Sample Question Paper - 25
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.

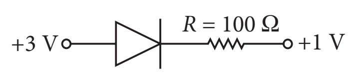
(iii) Section A contains three questions of two marks each, Section B contains eight questions of three marks each, Section C contains one case study-based question of five marks.

(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. Assuming that the junction diode is ideal, find the current in the arrangement shown in figure.



2. The refractive index of the material of an equilateral prism is 1.6. Find the angle of minimum deviation due to the prism.

OR

A parallel beam of light of 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Calculate the width of the slit.

3. An intrinsic semiconductor has a resistivity of 0.50 Ω m at room temperature. Find the intrinsic carrier concentration if the mobilities of electrons and holes are 0.39 m^2/volt sec and 0.11 m^2/volt sec respectively.

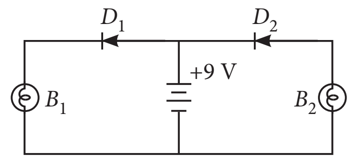
SECTION - B

4. Two monochromatic waves emanating from two coherent sources have the displacements represented by $y_1 = a \cos \omega t$ and $y_2 = a \cos (\omega t + \phi)$ where ϕ is the phase difference between the two displacements. Show that the resultant intensity at a point due to their superposition is given by $I = 4 I_0 \cos^2 \phi/2$, where $I_0 = a^2$.

5. Name the parts of the electromagnetic spectrum which is
(a) suitable for radar systems used in aircraft navigation.
(b) used to treat muscular strain.
(c) used as a diagnostic tool in medicine.
Write in brief, how these waves can be produced.

6. A small bulb (assumed to be a point source) is placed at the bottom of a tank containing water to a depth of 80 cm. Find out the area of the surface of water through which light from the bulb can emerge. Take the value of the refractive index of water to be 4/3.

7. (a) In the following diagram, which bulb out of B_1 and B_2 will glow and why?



(b) Explain briefly the three processes due to which generation of emf takes place in a solar cell.

8. Use this equation to explain the concept of (i) threshold frequency and (ii) stopping potential.

OR

The kinetic energy of a given electron is five times more than a certain proton. How much the de-Broglie's wavelength of electron is bigger than the corresponding wavelength of the proton. (Assume that both particles are non-relativistic and $m_p = 2000\ m_e$)

9. When four hydrogen nuclei combine to form a helium nucleus estimate the amount of energy in MeV released in this process of fusion (Neglect the masses of electrons and neutrons). Given:

(i) Mass of ${}^1_1\text{H} = 1.007825$ u

(ii) Mass of helium nucleus = 4.002603 u, 1u = 931 MeV/c^2

10. When the frequency of the light used is changed from $4 \times 10^{14}\ \text{s}^{-1}$ to $5 \times 10^{14}\ \text{s}^{-1}$, the angular width of the principal (central) maximum in a single slit Fraunhoffer diffraction pattern changes by 0.6 radian. What is the width of the slit (assume that the experiment is performed in vacuum)?

11. Draw a ray diagram to show the formation of the image of an object placed on the axis of a convex refracting surface of radius of curvature 'R', separating the two media of refractive indices 'n_1' and 'n_2' ($n_2 > n_1$). Use this diagram to deduce the relation $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$, where u and v represent respectively the distance of the object and the image formed.

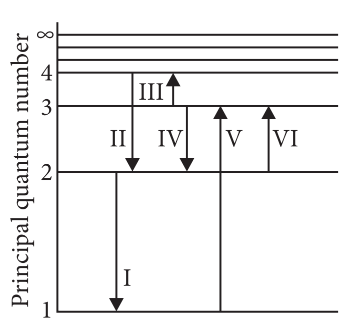
OR

An object is placed 30 cm in front of a plano-convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed.

SECTION - C

12. CASE STUDY : ELECTRON TRANSITIONS FOR THE HYDROGEN ATOM

Bohr's model explains the spectral lines of hydrogen atomic emission spectrum. While the electron of the atom remains in the ground state, its energy is unchanged. When the atom absorbs one or more quanta of energy, the electrons moves from the ground state orbit to an excited state orbit that is further away.



The given figure shows an energy level diagram of the hydrogen atom. Several transitions are marked as I, II, III and so on. The diagram is only indicative and not to scale.

