Sample Question Paper - 8
Physics (042)
Class- XII, Session: 2021-22
TERM II

Time Allowed: 2 hours **Maximum Marks: 35**

General Instructions:

1. There are 12 questions in all. All questions are compulsory.
2. This question paper has three sections: Section A, Section B and Section C.
3. 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.
4. 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.
5. You may use log tables if necessary but use of calculator is not allowed.

Section A

1. i. Why is a photodiode operated in reverse bias mode? For what purpose is a photodiode used? **[2]**
   ii. Draw its I-V characteristics for different intensities of illumination.

2. Use de-Broglie's hypothesis to write the relation for the nth radius of Bohr orbit in terms of Bohr's quantization condition of orbital angular momentum. **[2]**

   OR

   Find the number of photons emitted per minute by a 25 W source of monochromatic light of wavelength 5000 $\overset{o}{\mathrm{A}}$.

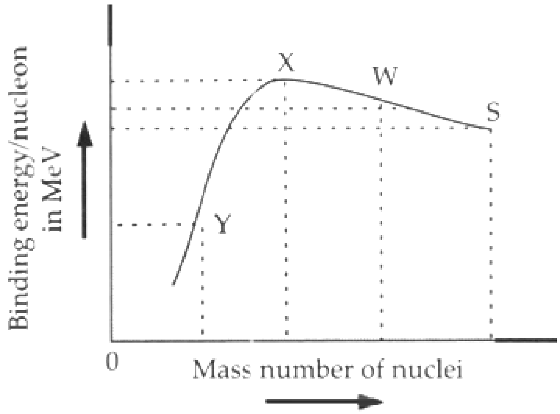
3. Distinguish between a metal and an insulator on the basis of energy band diagram. **[2]**

Section B

4. Using Rydberg formula, calculate the wavelengths of the first four spectral lines in the Balmer series of hydrogen atom spectrum. **[3]**

5. i. Why are photodiodes preferably operated under reverse bias when the current in the forward bias is known to be more than that in reverse bias? **[3]**
   ii. The two optoelectronic devices: Photodiode and solar cell, have the same working principle but differ in terms of their process of operation.
   Explain the difference between the two devices in terms of (i) biasing, (ii) junction area and (iii) I-V characteristics.

6. Binding energy per nucleon versus mass number curve is as shown. ${}_{Z}^{A}S,\ {}_{Z1}^{A1}W,\ {}_{Z2}^{A2}X$, and ${}_{Z3}^{A3}Y$ are four nuclei indicated on the curve. **[3]**



Based on the graph:

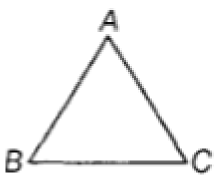
i. Arrange X, W, and S in the increasing order of stability.
ii. Write the relation between the relevant A and Z values for the following nuclear reaction. S $\rightarrow$ X + W
iii. Explain why binding energy for heavy nuclei is low.

7. Define the term wavefront. State Huygen's principle. Consider a plane wavefront incident on a thin convex lens. Draw a proper diagram to show how the incident wavefront traverses through the lens and after refraction focusses on the focal point of the lens, giving the shape of the emergent wavefront. **[3]**

8. A small bulb is placed at the bottom of a tank containing water to a depth of 80 cm. What is the area of the surface of water through which light from the bulb can emerge out? Refractive index of water is 1.33. (Consider the bulb to be a point source.) **[3]**

OR

i. A ray of light incident on the 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.



9. **[3]**
   a. Draw a plot showing the variation of photoelectric current with collector potential for different frequencies but same intensity of incident radiations.
   b. Use Einstein's photoelectric equation to explain the observations from this graph.
   c. What change will you observe if the intensity of incident radiation is changed but the frequency remains the same?

10. A 4.5 cm needle is placed 12 cm away from a convex mirror of focal length 15 cm. Give the location of the image and the magnification. Describe what happens as the needle is moved farther from the mirror. **[3]**

11. Identify the type of waves which are produced by the following way and write one application for each: **[3]**

i. Radioactive decay of the nucleus.
ii. Rapid acceleration and decelerations of electrons in aerials.
iii. Bombarding a metal target by high energy electrons.

OR

In a Young's double-slit experiment, red light of wavelength 6000 $\overset{\circ}{A}$ is used and the nth bright fringe is obtained at a point P on the screen. Keeping the same setting, the source is replaced by the green light of 5000 $\overset{\circ}{A}$ and now (n + 1)th bright fringe is obtained at the point P. Calculate the value of n.

