

Sample Question Paper - 14
Physics (042)
Class- XII, Session: 2021-22
TERM II

Time : 2 Hours

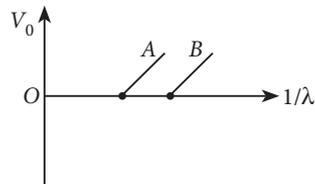
Max. Marks : 35

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. Explain, how the heavy doping of both p and n -side of a p - n junction diode results in the electric field of the junction being extremely high even with a reverse bias voltage of a few volts.
2. What is the conductivity of a semiconductor sample having electron concentration of $5 \times 10^{18} \text{ m}^{-3}$, hole concentration of $5 \times 10^{19} \text{ m}^{-3}$, electron mobility of $2.0 \text{ m}^2 \text{ V}^{-1} \text{ s}^{-1}$ and hole mobility of $0.01 \text{ m}^2 \text{ V}^{-1} \text{ s}^{-1}$? (Take charge of electron as $1.6 \times 10^{-19} \text{ C}$)
3. Figure shows the stopping potential (V_0) for the photo electron versus $(1/\lambda)$ graph, for two metals A and B, λ being the wavelength of incident light. How is the value of Planck's constant determined from the graph?



OR

Write two main observations of photoelectric effect experiment which could only be explained by Einstein's photoelectric equation.

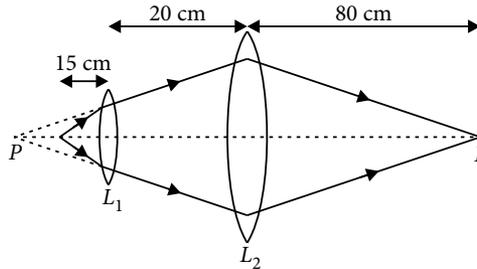
SECTION - B

4. Write three characteristic properties of nuclear force.
5. A parallel beam of light of wavelength 600 nm is incident normally on a slit of width d . If the distance between the slits and the screen is 0.8 m and the distance of 2^{nd} order maximum from the centre of the screen is 15 mm. Find the width of the slit.
6. A diatomic molecule is made of two masses m_1 and m_2 which are separated by a distance r . Calculate its rotational energy by applying Bohr's rule of angular momentum quantization.
7. A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}$ of the angle of prism. Calculate the speed of light in the prism.

OR

Draw a ray diagram to show the image formation of a distant object by a refracting telescope. Write the expression for its angular magnification in terms of the focal lengths of the lenses used.

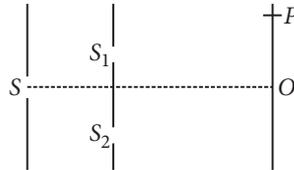
8. An electron and a photon each have a wavelength 1.00 nm. Find
 (i) their momenta,
 (ii) the energy of the photon and
 (iii) the kinetic energy of electron.
9. In the following diagram, an object 'O' is placed 15 cm in front of a convex lens L_1 of focal length 20 cm and the final image is formed at I at a distance of 80 cm from the second lens L_2 . Find the focal length of the lens L_2 .



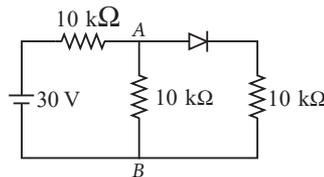
10. Answer the following questions:
 (i) Show, by giving a simple example, how *e.m.* waves carry energy and momentum.
 (ii) How are microwaves produced? Why is it necessary in microwave ovens to select the frequency of microwaves to match the resonant frequency of water molecules?
 (iii) Write two important uses of infrared waves.

OR

In a modified set-up of Young's double slit experiment, it is given that $SS_2 - SS_1 = \lambda/4$, *i.e.* the source 'S' is not equidistant from the slits S_1 and S_2 .



