Sample Question Paper - 17
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. If the rms value of sinusoidal input to a full wave rectifier is $\frac{V_0}{\sqrt{2}}$ then find the rms value of the rectifier's output.

2. The focal length of an equiconcave lens is 3/4 times of radius of curvature of its surfaces. Find the refractive index of the material of the lens. Under what condition will this lens behave as a converging lens?

OR

A fish in a water tank sees the outside world as if it (the fish) is at the vertex of a cone such that the circular base of the cone coincides with the surface of water. Given the depth of water, where fish is located, being 'h' and the critical angle for water-air interface being 'i_c', find out by drawing a suitable ray diagram the relationship between the radius of the cone and the height 'h'.

3. A pure semiconductor has equal electron and hole concentration of 10^{16} m^{-3}. Doping by indium increases n_h to 5×10^{22} m^{-3}. Then, find the value of n_e in the doped semiconductor.

SECTION - B

4. Draw a graph showing the variation of potential energy between a pair of nucleons as a function of their separation. Indicate the regions in which the nuclear force is (i) attractive, (ii) repulsive.

5. Define the term, "refractive index" of a medium. Verify Snell's law of refraction when a plane wavefront is propagating from a denser to a rarer medium.

6. A prism is made up of material of refractive index $\sqrt{2}$. The angle of the prism is A. If the angle of minimum deviation is equal to the angle of the prism, then find the value of A.

7. How does an oscillating charge produce electromagnetic wave? Explain.
Draw a sketch showing the propagation of plane *e.m.* wave along the Z-direction, clearly depicting the directions of oscillating electric and magnetic field vectors.

8. The value of ground state energy of hydrogen atom is –13.6 eV.

(i) Find the energy required to move an electron from the ground state to the first excited state of the atom.

(ii) Determine (a) the kinetic energy and (b) orbital radius in the first excited state of the atom. (Given the value of Bohr radius = 0.53 Å).

OR

State Bohr's postulate to define stable orbits in hydrogen atom. How does de-Broglie's hypothesis explain the stability of these orbits?

9. Define the terms 'depletion layer' and 'barrier potential' for a *p-n* junction. How does (i) an increase in the doping concentration and (ii) biasing across the junction, affect the width of the depletion layer?

10. Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light.

11. A monochromatic source of wavelength 600 nm was used in Young's double silt experiment to produce interference pattern. I_1 is the intensity of light at a point on the screen where the path difference is 150 nm. Find the intensity of light at a point where the path difference is 200 nm.

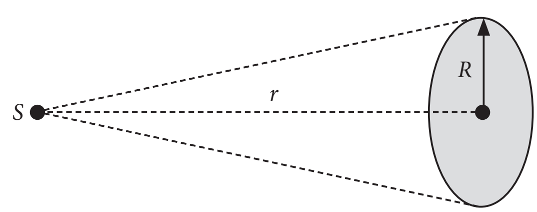
OR

A narrow slit of width 2 mm is illuminated by monochromatic light of wavelength 500 nm. What will be the distance between the first minima on either side on a screen at a distance of 1 m?

SECTION - C

12. CASE STUDY : EXPERIMENTAL STUDY OF PHOTOELECTRIC EFFECT

A point source S of power $P = 6{\cdot}4 \times 10^{-3}$W emits mono energetic photons each of energy 6·0 eV. The source is located at a distance of $r = 0{\cdot}8$ m from the centre of a stationary metallic sphere of work function 3·0 eV and of radius $1{\cdot}6 \times 10^{-3}$ m as shown in figure. The sphere is isolated and initially neutral and photoelectrons are instantly taken away from sphere after emission. The efficiency of photoelectric emission is one for very 10^5 incident photons.