CASE STUDY

12. **Read the source given below and answer the following questions:** **[5]**

An astronomical telescope is an optical instrument which is used for observing distinct images of heavenly bodies libe stars, planets etc. It consists of two lenses. In normal adjustment of telescope, the final image is formed at infinity. Magnifying power of an astronomical telescope in normal adjustment is defined as the ratio of the angle subtended at the eye by the angle subtended at the eye by the final image to the angle subtended at the eye, by the object directly, when the final image and the object both lie at infinite distance from the eye. It is given by, $m = \frac{f_0}{f_e}$. To increase magnifying power of an astronomical telescope in normal adjustment, focal length of objective lens should be large and focal length of eye lens should be small.

i. An astronomical telescope of magnifying power 7 consists of the two thin lenses 40 cm apart, in normal adjustment. The focal lengths of the lenses are
   a. 5 cm, 35 cm
   b. 7 cm, 35 cm
   c. 17 cm, 35 cm
   d. 5 cm, 30 cm

ii. An astronomical telescope has a magnifying power of 10. In normal adjustment, distance between the objective and eye piece is 22 cm. The focal length of objective lens is
   a. 25 cm
   b. 10 cm
   c. 15 cm
   d. 20 cm

iii. In astronomical telescope compare to eye piece, objective lens has
   a. negative focal length
   b. zero focal length
   c. small focal length
   d. large focal length

iv. To see stars, use
   a. simple microscope
   b. compound microscope
   c. endoscope
   d. astronomical telescope

v. For large magnifying power of astronomical telescope
   a. $f_0 << f_e$

b. $f_o = f_e$

c. $f_o >> f_e$

d. none of these

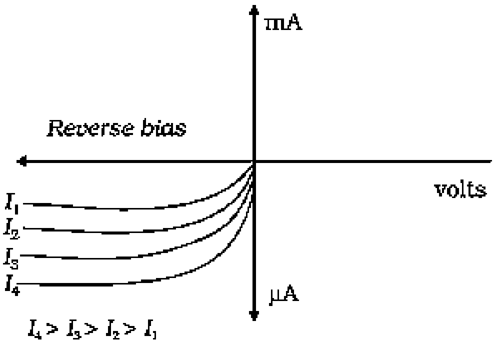
Solution

PHYSICS - 042

Class 12 - Physics

Section A

1. i. A photodiode is always operated in reverse bias. It is because saturation current during reverse bias increases linearly with the increase of the intensity of light. As such, the change in reverse current is directly proportional to the change in the intensity of light and it can be easily measured. Photodiode is used as an optical detector.
   ii. A typical I-V characteristics is shown in the Fig.

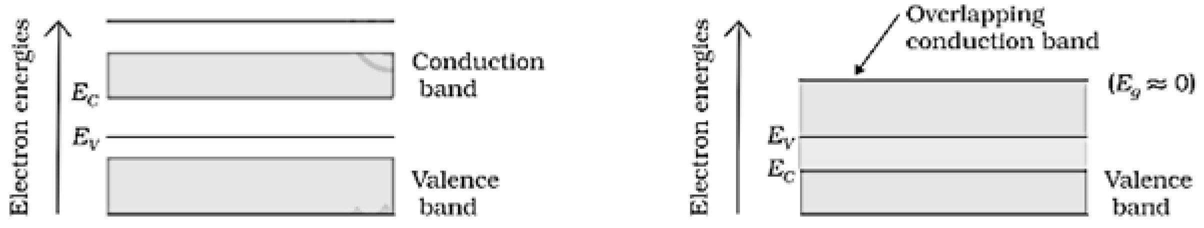


2. According to Bohr's postulates,
$mvr = \frac{nh}{2\pi}$.........(1) (where, mvr =angular momentum of an electron and n is an integer).
Also, the centripetal force, mv^2 /r (experienced by the electron) is due to the electrostatic attraction, $\frac{kZe^2}{r^2}$
where, Z= atomic number of the atom.
Therefore, $\frac{mv^2}{r} = \frac{kZe^2}{r^2}$
Substituting the value of v^2 from Eq. (i), we obtain
$\frac{m}{r} \cdot \frac{n^2h^2}{4\pi^2m^2r^2} = \frac{kZe^2}{r^2}$
$\therefore r = \frac{n^2h^2}{4\pi^2mkZe^2}$