(i) In which transition is a Balmer series photon absorbed?
(a) II (b) III (c) IV (d) VI

(ii) The wavelength of the radiation involved in transition II is
(a) 291 nm (b) 364 nm (c) 487 nm (d) 652 nm

(iii) Which transition will occur when a hydrogen atom is irradiated with radiation of wavelength 103 nm?
(a) I (b) II (c) IV (d) V

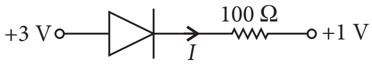
(iv) The electron in a hydrogen atom makes a transition from $n = n_1$ to $n = n_2$ state. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are
(a) $n_1 = 4, n_2 = 2$ (b) $n_1 = 8, n_2 = 2$ (c) $n_1 = 8, n_2 = 3$ (d) $n_1 = 6, n_2 = 2$

(v) The Balmer series for the H-atom can be observed
(a) if we measure the frequencies of light emitted when an excited atom falls to the ground state
(b) if we measure the frequencies of light emitted due to transitions between excited states and the first excited state
(c) in any transition in a H-atom
(d) none of these.

Solution

PHYSICS - 042

Class 12 - Physics

1. 

In the given circuit, the junction diode is forward biased and offers zero resistance.

$$\text{Current, } I = \frac{3\text{ V} - 1\text{ V}}{100\ \Omega} = 0.02\text{ A}$$

2. Here, $\mu = 1.6$, $A = 60°$

$$\text{As, } \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\therefore \quad \sin\left(\frac{60°+\delta_m}{2}\right) = 1.6\sin\left(\frac{60°}{2}\right)$$

$$\Rightarrow \sin\left(\frac{60°+\delta_m}{2}\right) = 0.8 \quad \Rightarrow \delta_m = 46.3°$$

OR

Position of first minimum in diffraction pattern $y = \frac{D\lambda}{a}$

So slit width, $a = \frac{D\lambda}{y} = \frac{1\times500\times10^{-9}}{2.5\times10^{-3}} = 2\times10^{-4}\text{ m}$

3. Here, $\rho = 0.50\ \Omega$ m, $\mu_e = 0.39\text{ m}^2/\text{V s}$, $\mu_h = 0.11\text{ m}^2/\text{V s}$

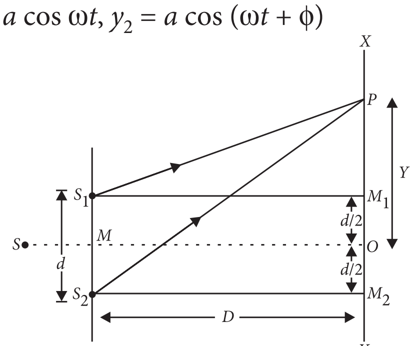
The resistivity of intrinsic semiconductor is

$$\rho = \frac{1}{en_i(\mu_e+\mu_h)} \Rightarrow n_i = \frac{1}{\rho e(\mu_e+\mu_h)}$$

Substituting the given values, we get

$$n_i = \frac{1}{(0.5)(1.6\times10^{-19})(0.39+0.11)} = 2.5\times10^{19}/\text{m}^3$$

4. $y_1 = a\cos\omega t$, $y_2 = a\cos(\omega t + \phi)$



where ϕ is phase difference between them.

Resultant displacement at point P will be,

$y = y_1 + y_2 = a\cos\omega t + a\cos(\omega t + \phi)$

$= a[\cos\omega t + \cos(\omega t + \phi)]$

$$= a\left[2\cos\frac{(\omega t+\omega t+\phi)}{2}\cos\frac{(\omega t-\omega t-\phi)}{2}\right]$$

$$y = 2a\cos\left(\omega t+\frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right) \quad \text{...(i)}$$

Let $y = 2a\cos\left(\frac{\phi}{2}\right) = A$, the equation (i) becomes

$$y = A\cos\left(\omega t+\frac{\phi}{2}\right)$$

where A is amplitude of resultant wave,

Now, $A = 2a\cos\left(\frac{\phi}{2}\right)$

On squaring, $A^2 = 4a^2\cos^2\left(\frac{\phi}{2}\right)$

Hence, resultant intensity,

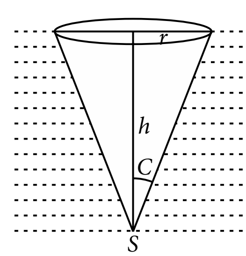
$$I = 4I_0\cos^2\left(\frac{\phi}{2}\right) \quad [\because I_0 = a^2]$$

5. (a) Microwaves are suitable for radar systems used in aircraft navigation.
These waves are produced by special vacuum tubes, namely Klystrons, Magnetrons and Gunn diodes.

(b) Infra-red waves are used to treat muscular pain. These waves are produced by hot bodies and molecules.

(c) X-rays are used as a diagnostic tool in medicine. These are produced when high energy electrons are stopped suddenly on a metal of high atomic number.

6.