(i) The power received by the sphere through radiations is

(a) $\frac{4R^2}{Pr}$ (b) $\frac{PR^2}{4r^2}$ (c) $\frac{p^2R}{2\pi r}$ (d) $\frac{PR}{4r}$

(ii) Number of photons striking the metal sphere per second is

(a) $6{\cdot}7 \times 10^9$ (b) $3{\cdot}3 \times 10^9$ (c) $6{\cdot}7 \times 10^{10}$ (d) $3{\cdot}3 \times 10^{10}$

(iii) The number of photoelectrons emitted per second is about

(a) $3{\cdot}3 \times 10^4$ (b) $6{\cdot}7 \times 10^4$ (c) $6{\cdot}7 \times 10^{15}$ (d) $3{\cdot}3 \times 10^{15}$

(iv) The photoelectric emission stops when the sphere acquires a potential about

(a) 2 V (b) 3 V (c) 4 V (d) 6 V

(v) If the distance of source becomes double from the centre of the metal sphere then the power received by the sphere

(a) $\frac{PR^2}{4r^2}$ (b) $\frac{PR^2}{16r^2}$ (c) $\frac{PR^2}{4r}$ (d) $\frac{P^2R^2}{16r^2}$

Solution

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1. The rms value of the output voltage at the load resistance, $V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}}$.

2. Given $f = \dfrac{-3R}{4}$,

From lens-maker's formula,

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \Rightarrow \frac{1}{\frac{-3R}{4}} = (\mu - 1)\left[\frac{1}{-R} - \frac{1}{R}\right]$$

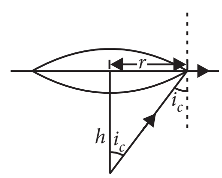
$$\frac{4}{3R} = \frac{2(\mu - 1)}{R} \Rightarrow \mu = \frac{5}{3}$$

It will behave as a converging lens if $(\mu - 1) < 0$ or $\mu < 1$.

OR

Radius,

$$r = h \tan i_c = h \frac{\sin i_c}{\cos i_c}$$



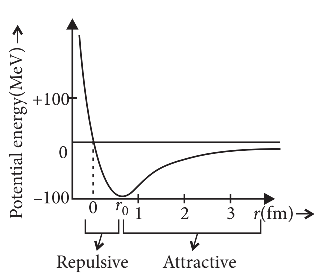
$$r = h \frac{1/\mu}{\sqrt{1 - \frac{1}{\mu^2}}} = \frac{h}{\sqrt{\mu^2 - 1}}$$

3. Here, $n_i = 10^6\ \text{m}^{-3}$,
$n_h = 5 \times 10^{22}\ \text{m}^{-3}$

As $n_e n_h = n_i^2$

$$\therefore\ n_e = \frac{n_i^2}{n_h} = \frac{(10^{16}\,\text{m}^{-3})^2}{5 \times 10^{22}\ \text{m}^{-3}} = 2 \times 10^9\ \text{m}^{-3}$$

4. Plot of potential energy of a pair of nucleons as a function of their separation is given in the figure.



Conclusions: (i) The nuclear force is much stronger than the coulomb force acting between charges or the gravitational forces between masses.

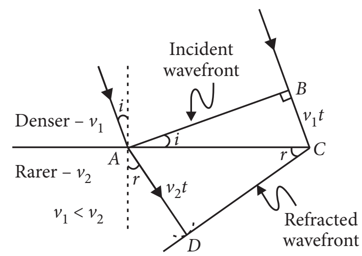
(ii) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few fermies.

(iii) For a separation greater than r_0, the force is attractive and for separation less than r_0, the force is strongly repulsive.

5. Refractive index (μ) : Refractive index of a medium is defined as the ratio of the speed of light in vacuum to the speed of light in that medium. *i.e.*,

$$\mu = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

Given figure shows the refraction of a plane wavefront at a rarer medium *i.e.*, $v_2 > v_1$



Let the angles of incidence and refraction be i and r respectively.

From right ΔABC, we have,

$$\sin \angle BAC = \sin i = \frac{BC}{AC}$$

From right ΔADC, we have,

$$\sin \angle DCA = \sin r = \frac{AD}{AC}$$

$$\therefore\ \frac{\sin i}{\sin r} = \frac{BC}{AD} = \frac{v_1 t}{v_2 t}$$

or $\dfrac{\sin i}{\sin r} = \dfrac{v_1}{v_2} = {}^1\mu_2$ (a constant)

This verifies Snell's law of refraction. The constant ${}^1\mu_2$ is called the refractive index of the second medium with respect to first medium.