OR

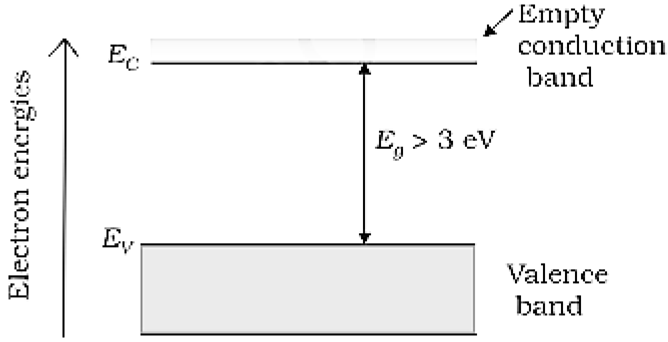
Time t = 60s, P = 25 W, λ = 5000 $\mathring{A}$ = 5000 $\times$ 10^{-10}
The energy of a photon, $E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})\times(3\times10^8)}{5000\times10^{-10}}$
= 3.97 $\times$ 10^{-9} J
Energy emitted by 25 W source per minute
Pt = 25 $\times$ 25 $\times$ 60 = 1500 J
Number of photons emitted per minute
$n = \frac{1500}{3.97\times10^{-19}}$ = 3.78 $\times$ 10^{21}

3. **Metals:** The energy band structure in solids have two possibilities:
(i) The valence band may be completely filled and the conduction band partially filled with an extremely small energy gap between them [Fig a(i)]
(ii) The valence band is completely filled and the conduction band is empty but the two overlap each other [Fig a(ii)].
In both situations, it can be assumed that there is a single energy band, which is partially filled. Therefore, on applying even a small electric field, the metals conduct electricity.



(i) (ii)
(a)

Insulators: In insulators, as shown in Fig. (b), a large band gap E_g exists (E_g > 3 eV). There are no electrons in the conduction band, and therefore no electrical conduction is possible. Note that the energy gap is so large that electrons cannot be excited from the valence band to the conduction band by thermal excitation.



(b)

Section B

4. The Rydberg formula is $E=E_0Z^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

$\frac{hc}{\lambda}=E_0Z^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

E_0 = -13.6 eV = $-13.6\times1.6\times10^{-19}J=-21.76\times10^{-19}J$

$\frac{hc}{\lambda_{n_{12}}}=21.76\times10^{-19}\left[\frac{1}{2^2}-\frac{1}{n_1^2}\right]$

$\therefore\lambda_{n_{12}}=\frac{hc}{21.76\times10^{-19}\times\left(\frac{1}{4}-\frac{1}{n_1^2}\right)}$

$\lambda_{n_{12}}=\frac{6.63\times10^{-34}\times3\times10^8\times4n_1^2}{21.76\times10^{-19}\times(n_1^2-4)}$

$\lambda_{n_{12}}=\frac{3.653n_1^2}{(n_1^2-4)}\times10^{-7}m=\frac{3653n_1^2}{(n_1^2-4)}\overset{o}{A}$

The wavelengths of the first four lines in the Balmer series correspond to transitions from n_1 = 3, 4, 5, 6, to n_2 = 2.

Substituting n_1 = 3, 4, 5, and 6, we get

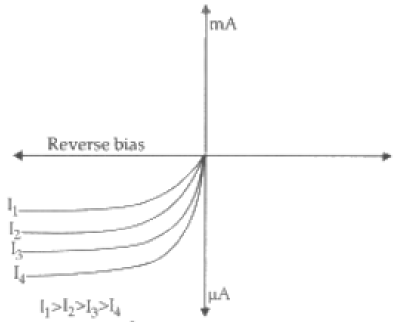
$\lambda_{32}=6575\overset{o}{A},\lambda_{42}=4870\overset{o}{A}$

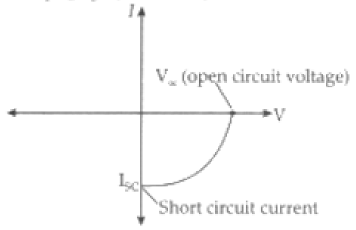
$\lambda_{52}=4348\overset{o}{A}$ and $\lambda_{62}=4109\overset{o}{A}$

5. i. The fractional change in majority charge carriers is very less compared to the fractional change in minority charge carriers on illumination.
   OR
   In reverse bias condition, the width of the depletion region increases which reduces the capacitance across the junction. Hence, the response time for absorption of photon increase which increases the sensitivity of photodiode which is required by it.
   ii. The difference in the working of two devices

	Photodiode	Solar cell
(i) Biasing	Used in reverse biasing	No external biasing is given
(ii) Junction Area	Small	Large for solar radiation to be incident on it.