- (a) Obtain the conditions for constructive and destructive interference at any point P on the screen in terms of the path difference $\delta = S_2P - S_1P$.
 (b) Does the observed central bright fringe lie above or below 'O'? Give reason to support your answer.
11. In the given figure, find the potential difference between A and B.



SECTION - C

12. CASE STUDY : SOURCES OF LIGHT

Consider the situation shown in figure. The two slits S_1 and S_2 placed symmetrically around the central line are illuminated by monochromatic light of wavelength λ . The separation between the slits is d . The light transmitted

Solution

PHYSICS - 042

Class 12 - Physics

1. If p -type and n -type semiconductor are heavily doped. Then due to diffusion of electrons from n -region to p -region, and of holes from p -region to n -region, a depletion region formed of size of order less than $1 \mu\text{m}$. The electric field directing from n -region to p -region produces a reverse bias voltage of about 5 V and electric field becomes very large.

$$\vec{E} = \frac{\Delta V}{\Delta x} = \frac{5\text{V}}{1 \mu\text{m}} \approx 5 \times 10^6 \text{ V/m}$$

2. Given; $n_e = 5 \times 10^{18} \text{ m}^{-3}$, $n_h = 5 \times 10^{19} \text{ m}^{-3}$,
 $\mu_e = 2 \text{ m}^2 \text{ V}^{-1} \text{ s}^{-1}$, $\mu_h = 0.01 \text{ m}^2 \text{ V}^{-1} \text{ s}^{-1}$

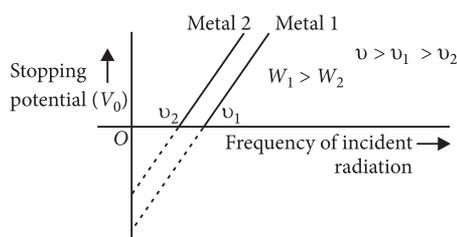
Then conductivity,

$$\sigma = e(n_e \mu_e + n_h \mu_h)$$

Putting values, we get

$$\begin{aligned} \sigma &= 1.6 \times 10^{-19} (5 \times 10^{18} \times 2 + 5 \times 10^{19} \times 0.01) \\ &= 1.6 \times 10^{-19} (10^{19} + 0.05 \times 10^{19}) = 1.68 (\Omega\text{-m})^{-1} \end{aligned}$$

3. The graph showing the variation of stopping potential (V_0) with the frequency of incident radiation (ν) for two different photosensitive materials having work functions W_1 and W_2 ($W_1 > W_2$) is shown in figure.



(i) Slope of the line $= \frac{\Delta V}{\Delta \nu} = \frac{h}{e}$ [$\because e\Delta V = h\Delta \nu$]

\therefore Slope of the line $= \frac{h}{e}$ i.e., it is a constant quantity and does not depend on nature of metal surface.

(ii) Intercept of graph 1 on the stopping potential axis $= \frac{\text{work function}(W)}{e} = -\frac{h\nu_0}{e}$

\therefore Intercept of the line depends upon the stopping function of the metal surface.

OR

On the basis of experiments on photoelectric effect, three observed features are :

(i) The emission of photoelectrons takes place only when the frequency of the incident radiations is above a certain critical value called threshold frequency ν_0 , which is characteristic of that metal emitting electrons.

Above threshold frequency ν_0 , maximum kinetic energy with which photoelectrons are emitted is directly proportional to frequency ν of incident radiation.

(ii) The maximum kinetic energy with which a photoelectron is emitted from a metallic surface is independent of the intensity of light and depends only upon its frequency.

4. Properties of nuclear force are :

(i) Nuclear forces are short range forces and are strongly attractive within a range of 1 fermi to 4.2 fermi.

(ii) Nuclear forces above 4.2 fermi are negligible, whereas below 1 fermi, they become repulsive in nature. It is this repulsive nature below 1 fermi, which prevents the nucleus from collapsing under strong attractive force.

