# Sample Question Paper - 18
# 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.** Draw *V-I* characteristics of a *p-n* junction diode. Explain, why the current under reverse bias is almost independent of the applied voltage up to the critical voltage.

**2.** The contribution to the total current in a semiconductor, due to electrons and holes are 0.75 and 0.25 respectively. The drift velocity of electrons is $\frac{3}{2}$ times that of holes at this temperature. Then find the ratio between electron concentration and hole concentration.

**3.** Show that the radius of the orbit in hydrogen atom varies as $n^2$, where $n$ is the principal quantum number of the atom.

**OR**

The short wavelength limit for the Lyman series of the hydrogen spectrum is 913.4 Å. Calculate the short wavelength limit for Balmer series of the hydrogen spectrum.

## SECTION - B

**4.** A particle of mass $m$ moves in circular orbits with potential energy $V(r) = Fr$, where $F$ is a positive constant and $r$ is its distance from the origin. Its energies are calculated using the Bohr model. If the radius of the particle's orbit is denoted by $R$ and its speed and total energy are denoted by $v$ and $E$, respectively, then for the $n^{th}$ orbit find the total energy. (Here $h$ is the Planck's constant.)

**5.** Three photodiodes $D_1$, $D_2$ and $D_3$ are made of semiconductors having band gaps of 2.5 eV, 2 eV and 3 eV respectively. Which one will be able to detect light of wavelength 600 nm?

**6.** A parallel beam of monochromatic light falls normally on a narrow slit of width '*a*' to produce a diffraction pattern on the screen placed parallel to the plane of the slit.
Use Huygens' principle to explain that the central bright maxima is twice as wide as the other maxima.

**7.** (a) Write the conditions under which light sources can be said to be coherent.
(b) Why is it necessary to have coherent sources in order to produce an interference pattern?

(c) Write the conditions on path difference under which (i) constructive (ii) destructive interference occur in Young's double slit experiment.

**OR**

What is a wavefront? How does it propagate? Using Huygens' principle, explain reflection of a plane wavefront from a surface and verify the laws of reflection.

**8.** The fission properties of $^{239}_{94}$Pu are very similar to those of $^{235}_{92}$U. The average energy released per fission is 180 MeV. If all the atoms in 1 kg of pure $^{239}_{94}$Pu undergo fission, then find the total energy released in MeV.

**9.** (a) Light of wavelength 2000 Å falls on a metal surface of work function 4.2 eV. What is the kinetic energy (in eV) of the fastest electrons emitted from the surface?

(b) What will be the change in the energy of the emitted electrons if the intensity of light with same wavelength is doubled?

(c) If the same light falls on another surface of work function 6.5 eV, what will be the energy of emitted electrons?

**10.** How does the refractive index of a transparent medium depend on the wavelength of incident light used? Velocity of light in glass is $2 \times 10^8$ m/s and in air is $3 \times 10^8$ m/s. If the ray of light passes from glass to air, calculate the value of critical angle.

**OR**

An optical instrument uses an objective lens of power 100 D and an eyepiece of power 40 D. The final image is formed at infinity when the tube length of the instrument is kept at 20 cm.

(i) Identify the optical instrument.

(ii) Calculate the angular magnification produced by the instrument.

**11.** (a) Name the constituent radiation of electromagnetic spectrum which is used for

(i) aircraft navigation.

(ii) studying crystal structure.

Write the frequency range for each.

(b) The small ozone layer on top of the stratosphere is crucial for human survival. Why?

## SECTION - C

**12. CASE STUDY : TOTAL INTERNAL REFLECTION**

Total internal reflection is the phenomenon of reflection of light into denser medium at the interface of denser medium with a rarer medium. For this phenomenon to occur necessary condition is that light must travel from denser to rarer and angle of incidence in denser medium must be greater than critical angle ($C$) for the pair of media in contact. Critical angle depends on nature of medium and wavelength of light. We can show that $\mu = \frac{1}{\sin C}$.

(i) Critical angle for glass air interface, where $\mu$ of glass is $\frac{3}{2}$, is

(a) 41.8° (b) 60° (c) 30° (d) 15°

(ii) Critical angle for water air interface is 48.6°. What is the refractive index of water?

