Sample Question Paper - 4
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. What is solar cell? How does it work? Give one of its uses. **[2]**

2. Obtain the first Bohr's radius and the ground state energy of a muonic hydrogen atom [i.e. an atom in which a negatively charged muon (μ^{-}) of mass about 207 m_e orbits around a proton]. **[2]**

OR

Draw a graph between the frequency of incident radiation (ν) and the maximum kinetic energy of the electrons emitted from the surface of a photosensitive material. State clearly how this graph can be used to determine (i) Planck's constant and (ii) work function of the material.

3. A 10 V zener diode along with a series Resistance is connected across a 40 V supply. Calculate the minimum value of the resistance required, if the maximum zener current is 50 mA. **[2]**

Section B

4. In the study of Geiger-Marsden experiment on the scattering of particles by a thin foil of gold, draw the trajectory of α-particles in the Coulomb field of the target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study. **[3]**

5. Explain, with the help of a circuit diagram, the working of a photo-diode. Write briefly how it is used to detect the optical signals. Draw its I-V characteristics. **[3]**

6. Calculate the binding energy per nucleon (in MeV) for ${}_{2}^{4}He$ and ${}_{3}^{4}He$. Comment on the difference of these binding energies and its significance in relation to α-decay of the nuclei. [Given: mass of ${}_{1}^{1}H$ =1.00783 u, mass of ${}_{0}^{1}n$= 1.00867 u, mass of ${}_{2}^{3}He$ = 3.01664 u, mass of ${}_{2}^{4}He$ = 4.00387 u] **[3]**

7. A beam of light consisting of two wavelengths $6500\overset{o}{A}$ and $5200\overset{o}{A}$, is used to obtain interference fringes in a Young's double slit experiment. **[3]**

i. Find the distance of the third bright fringe on the screen from the central maximum for wavelength $6500\overset{o}{A}$.

ii. What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?The distance between the slits is 2 mm and the distance between the plane of the slits and the screen is 120 cm.

8. A person with a normal near point (25 cm) using a compound microscope with objective of focal length 8.0 mm and an eye piece of focal length 2.5 cm can bring an object placed 9.0 mm from the objective in sharp focus. What is the separation between the two lenses? Calculate the magnifying power of the microscope. **[3]**

OR

At what angle should a ray of light be incident on the face of a prism of refracting angle 60° so that it just suffers total internal reflection at the other face? The refractive index of the material of the prism is 1.524

9. An electron and a proton are accelerated through the same potential. Which one of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less momentum? Justify your answer. **[3]**

10. Draw a labelled ray diagram to show the image formation in a refracting type astronomical telescope in the normal adjustment position. Write two drawbacks of refracting type telescopes. **[3]**

11. Suppose that the electric field amplitude of an electromagnetic wave E_0 = 120 NC^{-1} and that its frequency is ν = 50.0 MHz. **[3]**

i. Determine, B_0, ω, k, and λ.

ii. Find expressions for E and B.

OR

In a single slit diffraction experiment, a slit of width d is illuminated by red light of wavelength 650 nm. For what value of d will

i. the first minimum fall is at an angle of diffraction of 30°and

ii. the first maximum fall is at an angle of diffraction of 30°?

CASE STUDY

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

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 θ_1 and that of water is θ_2. The critical angle for water and glass surface would be $(\mu_g = 3/2, \mu_w = 4/3)$.

a. less than θ_2
b. between θ_1 and θ_2
c. greater than θ_2
d. less than θ_1

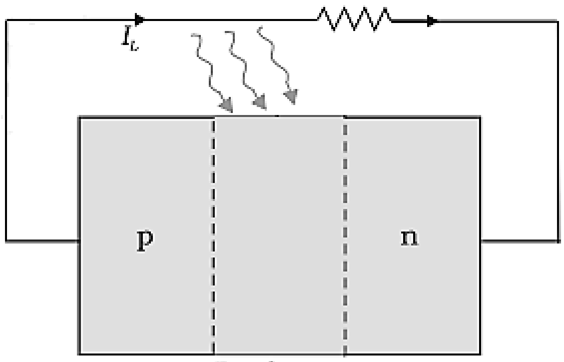
Solution

PHYSICS - 042

Class 12 - Physics

Section A

1. A solar cell is basically a p-n junction which generates emf when solar radiation falls on the p-n junction. A typical illuminated p-n junction solar cell is shown in the Figure.



The generation of emf by a solar cell, when light falls on, it is due to the following three basic processes: generation, separation and collection—
(i) generation of e-h pairs due to light (with $h\nu > E_g$) close to the junction;
(ii) separation of electrons and holes due to electric field of the depletion region. 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 becomes negative giving rise to photovoltage.
When an external load is connected as shown in the Fig., a photocurrent I_L flows through the load.