(iii) Nuclear forces are charge independent. The same magnitude of nuclear force act between a pair of protons, pair of proton and neutron and pair of neutrons. The attractive nuclear force is due to exchange of π mesons (π^0, π^+, π^-) between them.

5. Distance of 2nd order maximum from the centre of the screen

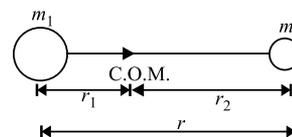
$$x = \frac{5 D \lambda}{2 d}$$

Here, $D = 0.8 \text{ m}$, $x = 15 \text{ mm} = 15 \times 10^{-3} \text{ m}$

$$\lambda = 600 \text{ nm} = 600 \times 10^{-9} \text{ m}$$

$$\therefore d = \frac{5 D \lambda}{2 x} = \frac{5}{2} \times \frac{0.8 \times 600 \times 10^{-9}}{15 \times 10^{-3}} = 80 \mu\text{m}$$

6. A diatomic molecule consists of two atoms of masses m_1 and m_2 at a distance r apart. Let r_1 and r_2 be the distances of the atoms from the centre of mass.



The moment of inertia of this molecule about an axis passing through its centre of mass and perpendicular to a line joining the atoms is

$$I = m_1 r_1^2 + m_2 r_2^2 \text{ as } m_1 r_1 = m_2 r_2 \Rightarrow r_1 = \frac{m_2}{m_1} r_2$$

$$\therefore r_1 + r_2 = r \quad \therefore r_1 = \frac{m_2}{m_1} (r - r_1) \Rightarrow r_1 = \frac{m_2 r}{m_1 + m_2}$$

Similarly, $r_2 = \frac{m_1 r}{m_1 + m_2}$

Therefore, the moment of inertia can be written as

$$I = m_1 \left(\frac{m_2 r}{m_1 + m_2} \right)^2 + m_2 \left(\frac{m_1 r}{m_1 + m_2} \right)^2 = \frac{m_1 m_2}{m_1 + m_2} r^2 \quad \dots(i)$$

According to Bohr's quantisation condition

$$L = \frac{nh}{2\pi} \quad \text{or} \quad L^2 = \frac{n^2 h^2}{4\pi^2} \quad \dots(ii)$$

Rotational energy, $E = \frac{L^2}{2I} \therefore E = \frac{n^2 h^2}{8\pi^2 I}$ (Using (ii))

$$= \frac{n^2 h^2 (m_1 + m_2)}{8\pi^2 (m_1 m_2) r^2} \quad \text{(Using (i))}$$

$$= \frac{n^2 \hbar^2 (m_1 + m_2)}{2m_1 m_2 r^2} \quad \left(\because \hbar = \frac{h}{2\pi} \right)$$

7. For equilateral prism $A = 60^\circ$

For minimum angle of deviation,

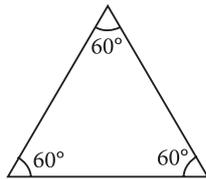
$$i + e = A + \delta_m$$

$$2i = A + \delta_m$$

$$\frac{2 \times 3A}{4} = A + \delta_m$$

$$\delta_m = \frac{3A}{2} - A = \frac{A}{2}$$

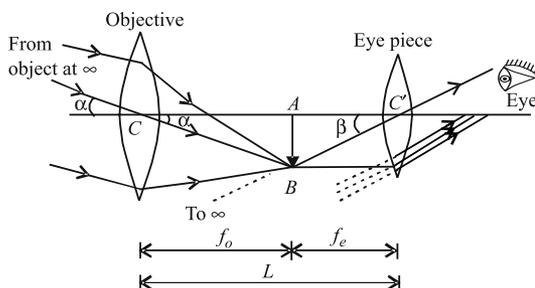
$$\therefore \mu = \frac{\sin\left(\frac{A + \frac{A}{2}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$



$$\Rightarrow \mu = \frac{\sin\left(\frac{3A}{4}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin 45^\circ}{\sin 30^\circ} = \frac{0.7071}{0.5} = 1.414$$