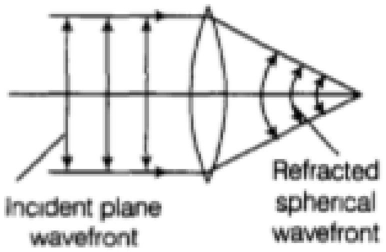
I-V characteristics

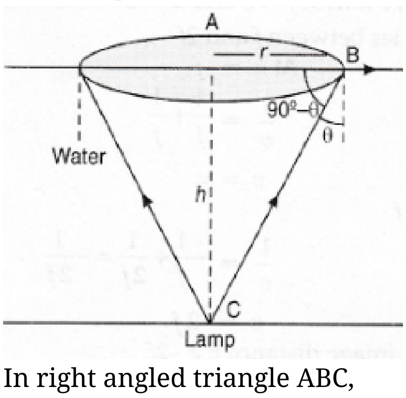




6. i. S, W, X
   ii. Relation between A and Z is given by : Z = Z_1 + Z_2

   A = A_1 + A_2
   iii. **Reason for low binding energy:** In heavier nuclei, the Colombian repulsive effects can increase considerably and can match/ offset the attractive effects of the nuclear forces. This can result in such nuclei being unstable.
7. When light is emitted from a source, then the particles present around it begins to vibrate. The locus of all such particles which are vibrating in the same phase is termed as wavefront.
   Huygens' principle: Every point on a wave-front may be considered a source of secondary spherical wavelets which spread out in the forward direction at the speed of light. The new wave-front is the tangential surface to all of these secondary wavelets.
   Now when a plane wavefront (parallel rays) is incident on a thin convex lens, the emergent rays are focused on the focal point of the lens. Thus the shape of emerging wavefront is spherical.



8. 

In right angled triangle ABC,

$\tan(90^\circ - \theta) = \frac{h}{r} \Rightarrow \cot\theta = \frac{h}{r}$ .... (i)

where h is the depth of water and r is the radius of a water surface.

Given: $\mu = \frac{4}{3}$, h = 80 cm = 0.8 m

Now, $\mu = \frac{1}{\sin\theta}$

$\therefore \quad \sin\theta = \frac{3}{4}$

$\cot\theta = \frac{\sqrt{7}}{3}$

From eqn. (i),

$\frac{\sqrt{7}}{3}=\frac{0.8}{r}$

$\Rightarrow$ r = 0.9 m

Surface area (A) = πr^2

$=3.14\times0.9^2$

= 2.5 m^2

OR

i. Given, angle of minimum deviation, $\delta_m=30^\circ$

$\therefore$ Angle of prism, A = 60^0

By prism formula

$\mu=\frac{\sin\frac{\delta m+A}{2}}{\sin A/2}=\frac{\sin\frac{30^\circ+60^\circ}{2}}{\sin 30^\circ}=\frac{\sin 45^\circ}{\sin 30^\circ}$

$=\frac{1}{\sqrt{2}}\times2=\sqrt{2}$

Also, $\mu=\frac{\text{speed of light in vacuum }(c)}{\text{speed of light in prism }(y)}$

$\Rightarrow v=\frac{c}{\mu}=\left(\frac{3\times10^8}{\sqrt{2}}\right)$ = 2.12 $\times$ 10^8 m/s

ii. Critical angle i_c is given as,

$\sin i_c=\frac{1}{\sqrt{2}}$ [$\because \sin i_c=\frac{1}{\mu}$]

$\Rightarrow i_c=45^o$

$A=r+i_c=60^o$

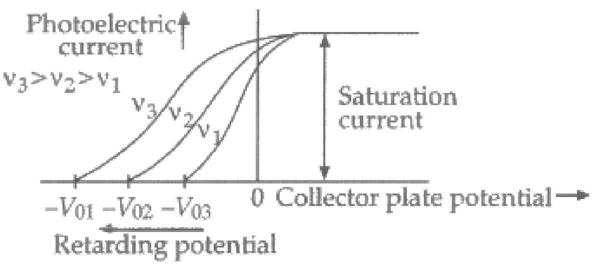
$\Rightarrow r=60^o-45^o=15^o$

$\frac{\sin i}{\sin r}=\mu=\sqrt{2}$ (using Snell's law)

$\Rightarrow \sin i=\sqrt{2}\sin r=\sqrt{2}\times\sin 15^o$

$i=\sin^{-1}(\sqrt{2}\sin 15^o)=21.47^o$

9. a. Fig. shows the variation of photoelectric current with collector plate potential for different frequencies of incident radiations.