(a) 1 (b) $\frac{3}{2}$ (c) $\frac{4}{3}$ (d) $\frac{3}{4}$

(iii) Critical angle for air water interface for violet colour is 49°. Its value for red colour would be

(a) 49° (b) 50° (c) 48° (d) cannot say

(iv) Which of the following is not due to total internal reflection?

(a) Working of optical fibre.

(b) Difference between apparent and real depth of a pond.

(c) Mirage on hot summer days.

(d) Brilliance of diamond.

(v) Critical angle of glass is $\theta_1$ and that of water is $\theta_2$. The critical angle for water and glass surface would be ($\mu_g = 3/2$, $\mu_w = 4/3$).

(a) less than $\theta_2$

(b) between $\theta_1$ and $\theta_2$

(c) greater than $\theta_2$

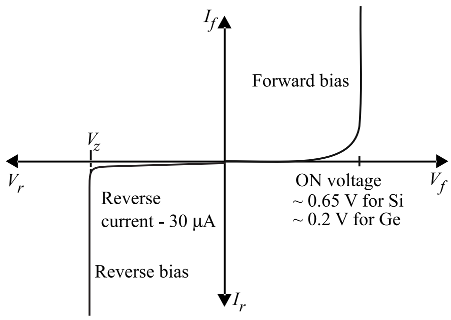
(d) less than $\theta_1$

## Solution

## PHYSICS - 042

## Class 12 - Physics

**1.**




The reverse current is due to minority charge carriers and even a small voltage is sufficient to sweep the minority carriers from one side of the junction to the other side of the junction. Here the current is not limited by the magnitude of the applied voltage but is limited due to the concentration of the minority carrier on either side of the junction.

**2.** $I = I_e + I_h$

Also, $I = neAv$

$\therefore \quad I_h = n_h eAv_h \quad \text{or} \quad \frac{1}{4}I = n_h eAv_h$ ...(i)

Similarly, $\frac{3}{4}I = n_e A v_e e$ ... (ii)

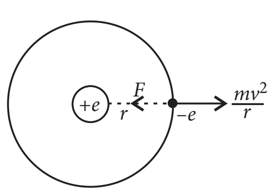
From equation (i) and (ii), we get

$$\frac{3}{1} = \frac{n_e v_e}{n_h v_h} = \frac{n_e}{n_h} \times \frac{3}{2} \qquad \left[\because \frac{v_e}{v_h} = \frac{3}{2}\right]$$

or $\frac{n_e}{n_h} = \frac{2}{1}$

**3.** Radius of $n^{th}$ orbit of hydrogen atom : In H-atom, an electron having charge $-e$ revolves around the nucleus of charge $+e$ in a circular orbit of radius r, such that necessary centripetal force is provided by the electrostatic force of attraction between the electron and nucleus.

*i.e.*, $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e.e}{r^2}$ or $mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$ ...(i)




From Bohr's quantization condition

$mvr = \frac{nh}{2\pi}$ or $v = \frac{nh}{2\pi mr}$ ...(ii)

Using equation (ii) in (i), we get

$$m \cdot \left(\frac{nh}{2\pi mr}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \quad \text{or} \quad \frac{m \cdot n^2h^2}{4\pi^2m^2r^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

or $r = \frac{n^2h^2\varepsilon_0}{\pi me^2}$ ...(iii)

where $n = 1, 2, 3, ...$ is principal quantum number. Equation (iii), gives the radius of $n^{th}$ orbit of H-atom. So the radii of the orbits increase proportionally with $n^2$ *i.e.*, $[r \propto n^2]$. Radius of first orbit of H-atom is called Bohr radius $a_0$ and is given by

$a_0 = \frac{h^2\varepsilon_0}{\pi me^2}$ for $n = 1$ or $a_0 = 0.529$ Å

So, radius of $n^{th}$ orbit of H-atom then becomes $r = n^2 \times 0.529$ Å

**OR**

Short wavelength limit for the Lyman series of the hydrogen atom $\frac{1}{\lambda_{min}} = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$

(As $\lambda_{min} = 913.4$ Å)