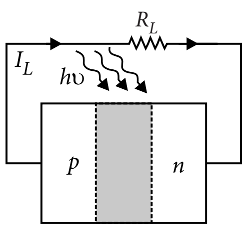
The light rays starting from bulb can pass through the surface if angle of incidence at surface is less than or equal to critical angle (C) for water air interface. If h is the depth of bulb from the surface, the light will emerge only through a circle of radius r given by

$$r = \frac{h}{\sqrt{\mu^2-1}}$$

Area of water surface $= \frac{\pi h^2}{\mu^2-1}$

$$= \frac{22}{7}\times\frac{(0.80)^2}{(1.33)^2-1} = 2.6\text{ m}^2$$

7. (a) Bulb B_1 will glow, as diode D_1 is forward biased. Bulb B_2 will not glow as diode D_2 is reverse biased.
(b) A solar cell works on the principle of photovoltaic effect according to which when light photons of energy greater than energy band gap of a semiconductor are incident on *p-n* junction of that semiconductor, electron-hole pairs are generated which give rise to an emf.
Generation of emf : Three basic processes are involved in the generation of emf by a solar cell when solar radiations are incident on it. These are:
(i) The generation of electron-hole pairs close to the junction due to incidence of light with photo energy $h\upsilon \geq E_b$.
(ii) The separation of electrons and holes due to the electric field of the depletion region. So, electrons are swept to *n*-side and holes to *p*-side.
(iii) The electrons reaching the *n*-side are collected by the front contact and holes reaching *p*-side are collected by the back contact. Thus, *p*-side becomes positive and *n*-side become negative giving rise to a photo voltage.



Depletion layer

When an external load R_L is connected as shown in figure, a photocurrent I_L begins to flow through the load.

8. Einstein's photoelectric equation : According to Einstein, when light is incident on metal surface, incident photons are absorbed completely by valence electrons of atoms of metal on its surface. Energy $h\upsilon$ of each photon is partially utilized by an electron to become free or to overcome its "work function" W_0 and rest of the absorbed energy provides the maximum kinetic energy to the photoelectron during the emission. *i.e.*

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

(i) The minimum value of the frequency of incident radiation below which the photoelectric emission stops *i.e.* kinetic energy of photoelectron is zero is called threshold frequency (υ_0).

Threshold frequency, $\upsilon_0 = \dfrac{W}{h}$

$$\frac{1}{2}mv_{\text{max}}^2 = K.E._{\text{max}} = h\upsilon - W_0$$

or, $K.E._{\text{max}} = eV_0$
(ii) When work done by collecting electrode potential on a photoelectron is equal to its maximum kinetic energy then the electrode potential is known as stopping potential.

Stopping potential, $V_0 = \dfrac{K.E._{\text{max}}}{e}$

OR

For non-relativistic electron, wavelength

$$\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2m_eE_e}} \quad \text{...(i)}$$

Also for non-relativistic proton, wavelength

$$\lambda_p = \frac{h}{p} = \frac{h}{\sqrt{2m_pE_p}} \quad \text{...(ii)}$$

Given, kinetic energy of electron = 5 times kinetic energy of proton *i.e.*, $E_e = 5E$ and $m_p = 2000m_e$
From equation (i) and (ii)

$$\Rightarrow \frac{\lambda_e}{\lambda_p} = \frac{\sqrt{2m_pE_p}}{\sqrt{2m_eE_e}} = \frac{\sqrt{2\times 2000\, m_e \times E_p}}{\sqrt{2\times m_e \times 5E_p}}$$

$$\text{or} \quad \frac{\lambda_e}{\lambda_p} = \sqrt{400} = 20 \Rightarrow \lambda_e = 20\lambda_p$$

9. Energy released = $\Delta m \times 931$ MeV
$\Delta m = 4m\,(^1_1\text{H}) - m\,(^4_2\text{He})$
Energy released
$Q = [4m\,(^1_1\text{H}) - m\,(^4_2\text{He})] \times 931\text{ MeV}$
$= [4 \times 1.007825 - 4.002603] \times 931$ MeV $= 26.72$ MeV.

