Sample Question Paper - 29
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. What is the function of a photodiode ?

2. Show that density of nucleus is independent of its mass number A.

OR

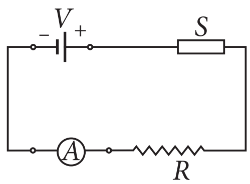
If the nuclear radius of ^{27}Al is 3.6 fermi, then find the approximate nuclear radius of ^{64}Cu in fermi.

3. The intrinsic carrier concentration of silicon sample at 300 K is 1.5×10^{16} m^{-3}. What is the density of minority carrier? (after doping, the number of majority carriers is 5×10^{20} m^{-3})

SECTION - B

4. Write the expression for the speed of light in a material medium of relative permittivity ε_r and relative magnetic permeability μ_r. Also prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field.

5. (a) In the following diagram 'S' is a semiconductor. Would you increase or decrease the value of R to keep the reading of the ammeter A constant when S is heated? Give reason for your answer.



(b) Draw the circuit diagram of a photodiode and explain its working. Draw its I-V characteristics.

6. (i) A ray of light incident on face AB of an equilateral glass prism, shows minimum deviation of 30°. Calculate the speed of light through the prism.

(ii) Find the angle of incidence at face AB so that the emergent ray grazes along the face AC.

7. Calculate the wavelength of H_α line in Balmer series of hydrogen atom, given Rydberg constant $R = 1.097 \times 10^7\ m^{-1}$.

8. Depict the shape of a wavefront in each of the following cases.
(i) Light diverging from point source.
(ii) Light emerging out of a convex lens when a point source is placed at its focus.
(iii) Using Huygen's construction of secondary wavelets, draw a diagram showing the passage of a plane wavefront from a denser into a rarer medium.

OR

(a) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern.
(b) What kind of fringes do you expect to observe if white light is used instead of monochromatic light?

9. If the wavelength of the first line of the Balmer series of hydrogen is 6561 Å, then the wavelength of the second line of the series?

10. Define power of a lens. Write its units. Deduce the relation $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ for two thin lenses kept in contact coaxially.

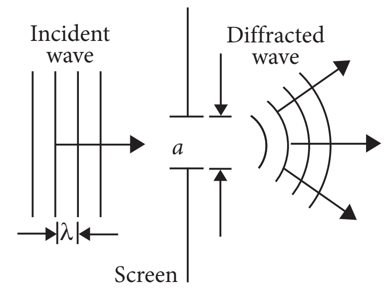
11. Draw a graph showing the variation of stopping potential with frequency of incident radiation for two photosensitive materials having work functions W_1 and $W_2 (W_1 > W_2)$. Write two important conclusions that can be drawn from the study of these plots.

OR

Write Einstein's photoelectric equation and mention which important features in photoelectric effect can be explained with the help of this equation.
The maximum kinetic energy of the photoelectrons gets doubled when the wavelength of light incident on the surface changes from λ_1 to λ_2. Derive the expressions for the threshold wavelength λ_0 and work function for the metal surface.

SECTION - C

12. **CASE STUDY : DIFFRACTION OF LIGHT**
The phenomenon of bending of light around the sharp corners and the spreading of light within the geometrical shadow of the opaque obstacles is called diffraction of light. The light thus deviates from its linear path. The deviation becomes much more pronounced, when the dimensions of the aperture or the obstacle are comparable to the wavelength of light.



(i) Light seems to propagate in rectilinear path because
(a) its spread is very large
(b) its wavelength is very small
(c) reflected from the upper surface of atmosphere
(d) it is not absorbed by atmosphere.

(ii) In diffraction from a single slit the angular width of the central maxima does not depends on
(a) λ of light used
(b) width of slit
(c) distance of slits from the screen
(d) ratio of λ and slit width.

(iii) For a diffraction from a single slit, the intensity of the central point is
   (a) infinite
   (b) finite and same magnitude as the surrounding maxima
   (c) finite but much larger than the surrounding maxima
   (d) finite and substantially smaller than the surrounding maxima.

(iv) Magnification power of telescope increases when
   (a) wavelength of light decreases
   (b) wavelength of light increases
   (c) focal length of eye-piece increases
   (d) focal length of eye-piece decreases.