6. The refractive index of the material of a prism is

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

where δ_m is the angle of minimum deviation.

Here, $\mu = \sqrt{2},\ A = \delta_m$

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

$$= \frac{2\sin\frac{A}{2}\cos\frac{A}{2}}{\sin\frac{A}{2}} = 2\cos\frac{A}{2}$$

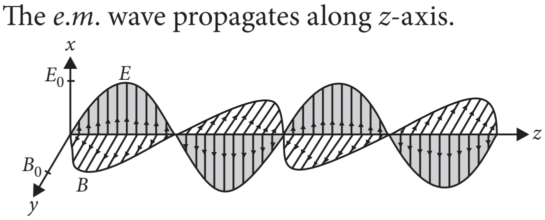
or $\cos\frac{A}{2} = \frac{1}{\sqrt{2}}$ or $\cos\frac{A}{2} = \cos 45°$

or $A = 90°$

7. (a) An oscillating or accelerated charge is supposed to be source of an electromagnetic wave. An oscillating charge produces an oscillating electric field in space which further produces an oscillating magnetic field which in turn is a source of electric field. These oscillating electric and magnetic field hence, keep on regenerating each other and an electromagnetic wave is produced.

(b) Electromagnetic waves or photons transport energy and momentum. When an electromagnetic wave interacts with a small particle, it can exchange energy and momentum with the particle. The force exerted on the particle is equal to the momentum transferred per unit time. Optical tweezers use this force to provide a non-invasive technique for manipulating microscopic-sized particles with light.

(i) The *e.m.* wave propagates along *z*-axis.



For an *e.m.* wave propagating in *Z*-direction, electric field is directed along *X*-axis and magnetic field is directed along *Y*-axis.

$\hat{k} = \hat{i} \times \hat{j}$

8. (i) Since, $E_n = \frac{-13.6}{n^2}$ eV

Energy of the photon emitted during a transition of the electron from the first excited state to its ground state is,

$\Delta E = E_2 - E_1$

$$= \frac{-13.6}{2^2} - \left(\frac{-13.6}{1^2}\right) = \frac{-13.6}{4} + \frac{13.6}{1} = -3.40 + 13.6$$

$= 10.2$ eV

This transition lies in the region of Lyman series.

(ii) (a) The energy levels of H-atom are given by

$$E_n = -\frac{Rhc}{n^2} = -\frac{13.6}{n^2} \text{ eV}$$

For first excited state $n = 2$

$$E_2 = -\frac{13.6}{(2)^2} \text{ eV} = -3.4 \text{ eV}$$

Kinetic energy of electron in ($n = 2$) state is

$K_2 = -E_2 = +3.4$ eV

(b) Radius in the first excited state

$r_1 = (2)^2 (0.53)$ Å

$r_1 = 2.12$ Å

OR

Bohr's quantization condition : The electron revolves around the nucleus only in those orbits for which the angular momentum is an integral multiple of $h/2\pi$.

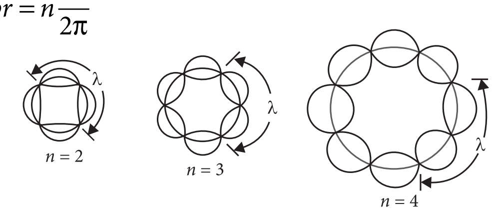
i.e., $L = mvr = n\frac{h}{2\pi}$; $n = 1, 2, 3, ...$

de-Broglie hypothesis may be used to derive Bohr's formula by considering the electron to be a wave spread over the entire orbit, rather than as a particle which at any instant is located at a point in its orbit. The stable orbits in an atom are those which are standing waves. Formation of standing waves require that the circumference of the orbit is equal in length to an integral multiple of the wavelength. Thus, if *r* is the radius of the orbit

$$2\pi r = n\lambda = \frac{nh}{p} \qquad \left(\because \lambda = \frac{h}{p}\right)$$

which gives the angular momentum quantization.

$$L = pr = n\frac{h}{2\pi}$$



9. 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) As reverse voltage supports the potential barrier and effective barrier potential increases. It makes the width of the depletion layer larger.