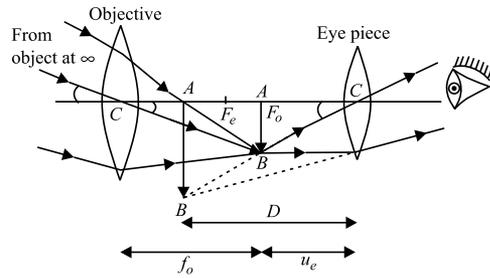
$$v = \frac{c}{\lambda} = \frac{3 \times 10^8}{1.414} = 2.1216 \times 10^8 \text{ m s}^{-1}$$

When final image is formed at infinity :



Magnification, $M = -\frac{f_o}{f_e}$

When the final image is formed at least distance of distinct vision :



Magnification, $M = -\frac{f_o}{f_e} \left(1 + \frac{f_e}{D} \right)$

8. (i) Momentum of photon

$$p = \frac{h}{\lambda} = \frac{6.6 \times 10^{-34}}{1 \times 10^{-9}} = 6.6 \times 10^{-25} \text{ kg m s}^{-1}$$

Momentum of electron

$$p = \frac{6.6 \times 10^{-34}}{1 \times 10^{-9}} = 6.6 \times 10^{-25} \text{ kg m s}^{-1}$$

(ii) Energy of photon

$$E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1 \times 10^{-9}} = 1.98 \times 10^{-16} \text{ J}$$

(iii) Kinetic energy of electron

$$E_e = \frac{p^2}{2m} = \frac{(6.6 \times 10^{-25})^2}{2 \times 9.1 \times 10^{-31}} = 2.39 \times 10^{-19} \text{ J}$$

9. As per the figure,

The image formed by lens L_1 is at P . Therefore, using

lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

As per the parameters given in the question

$$u = -15 \text{ cm}, f_{L_1} = 20 \text{ cm}$$

So, the image distance will be

$$\frac{1}{v} - \frac{1}{(-15)} = \frac{1}{20}; v = -60 \text{ cm}$$

Now, this image is acting as an object for the lens L_2 . We can again use the lens formula and other parameters given in the question and question figure to find the focal length of lens L_2 .

$$\frac{1}{v_{L_2}} - \frac{1}{u_{L_2}} = \frac{1}{f_{L_2}}$$

Here, $u_{L_2} = v + (-20) = -60 - 20 = -80 \text{ cm}$

$$v_{L_2} = 80 \text{ cm}$$

$$\frac{1}{80} - \frac{1}{(-80)} = \frac{1}{f_{L_2}}$$

$$f_{L_2} = 40 \text{ cm}$$

So, the focal length of the lens $L_2 = 40 \text{ cm}$.

10. (i) Consider a plane perpendicular to the direction of propagation of the wave. An electric charge, on the plane will be set in motion by the electric and magnetic fields of *e.m.* wave, incident on this plane. This illustrates that *e.m.* waves carry energy and momentum.

(ii) Microwaves are produced by special vacuum tube like the klystron, magnetron and gunn diode.

The frequency of microwaves is selected to match the resonant frequency of water molecules, so that energy is transformed efficiently to the kinetic energy of the molecules.

(iii) Uses of infra-red waves :

(a) They are used in night vision devices during warfare. This is because they can pass through haze, fog and mist.

(b) Infra-red waves are used in remote switches of household electrical appliances.