(v) In a single diffraction pattern observed on a screen placed at D metre distance from the slit of width d metre, the ratio of the width of the central maxima to the width of other secondary maxima is
   (a) 2 : 1
   (b) 1 : 2
   (c) 1 : 1
   (d) 3 : 1

Solution

PHYSICS - 042

Class 12 - Physics

1. Photodiode is used to detect the light signal and to measure light intensity.

2. Nucleus was first discovered in 1911 by Lord Rutherford and his associates by experiments on scattering of α-particle by atoms. He found that the scattering result could be explained, if atoms consists of a small, central, massive and positive core surrounded by orbiting electron. The experiment results indicated that the size of the nucleus is of the order of 10^{-14} metres and it thus 10,000 times smaller than the size of atom.

Relation between the radius and mass number of the nucleus $R = R_0 A^{1/3}$

If m is the average mass of a nucleon and R is the nuclear radius, then mass of nucleus = mA, where A is the mass number of the element.

Volume of the nucleus, $V = \frac{4}{3}\pi R^3$

$$\therefore \; V = \frac{4}{3}\pi\left(R_0\ A^{1/3}\right)^3$$

$$\Rightarrow \; V = \frac{4}{3}\pi R_0^3 A$$

Density of nuclear matter, $\rho = \frac{mA}{V}$

$$\Rightarrow \; \rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} \quad \Rightarrow \; \rho = \frac{3m}{4\pi R_0^3}$$

This shows that the nuclear density is independent of A.

OR

Nuclear radius, $R = R_0 A^{1/3}$

where R_0 is a constant and A is the mass number

$$\frac{R_{\text{Al}}}{R_{\text{Cu}}} = \frac{(27)^{1/3}}{(64)^{1/3}} = \frac{3}{4}$$

$$\text{or } R_{\text{Cu}} = \frac{4}{3} \times R_{\text{Al}} = \frac{4}{3} \times 3.6 \text{ fm} = 4.8 \text{ fm}$$

3. $n_i = 1.5 \times 10^{16}\ \text{m}^{-3}$; $n_o = 5 \times 10^{20}\ \text{m}^{-3}$

$$\text{Density} = \frac{n_i^2}{n_o} = \frac{(1.5\times10^{16}\ \text{m}^{-3})^2}{5\times10^{20}\ \text{m}^{-3}} = 4.5\times10^{11}\ \text{m}^{-3}$$

4. The speed of electromagnetic wave in a medium,

$$v = \frac{1}{\sqrt{\mu\varepsilon}}$$

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

is the speed of light.

In an electromagnetic wave, both E and B fields vary sinusoidally in space and time. The average energy density u of an e.m. wave can be obtained by replacing E and B by their rms value

$$u = \frac{1}{2}\varepsilon_0 E_{\text{rms}}^2 + \frac{1}{2\mu_0}B_{\text{rms}}^2 \quad \text{or} \quad u = \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4\mu_0}B_0^2$$

$$\left[\because\ E_{\text{rms}} = \frac{E_0}{\sqrt{2}}, B_{\text{rms}} = \frac{B_0}{\sqrt{2}}\right]$$

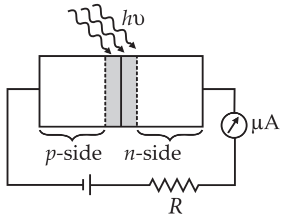
Moreover, $E_0 = cB_0$ and $c^2 = \frac{1}{\mu_0\varepsilon_0}$, therefore

$$u_E = \frac{1}{4}\varepsilon_0 E_0^2 = \frac{1}{4}\varepsilon_0 (cB_0)^2$$

$$u_E = \frac{1}{4}\varepsilon_0 \cdot \frac{B_0^2}{\mu_0\varepsilon_0} = \frac{1}{4\mu_0}B_0^2 = u_B$$

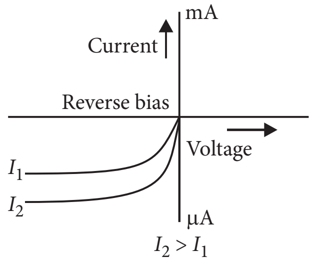
5. (a) We will increase the value of R. On heating a semiconductor, its resistance decreases with rise in temperature. As the semiconductor, S is in series, so net resistance of the circuit also decreases. So by increasing the value of R we can keep the resistance of circuit constant and hence the current in the circuit or the reading of ammeter A can be kept constant.

(b) Working of photodiode : A junction diode made from light sensitive semiconductor is called a photodiode. A photodiode is a p-n junction diode arranged in reverse biasing.



The number of charge carriers increases when light of suitable frequency is made to fall on the p-n junction, because new electron holes pairs are created by absorbing the photons of suitable frequency. Intensity of light controls the number of charge carriers. Due to this property photodiodes are used to detect optical signals.