10. Given : wavelength in air, $\lambda_a = 589$ nm

$= 5.89 \times 10^{-7}$ m

Refractive index of water, $\mu_w = 1.33$

$\because$ speed of light in vacuum, $c = 3 \times 10^8$ m/s

$\therefore$ frequency, $\upsilon = \frac{c}{\lambda_a}$

$$= \frac{3\times10^8 \text{ m/s}}{5.89\times10^{-7} \text{ m}} = 5.093\times10^{14} \text{ Hz}$$

($\because$ speed in air $\approx c$)

Now, speed of light in water, $v = \frac{c}{\mu_w}$

$$= \frac{3\times10^8 \text{ m/s}}{1.33} \approx 2.2605\times10^8 \text{ m/s}$$

$\therefore$ Wavelength in water, $\lambda_w = \frac{v}{\upsilon}$

$$= \frac{\frac{c}{\mu_w}}{\frac{c}{\lambda_a}} = \frac{\lambda_a}{\mu_w} = \frac{5.89\times10^{-7} \text{ m}}{1.33} \approx 4.43 \times 10^{-7} \text{ m}$$

Thus, for the refracted light

Wavelength, $\lambda_w \approx 4.43 \times 10^{-7}$ m

Frequency, $\upsilon = 5.09 \times 10^{14}$ Hz and

Speed, $v \approx 2 \times 10^8$ m/s

11. Path difference $= \frac{\lambda}{4}$; phase difference, $\delta = 90°$

$$I_1 = I_0 \cos^2 \frac{90}{2} = I_0 \times \frac{1}{2} \Rightarrow I_0 = 2I_1$$

Path difference $= \frac{\lambda}{3}$; phase difference, $\delta = 120°$

$$I = I_0 \cos^2 60° = 2I_1 \times \frac{1}{4} = \frac{I_1}{2}$$

OR

Here, $a = 2$ mm $= 2 \times 10^{-3}$ m

$\lambda = 500$ nm $= 500 \times 10^{-9}$ m $= 5 \times 10^{-7}$ m, $D = 1$ m

The distance between the first minima on either side on a screen is

$$= \frac{2\lambda D}{a} = \frac{2\times5\times10^{-7}\times1}{2\times10^{-3}}$$

$= 5 \times 10^{-4}$ m $= 0.5 \times 10^{-3}$ m $= 0.5$ mm

12. (i) **(b) :** Let R be the radius of the metallic sphere and r be its distance from the source S. The power received at the sphere is

$$P' = \frac{P\times\pi R^2}{4\pi r^2} = \frac{PR^2}{4r^2}$$

(ii) **(a):** Number of photons striking the metal sphere per second is

$$n' = \frac{P'}{E} = \frac{6\cdot4\times10^{-9}}{6\cdot0\times1\cdot6\times10^{-19}} = 6\cdot7\times10^9 \text{ s}^{-1}$$

(iii) **(b):** Number of photoelectrons emitted from metal sphere, $\frac{n'}{10^5} = \frac{6\cdot7\times10^{-9}}{10^5} = 6\cdot7\times10^4$

(iv) **(b):** Kinetic energy of the fastest photoelectrons is

$K_{max.} = 6{\cdot}0 - 3{\cdot}0 = 3{\cdot}0$ eV

$\therefore$ Stopping potential, $V_s = \frac{K_{max}}{e} = \frac{3\cdot0\text{eV}}{e} = 3.0$ V

(v) **(b):** When $r = 2r$, then power received by the sphere

$$P'' = \frac{P\pi R^2}{4\pi(2r)^2} = \frac{1}{4}\left(\frac{PR^2}{4r^2}\right)$$