b. According to Einstein’s photoelectric equation

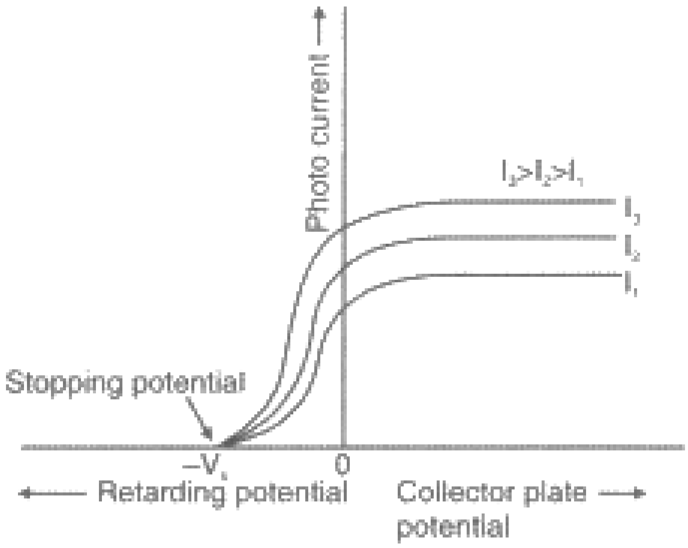
$K_{max}=h\nu-\phi_0$

If V_0 is stopping potential then

$eV_0=h\nu-\phi_0$

Thus, for different values of frequency (ν) there will be different values of cut off potential V_0.

c.



10. u = -12 cm, f = +15 cm, O = 4.5 cm

As, $\frac{1}{u}+\frac{1}{v}=\frac{1}{\text{f}}$

$\frac{1}{v}=\frac{1}{\text{f}}-\frac{1}{u}=\frac{1}{15}+\frac{1}{12}=\frac{4+5}{60}=\frac{9}{60}$

$v=\frac{60}{9}=6.7cm$

i.e., image is formed 6.7 cm behind the convex mirror. It must be virtual and erect.

As, $m=\frac{I}{O}=-\frac{v}{u}$

$\therefore\frac{I}{4.5}=\frac{6.7}{-12}$ or $I=\frac{6.7\times4.5}{12}$ = 2.5 cm

$\therefore$ Image is erect, and virtual.

As the needle is moved farther from the mirror, image moves away from the the mirror till it is at focus F of the mirror. The size of the image goes on decreasing.

11.

S.No.	Type of wave	Applications
(i)	Gamma rays	Treatment of tumors
(ii)	Radio waves	Radio and television Communication system
(iii)	X-rays	Study of crystals , **X-ray** therapy to destroy diseased cells.

OR

Let x be the distance of point P from the centre of the screen.

When red light (λ = 6000 $\overset{\circ}{A}$) is used, nth bright fringe is obtained at point P

$\therefore\quad x=\frac{nD\lambda}{d}=\frac{nD\times6000\times10^{-10}}{d}$

When green light (λ' = 5000 $\overset{\circ}{A}$) is used, (n + 1)th bright fringe is obtained at the same point P

$\therefore\quad x=\frac{(n+1)D\lambda'}{d}=\frac{(n+1)D\times5000\times10^{-10}}{d}$

Equating the two values of x, we get

$\frac{nD\times6000\times10^{-10}}{d}=\frac{(n+1)D\times5000\times10^{-10}}{d}$

or 6n = 5(n + 1)

or n = 5

CASE STUDY

12. i. (a): $m=\frac{f_o}{f_e}=7$

$f_o=7f_e$

In normal adjustment, distance between the lenses, $f_o+f_e=40$

$7f_o+f_e=40\Rightarrow f_e=\frac{40}{8}=5\text{ cm}$

$f_o=7f_e=7\times5=35\text{ cm}$

ii. (d): m = -10 ; L = 22 cm

As $m = \frac{-f_o}{f_e} \Rightarrow -10 = -\frac{f_o}{f_e}$

$f_o = 10f_e$

As $L = f_o + f_e$

$22 = 10f_e + f_e = 11f_e$

or $f_e = \frac{22}{11} = 2cm$

$f_o = 10f_e = 20cm$

iii. (d): Objective lens has larger focal length than eye-piece.

iv. (d): Astronomial telescope is used to see stars, sun etc.

v. (c) : $f_o \gg f_e$