V-I characteristics :



6. (i) The refractive index of the material of prism,

$$\mu = \frac{\sin\left[\frac{A+\delta_m}{2}\right]}{\sin\frac{A}{2}}$$

Given : $A = 60°$, $\delta_m = 30°$

$$\mu = \frac{\sin 45°}{\sin 30°} = \frac{1}{\sqrt{2}}.2 \Rightarrow \mu = \sqrt{2}$$

$$\because \mu = \frac{c}{v} \Rightarrow v = \frac{c}{\mu} = \frac{3\times10^8}{1.414} = 2.12\times10^8 \text{ m s}^{-1}$$

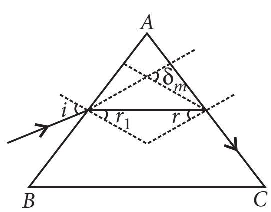
(ii) $\sin i_C = \frac{1}{\mu} = \frac{1}{\sqrt{2}}$

$i_C = r = 45°$

$A = r_1 + r$

$\Rightarrow r_1 = 15°$

$\frac{\sin i}{\sin r_1} = \sqrt{2}$



$$\sin i = \sqrt{2}\sin 15° = \frac{(\sqrt{3}-1)}{2\sqrt{2}}\times\sqrt{2}$$

$$\sin i = \frac{\sqrt{3}-1}{2}$$

$$i = \sin^{-1}\left(\frac{\sqrt{3}-1}{2}\right)$$

7. For longest wavelength of Lyman series $n_i = 2$

$$\frac{1}{\lambda_{max}} = R\left(\frac{1}{1^2}-\frac{1}{2^2}\right) = \frac{3R}{4}$$

$$\lambda_{max} = \frac{4}{3R} = \frac{4}{3\times1.097\times10^7} = 1.215\times10^{-7}\text{ m}$$

$\lambda_{max} = 1215$ Å

The lines of the Lyman series are found in ultraviolet region.

For longest wavelength of Balmer series $n_i = 3$

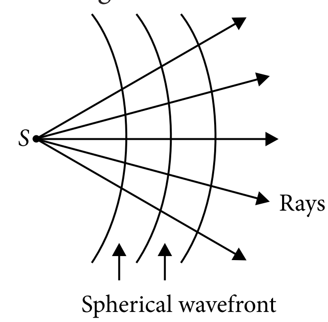
$$\frac{1}{\lambda_{max}} = R\left(\frac{1}{2^2}-\frac{1}{3^2}\right) = \frac{5}{36}R$$

$$\lambda_{max} = \frac{36}{5R} = \frac{36}{5\times1.097\times10^7} = 6.563\times10^{-7}\text{ m}$$

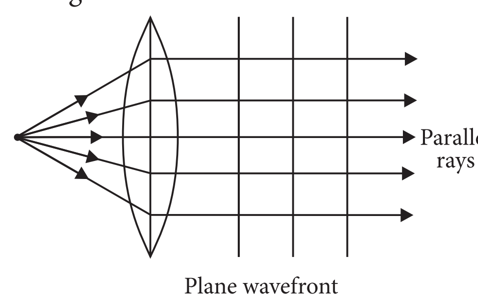
$= 6563$ Å

Balmer series lie in the visible region of electromagnetic spectrum.

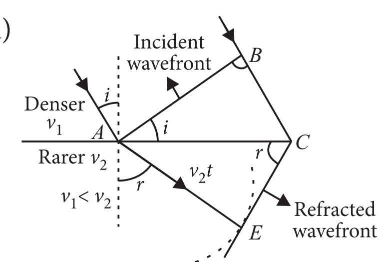
8. (i) The wavefront will be spherical of increasing radius as shown in figure.



(ii) When source is at the focus, the rays coming out of the convex lens are parallel, so wavefront is plane as shown in figure.



(iii)



OR

(a) We know, $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2}$

According to question, $I_2 = 50\%$ of I_1

$I_2 = 0.5I_1$; $a_2^2 = 0.5\,a_1^2$ $(\because I \propto a^2)$

$$a_2 = \frac{a_1}{\sqrt{2}}$$

Hence,

$$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_1/\sqrt{2})^2}{(a_1-a_1/\sqrt{2})^2} = \frac{(1+1/\sqrt{2})^2}{(1-1/\sqrt{2})^2} = \left(\frac{\sqrt{2}+1}{\sqrt{2}-1}\right)^2 \approx 34$$

(b) The central fringes are white. On the either side of the central white fringe the coloured bands (few coloured maxima and minima) will appear. This is because fringes of different colours overlap.