$\therefore \quad R = \frac{1}{913.4 \times 10^{-10}}$

Now, short wavelength limit for the Balmer series of the hydrogen atom,

$$\frac{1}{\lambda_{min}} = \frac{1}{913.4 \times 10^{-10}}\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right]$$

or $\frac{1}{\lambda_{min}} = \frac{10^{10}}{4 \times 913.4}$

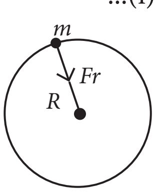
$\therefore \quad \lambda_{min} = 3653.6 \times 10^{-10}\text{m} = 3653.6$ Å

**4.** Given potential energy

$V(r) = Fr$ ...(i)

$\therefore$ The force acting on the particle,

$f = -\frac{dV(r)}{dr} = -F$, which is a constant.




Now, this force provides the necessary centripetal force to the particle to be in its circular orbit. Then

$f = \frac{mv^2}{r}$ ...(ii)

where $v$ is the velocity of the particle.

Now according to Bohr's postulate, the angular momentum of the particle.

$mvr = \frac{nh}{2\pi}$ ...(iii)

From (i), (ii) and (iii), we have

$$v = \left(\frac{nhF}{2\pi m^2}\right)^{1/3}$$

$$\text{and } r = \left(\frac{n^2h^2}{4\pi^2 Fm}\right)^{1/3} \quad \text{...(iv)}$$

$$\Rightarrow \quad v \propto n^{\frac{1}{3}} \text{ and } r \propto n^{\frac{2}{3}}$$

Now, the kinetic energy of the particle

$$K = \frac{1}{2}mv^2 = \frac{Fr}{2} \qquad \left[\because \frac{mv^2}{r} = F\right]$$

and potential energy is given by, $V(r) = Fr$

$\therefore$ The total energy, $E = V(r) + K = \frac{3}{2}Fr$

Substituting the value of $r$ from equation (iv)

$$E = \frac{3}{2}\left(\frac{n^2F^2h^2}{4\pi^2 m}\right)^{1/3}$$

**5. (c) :** Given, $E_1 = 2.5$ eV ; $E_2 = 2$ eV ; $E_3 = 3$ eV

We know that, energy, $E = \frac{hc}{\lambda_{min}}$

where $\lambda_{min} = 600$ nm (given)

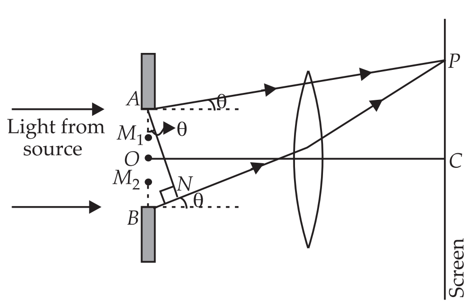
$$\therefore \quad \lambda_1 = \frac{hc}{E_1} = \frac{1242 \text{ eV nm}}{2.5 \text{ nm}} = 4968 \text{ Å}$$

$$\lambda_2 = \frac{hc}{E_3} = \frac{1242 \text{ eV nm}}{2 \text{ nm}} = 6210 \text{ Å}$$

$$\lambda_3 = \frac{hc}{E_3} = \frac{1242 \text{ eV nm}}{3 \text{ nm}} = 4140 \text{ Å}$$

Since $\lambda_{min}$ is 600 nm *i.e.*, 6000 Å, and $\lambda_1$ and $\lambda_3$ are less than $\lambda_{min}$. Thus only diode $D_2$ can detect a light of wavelength 600 nm.

**6.**




Consider a parallel beam of monochromatic light is incident normally on a single slit $AB$ of width $a$ as shown in the figure. According to Huygens principle every point of slit acts as a source of secondary wavelets spreading in all directions. The mid point of the slit is $O$.

A straight line through $O$ perpendicular to the slit plane meets the screen at $C$. At the central point $C$ on the screen, the angle $\theta$ is zero. All path differences are zero and hence all the parts of the slit contribute in phase. This gives maximum intensity at $C$.

Consider a point $P$ on the screen.

The observation point is now taken at $P$.