10. We know that fringe width of central maximum in Fraunhoffer diffraction, $\beta_0 = \dfrac{2\lambda D}{d}$

$\therefore$ Angular width of central maximum, $\theta = \dfrac{\beta_0}{D} = \dfrac{2\lambda}{d}$
On differentiating both sides, we get

$$\Delta\theta = \frac{2\Delta\lambda}{d} \Rightarrow d = \frac{2\Delta\lambda}{\Delta\theta}$$

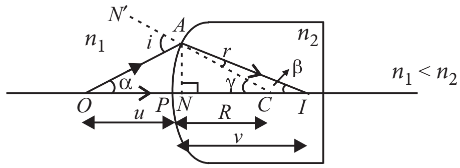
$$\text{Now, } \Delta\lambda = \left(\frac{c}{\upsilon_1} - \frac{c}{\upsilon_2}\right) = \frac{3\times 10^8}{4\times 10^{14}} - \frac{3\times 10^8}{5\times 10^{14}}$$

$$= 10^{-6}(0.75 - 0.6) = 0.15 \times 10^{-6} = 1.5 \times 10^{-7}\text{ m}$$

$\therefore$ Width of the slit, $d = \dfrac{2\times 1.5\times 10^{-7}}{0.6} = 5\times 10^{-7}$ m

11. Refraction at convex spherical surface :

When object is in rarer medium and image formed is real.



In ΔOAC, $i = \alpha + \gamma$

and in ΔAIC, $\gamma = r + \beta$ or $r = \gamma - \beta$

$\therefore$ Using Snell's law $^1n_2 = \frac{\sin i}{\sin r} \approx \frac{i}{r} = \frac{\alpha+\gamma}{\gamma-\beta}$

or $\frac{n_2}{n_1} = \frac{\alpha+\gamma}{\gamma-\beta}$ or $n_2\gamma - n_2\beta = n_1\alpha + n_1\gamma$

or $(n_2 - n_1)\gamma = n_1\alpha + n_2\beta$ ...(i)

As α, β and γ are small and P and N lie close to each other,

So, $\alpha \approx \tan\alpha = \frac{AN}{NO} \approx \frac{AN}{PO}$

$\beta \approx \tan\beta = \frac{AN}{NI} \approx \frac{AN}{PI}$

$\gamma \approx \tan\gamma = \frac{AN}{NC} \approx \frac{AN}{PC}$

On using them in equation (i), we get

$(n_2 - n_1)\frac{AN}{PC} = n_1\frac{AN}{PO} + n_2\frac{AN}{PI}$

or $\frac{n_2 - n_1}{PC} = \frac{n_1}{PO} + \frac{n_2}{PI}$

where, $PC = +R$, radius of curvature

$PO = -u$, object distance

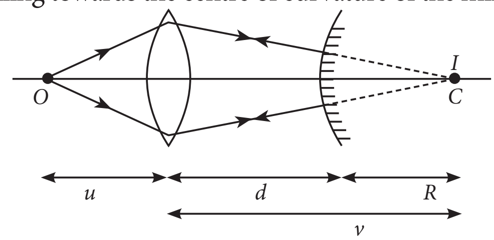
$PI = +v$, image distance

So $\frac{n_2 - n_1}{R} = \frac{n_1}{-u} + \frac{n_2}{v}$ or $\frac{n_2 - n_1}{R} = \frac{n_2}{v} - \frac{n_1}{u}$

This gives formula for refraction at spherical surface when object is in rarer medium.

OR

Since the final image coincides with the object, the rays from the object are retracing its path. So, the refracted rays are falling towards the centre of curvature of the mirror.



From lens formula,

$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} + \frac{1}{-12} \Rightarrow v = 60$ cm

$\therefore$ $R = v - d = 60 - 10 = 50$ cm

$\therefore$ $f = \frac{R}{2} = 25$ cm

12. (i) **(d) :** For Balmer series, $n_1 = 2$; $n_2 = 3, 4, \ldots$
(lower) (higher)

Therefore, in transition (VI), photon of Balmer series is absorbed.

(ii) **(c) :** In transition II,

$E_2 = -3.4$ eV, $E_4 = -0.85$ eV,

$\Delta E = 2.55 \text{ eV} \Rightarrow \Delta E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E} = 487$ nm

(iii) **(d) :** Wavelength of radiation = 1030 Å

$\Delta E = \frac{12400}{1030 \text{ Å}} = 12.0$ eV

So, difference of energy should be 12.0 eV (approx.)

Hence for $n_1 = 1$ to $n_2 = 3$

$E_{n_3} - E_{n_1} = -1.51 \text{ eV} - (-13.6 \text{ eV}) \approx 12$ eV

Therefore, transition V will occur.

(iv) **(a) :** $T^2 \propto r^3$ and $r \propto n^2 \Rightarrow T^2 \propto n^6 \Rightarrow T \propto n^3$

$\frac{T_1}{T_2} = \left(\frac{n_1}{n_2}\right)^3 \Rightarrow 8 = \left(\frac{n_1}{n_2}\right)^3$ or $\frac{n_1}{n_2} = 2$

(v) **(b)**