}$

Now path difference between the two waves from slit S_1 and S_2 on reaching point P on screen is

$\Delta x = (SS_2 + S_2P) - (SS_1 + S_1P)$

or $\Delta x = (SS_2 - SS_1) + (S_2P - S_1P)$

or $\Delta x = \frac{\lambda}{4} + \frac{yd}{D}$, where d is the slits separation.



For constructive interference at point P, path difference, $\Delta x = n\lambda$ or $\frac{\lambda}{4} + \frac{yd}{D} = n\lambda$

or $\frac{yd}{D} = \left(n - \frac{1}{4}\right)\lambda$ ...(i)

where $n = 0, 1, 2, 3, ...,$

(b) From equation (i), $y_n = \left(n - \frac{1}{4}\right)\frac{\lambda D}{d}$

and $y_{n-1} = \left(n - 1 - \frac{1}{4}\right)\frac{\lambda D}{d}$

The fringe width is given by separation of two consecutive bright fringes.

$$\beta = y_n - y_{n-1} = \left(n - \frac{1}{4}\right)\frac{\lambda D}{d} - \left(n - 1 - \frac{1}{4}\right)\frac{\lambda D}{d} = \frac{\lambda D}{d}$$

OR

(a) The angular width of central maximum is given by

$2\theta_0 = \frac{2\lambda}{a}$, ...(i)

where the letters have their usual meanings.

(i) Effect of slit width : From the equations (i), it follows that $\beta_0 \propto \frac{1}{a}$. Therefore, as the slit width is increased, the width of the central maximum will decrease.

(ii) Effect of distance between slit and screen (D) : From the equation (i), it follows that $2\theta_0$ is independent of D. So the angular width will remain same whatever the value of D.

(b) Difference between interference and diffraction

	Interference	Diffraction
1.	Interference is caused by superposition two waves starting from two coherent sources.	Diffraction is caused by superposition of a number of waves starting from the slit.
2.	All bright and dark fringes are of equal width.	Width of central bright fringe is double of all other maxima.
3.	All bright fringes are of same intensity.	Intensity of bright fringes decreases sharply as we move away from central bright fringe.
4.	Dark Fringes are perfectly dark.	Dark fringes are not perfectly dark.

11. (i) $\beta = \frac{\lambda D}{d} = \frac{5000 \times 10^{-10} \times 1}{1 \times 10^{-3}} = 0.5 \text{ mm}$

(ii) $y = (2n-1)\frac{\lambda D}{d}, n = 5 \Rightarrow y = 2.25 \text{ mm}$

(iii) At $y = \frac{1}{3}$ mm, $y << D \Rightarrow \Delta x = \frac{yd}{D}$

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x = 2\pi\frac{dy}{\lambda D} = \frac{4\pi}{3}$$

Now, resultant intensity

$$I = I_1 + I_2 + 2\cos\Delta\phi = 4I_0 + I_0 + 2\sqrt{4I_0^2}\cos\Delta\phi$$

$$= 5I_0 + 4I_0\cos\frac{4\pi}{3} = 3I_0$$

(iv) $\frac{d}{\lambda} = \frac{10^{-3}}{0.5 \times 10^{-6}} = 2000$

$n = 1000$ is not $<< 2000$

Hence, now $\Delta x = d\sin\theta$ must be used.

$\therefore$ $d\sin\theta = n\lambda = 1000\lambda \Rightarrow \sin\theta = 1000\frac{\lambda}{d} = \frac{1}{2}$

$\Rightarrow \theta = 30°$

$$y = D\tan\theta = \frac{1}{\sqrt{3}} \text{ m}$$

12. (i) **(c) :** In insulator, energy band gap is > 3 eV

(ii) **(b):** In conductor, separation between conduction and valence bands is zero and in insulator, it is greater than 1 eV. Hence in semiconductor the separation between conduction and valence band is 1 eV.

(iii) **(a):** According to band theory the forbidden gap in conductors $E_g \approx 0$, in insulators $E_g > 3$ eV and in semiconductors $E_g < 3$ eV.

(iv) **(a):** The four valence electrons of C, Si and Ge lie respectively in the second, third and fourth orbit. Hence energy required to take out an electron from these atoms (*i.e.* ionisation energy E_g) will be least for Ge, followed by Si and highest for C. Hence, the number of free electrons for conduction in Ge and Si are significant but negligibly small for C.

(v) **(b)**