Secondary minima : Now we divide the slit into two equal halves $AO$ and $OB$, each of width $\frac{a}{2}$. For every point, $M_1$ in $AO$, there is a corresponding point $M_2$ in $OB$, such that $M_1M_2 = \frac{a}{2}$. The path difference between waves arriving at $P$ and starting from $M_1$ and $M_2$ will be $\frac{a}{2}\sin\theta = \frac{\lambda}{2}$.

$a\sin\theta = \lambda$

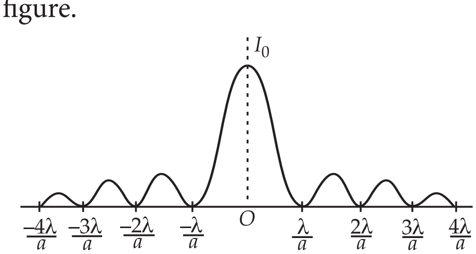
In general, for secondary minima

$a\sin\theta = n\lambda$ where $n = \pm1, \pm2, \pm3$......

Secondary maxima : Similarly it can be shown that for secondary maxima

$$a\sin\theta = (2n+1)\frac{\lambda}{2} \text{ where } n = \pm1, \pm2\text{........}$$

The intensity pattern on the screen is shown in the given figure.




Width of central maximum $= \frac{2D\lambda}{a}$

**7.** (a) : The essential condition, which must satisfied sources to be coherent are :

(i) the two light waves should be of same wavelength.

(ii) the two light waves should either be in phase or should have a constant phase difference.

(b) Because coherent sources emit light waves of same frequency or wavelength and of a stable phase difference.

(c) For constructive interference, Path difference, $\Delta x = n\lambda$ (where $n = 0, 1, 2, ...$)

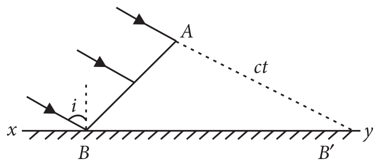
For destructive interference, $\Delta x = \left(n + \frac{1}{2}\right)\lambda$ (where $n = 0, 1, 2, ...$)

**OR**

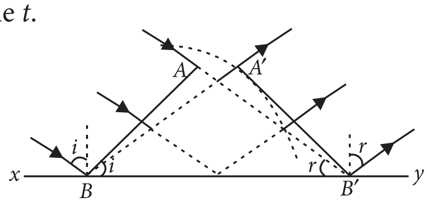
A source of light sends the disturbance in all the directions and continuous locus of all the particles vibrating in same phase at any instant is called as wavefront. Phase speed is the speed with which a wavefront moved outwards from the source.

Laws of reflection by Huygens' principle :

Let us consider a plane wavefront $AB$ incident on the plane reflecting surface $xy$. Incident rays are normal to the wavefront $AB$.




Let in time $t$ the secondary wavelets reaches $B'$ covering a distance $ct$. Similarly from each point on primary wavefront $AB$. Secondary wavelets start growing with the speed $c$. To find reflected wavefront after time $t$, let us draw a sphere of radius $ct$ taking $B$ as center and now a tangent is drawn from $B'$ on the sphere the tangent $B'A'$ represents reflected wavefront after time $t$.




For every point on wavefront $AB$ a corresponding point lie on the reflected wavefront $A'B'$.

So, comparing two triangle $\Delta BAB'$ and $\Delta B'A'B$

We find that

$AB' = A'B = ct$

$BB'$ = common

$\angle A = \angle A' = 90°$

Thus two triangles are congruent, hence $\angle i = \angle r$

This proves first law of reflection.

Also incident rays, reflected rays and normal to them all lie in the same plane. This gives second law of reflection.