OR

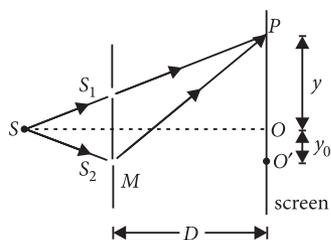
$$(a) \text{ Given : } SS_2 - SS_1 = \frac{\lambda}{4}$$

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

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

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

$$\text{or } \Delta x = \frac{\lambda}{4} + \frac{yd}{D}$$



(i) For constructive interference at point P , path difference, $\Delta x = n\lambda$

$$\text{or } \frac{\lambda}{4} + \frac{yd}{D} = n\lambda$$

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

where $n = 0, 1, 2, 3, \dots$,

(ii) For destructive interference at point P , path difference

$$\Delta x = (2n-1)\frac{\lambda}{2} \text{ or } \frac{\lambda}{4} + \frac{yd}{D} = (2n-1)\frac{\lambda}{2}$$

$$\text{or } \frac{yd}{D} = \left(2n-1 - \frac{1}{2}\right)\frac{\lambda}{2} = (4n-3)\frac{\lambda}{4} \quad \dots(ii)$$

where $n = 1, 2, 3, 4, \dots$

For central bright fringe, putting $n = 0$ in equation (i), we get

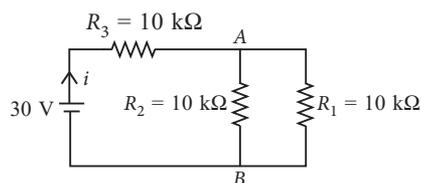
$$\frac{yd}{D} = -\frac{\lambda}{4} \text{ or } y = \frac{-\lambda D}{4d}$$

(b) The negative sign indicates that central bright fringe will be observed at a point O' below the centre O of screen.

11. In forward biasing, the diode offers negligible resistance to the circuit. So, the diode will act as a simple wire only. Therefore, the circuit can be redrawn as follows :

Here, R_1 and R_2 are in parallel.

$$R_p = \frac{10 \times 10}{10 + 10} = 5 \text{ k}\Omega$$



Now, R_3 and R_p are in series.

$$\therefore R_{eq} = 5 + 10 = 15 \text{ k}\Omega$$

$$\text{So, current, } i = \frac{V}{R_{eq}} = \frac{30}{15 \times 10^3} = 2 \times 10^{-3}$$

$$\text{Voltage across } R_3, V' = iR_3 = 2 \times 10^{-3} \times 10 \times 10^3 = 20 \text{ V}$$

$$\text{So, } V_{AB} = 30 - 20 = 10 \text{ V}$$

$$12. (i) (b): \text{ As } z = \frac{\lambda D}{2d}$$

$$\text{At } S_4: \frac{\Delta x}{d} = \frac{z}{D}$$

$$\Rightarrow \Delta x = \frac{\lambda D d}{2d D} = \frac{\lambda}{2}$$

$$(ii) (c): z = \frac{\lambda D}{d}$$

$$\Delta x \text{ at } S_4: \Delta x = \frac{\lambda D d}{d D} = \lambda$$

Hence, maxima at S_4 as well as S_3 .

Resultant intensity at $S_4, I = 4I_0$

$$\therefore \frac{I_{\max}}{I_{\min}} = \frac{[(4I_0)^{1/2} + 4(4I_0)^{1/2}]^2}{[(4I_0)^{1/2} - (4I_0)^{1/2}]^2} = \infty$$

(iii) **(a)**: When the screen is placed perpendicular to the line joining the sources, the fringes will be concentric circles.

(iv) **(b)**: Constructive interference occurs when the path difference ($S_1P - S_2P$) is an integral multiple of λ .

or $S_1P - S_2P = n\lambda$, where $n = 0, 1, 2, 3, \dots$

(v) **(d)**: Here, $A_1 = 3A$, $A_2 = 2A$ and $\phi = 60^\circ$

The resultant amplitude at a point is

$$\begin{aligned} R &= \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos \phi} \\ &= \sqrt{(3A)^2 + (2A)^2 + 2 \times 3A \times 2A \times \cos 60^\circ} \\ &= \sqrt{9A^2 + 4A^2 + 6A^2} = A\sqrt{19} \end{aligned}$$

As, Intensity \propto (Amplitude)²

Therefore, intensity at the same point is

$$I \propto 19A^2$$