9. For Balmer series, $n_1 = 2$, $n_2 = 3$ for 1st line and $n_2 = 4$ for second line.

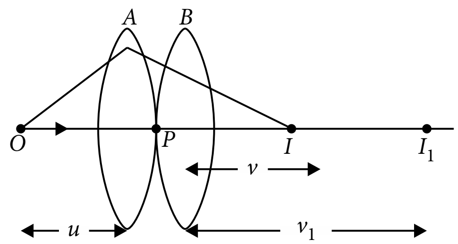
$$\frac{\lambda_1}{\lambda_2} = \frac{\left(\frac{1}{2^2} - \frac{1}{4^2}\right)}{\left(\frac{1}{2^2} - \frac{1}{3^2}\right)} = \frac{3/16}{5/36} = \frac{3}{16} \times \frac{36}{5} = \frac{27}{20}$$

$$\lambda_2 = \frac{20}{27}\lambda_1 = \frac{20}{27} \times 6561 = 4860 \text{ Å}$$

10. Power of lens : It is the reciprocal of focal length of a lens.

$P = \frac{1}{f}$ (f is in metre)

Unit of power of lens : Dioptre



An object is placed at point O. The lens A produces an image at I_1 which serves as a virtual object for lens B which produces final image at I.

Given, the lenses are thin. The optical centres (P) of the lenses A and B coincide with each other.

For lens A, we have

$$\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1} \quad \text{...(i)}$$

For lens B, we have $\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2}$ ...(ii)

Adding equations (i) and (ii),

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \quad \text{...(iii)}$$

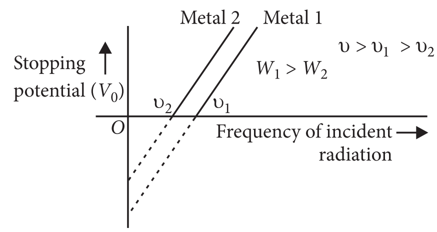
If two lenses are considered as equivalent to a single lens of focal length f, then

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{...(iv)}$$

From equation (iii) and equation (iv), we can write

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

11. The graph showing the variation of stopping potential (V_0) with the frequency of incident radiation (υ) 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 $= \frac{\Delta V}{\Delta \upsilon} = \frac{h}{e}$ $[\because e\Delta V = h\Delta\upsilon]$

$\therefore$ 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

$$= \frac{\text{Work function } (W)}{e} = -\frac{h\upsilon_0}{e}$$

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

OR

Einstein's photoelectric equation

$$K_{max} = \frac{1}{2}mv^2 = h\upsilon - \phi_0 = h\upsilon - h\upsilon_0 \quad \text{...(i)}$$

From eqn. (i)

$$K_{max} = \frac{hc}{\lambda} - \phi_0$$

According to question,

$$K_{max} = \frac{hc}{\lambda_1} - \phi_0 \quad \text{...(ii)}$$

$$2K_{max} = \frac{hc}{\lambda_2} - \phi_0 \quad \text{...(iii)}$$

From eqn. (ii) and (iii),

$$2\left(\frac{hc}{\lambda_1} - \phi_0\right) = \frac{hc}{\lambda_2} - \phi_0$$

$$\phi_0 = \frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2} = hc\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

Also, $\phi_0 = \frac{hc}{\lambda_0}$ $\therefore$ $\frac{hc}{\lambda_0} = hc\left(\frac{2}{\lambda_1} - \frac{1}{\lambda_2}\right)$

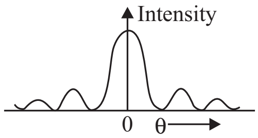
or $\frac{1}{\lambda_0} = \frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}; \lambda_0 = \frac{\lambda_1\lambda_2}{2\lambda_2 - \lambda_1}$

12. (i) **(b)** : The wavelength of visible light is very small, that is hardly shows diffraction, so it seems to propagate in rectilinear path,

(ii) **(c)** : Angular width of central maxima, $2\theta = 2\lambda/e$.

Thus, θ does not depend on screen *i.e.*, distance between the slits and the screen.

(iii) **(c)** **:** The intensity distribution of single slit diffraction pattern is shown in the figure. From the graph it is clear that the intensity of the central point is finite but much larger than the surrounding maxima.



(iv) **(d)** : Magnification power of telescope,

$$M = \frac{f_o}{f_e}$$

∴ It increases when focal length of eye piece decreases.

(v) **(a)** **:** Width of central maxima = $2\lambda D/e$

width of other secondary maxima = $\lambda D/e$

∴ Width of central maxima : width of other secondary maxima = 2 : 1