**8.** Number of atoms in 1 kg of pure $^{239}$Pu

$$= \frac{6.023\times10^{23}}{239}\times1000 = 2.52\times10^{24}$$

As average energy released per fission is 180 MeV

$\therefore$ Total energy released $= 2.52 \times 10^{24} \times 180$ MeV

$= 4.53 \times 10^{26}$ MeV

**9.** (a) **:** $\lambda = 2000$ Å $= 2000 \times 10^{-10}$ m

$W_0 = 4.2$ eV

$h = 6.63 \times 10^{-34}$ J s

$$\frac{hc}{\lambda} = W_0 + K.E. \text{ or } K.E. = \frac{hc}{\lambda} - W_0$$

$$= \frac{(6.63\times10^{-34})\times(3\times10^8)}{(2000\times10^{-10})}\times\frac{1}{1.6\times10^{-19}}\text{eV} - 4.2\text{ eV}$$

$= (6.2 - 4.2)$ eV $= 2.0$ eV

(b) The energy of the emitted electrons does not depend upon intensity of incident light, hence the energy remains unchanged.

(c) For this surface, electrons will not be emitted as the energy of incident light (6.2 eV) is less than the work function (6.5 eV) of the surface.

**10.** (i) The refractive index of a transparent medium is inversely proportional to the wavelength of incident light. The relationship between the two is given by

$$\mu = \frac{\lambda_0}{\lambda}$$

where

$\mu$ = Refractive index of medium

$\lambda_0$ = Wavelength of incident light in vacuum

$\lambda$ = Wavelength of incident light in medium

(ii) Given :

Velocity of light in air, $v_a = 3 \times 10^8$ m/s

Velocity of light in glass, $v_g = 2 \times 10^8$ m/s

The refractive index of glass is given by, $\mu_g = \frac{c}{v_g}$

where $c$ is speed of light in vacuum.

The refractive index of air is given by, $\mu_a = \frac{c}{v_a}$

$\therefore$ The refractive index of glass w.r.t. air will be

$$^a\mu_g = \frac{\mu_g}{\mu_a} \Rightarrow {}^a\mu_g = \frac{v_a}{v_g} = \frac{3\times10^8}{2\times10^8} = 1.5$$

We know

$$^a\mu_g = \frac{1}{\sin C}$$

where $C$ is the critical angle for the interface

$$\therefore \quad \frac{1}{\sin C} = 1.5 \Rightarrow \sin C = \frac{1}{1.5}$$

$\Rightarrow$ $C = \sin^{-1}(0.66)$ $\Rightarrow$ $C = 41.3°$

$\therefore$ Critical angle, $C = 41.3°$

**OR**

(i) $P_o = 100$ D, $\therefore f_o = 1$ cm, $P_E = 40$ D,

$\therefore$ $f_e = 2.5$ cm.

Since $f_o < f_e$, the instrument is a compound microscope.

(ii) Magnification, $m = \frac{L}{f_0}\left(\frac{D}{F_E}\right) = \frac{20}{1}\left(\frac{25}{2{\cdot}5}\right) = 200$

**11.** (a) (i) Microwaves are used in radar system for aircraft navigation. The frequency range is $3 \times 10^8$ Hz to $3 \times 10^{11}$ Hz.

(ii) X-rays are used for studying crystals structure of solids. Their frequency range is $3 \times 10^{16}$ Hz to $3 \times 10^{21}$ Hz.

(b) The small ozone layer on the top of the atmosphere is crucial for human survival because it absorbs harmful ultraviolet radiations present in sunlight and prevents it from reaching the earth's surface. These radiations can penetrate our skin and can cause harmful diseases like skin cancer etc.

**12.** (i) **(a) :** $\sin C = \frac{1}{\mu} = \frac{1}{3/2} = \frac{2}{3} = 0.6667$

$C = \sin^{-1}(0.6667) = 41.8°$

(ii) **(c) :** $\mu = \frac{1}{\sin C} = \frac{1}{\sin 48.6} = \frac{1}{0.75} = \frac{4}{3}$

(iii) **(c) :** From $\mu = \frac{1}{\sin C}$, $\sin C = \frac{1}{\mu}$

As $\mu_v > \mu_r \quad \therefore \quad C_v < C_r$

The correct alternative may be (c).

(iv) **(b) :** Difference between apparent and real depth of a pond is due to refraction. Other three are due to total internal reflection.

(v) **(c) :** As ${}^{w}\mu_g < {}^{a}\mu_w < {}^{a}\mu_g; \; \therefore \theta > \theta_2 > \theta_1$