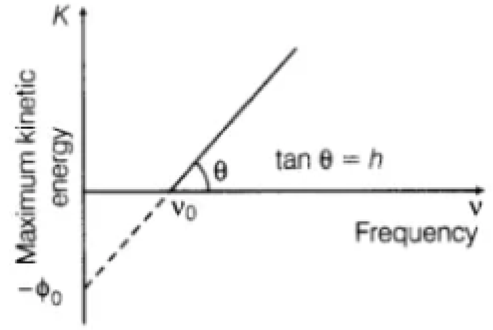
Solar cells are used to power electronic devices in satellites and space vehicles and also as power supply to some calculators.

2. A mounic hydrogen is the atom in which a negatively charged muon of mass about 207 m_e revolves around a proton.
In Bohr's atom model as, $r \propto \frac{1}{m}$
$\frac{r_\mu}{r_e} = \frac{m_e}{m_\mu} = \frac{m_e}{207 m_e} = \frac{1}{207}$
Here r_e is radius of first orbit of electron in hydrogen atom = 0.53 $\mathring{A}$= 0.53 $\times$ 10^{-10} m
$r_\mu = \frac{r_e}{207} = \frac{0.53 \times 10^{-10}}{207} = 2.56 \times 10^{-13} m$
Again in Bhor's atomic model,
$E \propto m$
$\therefore \frac{E_\mu}{E_e} = \frac{m_\mu}{m_e} = \frac{207 m_e}{m_e}, E_\mu = 207 E_e$
As ground state energy of electron in hydrogen atom is E_e = -13.6 eV
E_μ = 207(-13.6) eV = -2815.2 eV = -2.8152 KeV

OR

Kinetic energy of photoelectrons emitted from the surface of a photosensitive material,
$KE_{max} = h\nu - \phi_0$
A graph is shown between the frequency of incident radiation (ν) and the maximum kinetic energy of the

electrons emitted from the surface of a photosensitive material.



i. So the graph between K_{max} and ν is a straight line as shown in Figure. From this graph, the Planck constant can be calculated by the slope of the current.

Slope of $K_{max}-\nu$ graph = $\frac{\triangle K_{max}}{\triangle \nu}$ = h

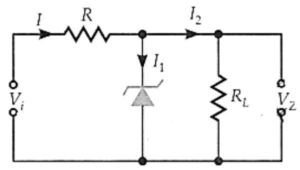
ii. Work function is the minimum energy required to eject the photo-electron from the metal surface,

$\phi_0 = h\nu_0$, where ν_0 = Threshold frequency

Now, Intercept on the negative K_{max} axis = ϕ_0

Thus, Intercept on the negative K_{max} axis gives the value of work function.

3. In figure, V_i = 40 V, I_1 = 50 mA



∴ Maximum current,

$I = I_1 + I_2 = 50 + 0 = 50 \text{ mA} = 50 \times 10^{-3} \text{A}$

This is because maximum current flows through zener diode, so $I_2 = 0$.

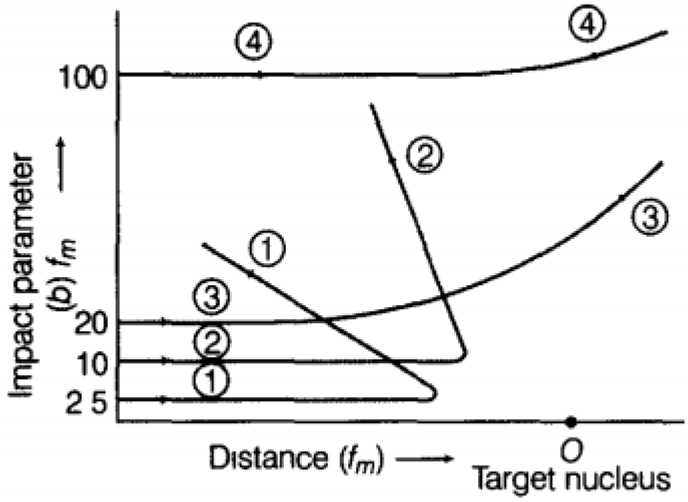
V_z = Voltage drop across zener diode = 10 V

As I is maximum, so maximum value of R is

$R = \frac{V_i - V_z}{I} = \frac{40-10}{50\times10^{-3}} = 600\ \Omega$

Section B

4. The trajectory of α-particles in the Coulomb field of the target nucleus is shown below:



From this experiment, the following is observed.

1. Most of the α-particles pass straight through the gold foil. It means that they do not suffer any collision with gold atoms.
2. About one α-particle in every 8000 α-particles deflect by more than 90°. As most of the α-particles go undeflected and only a few get deflected, this shows that most of the space in an atom is empty. Thus, with the help of these observations regarding the deflection of a-particles, the size of the nucleus was predicted.

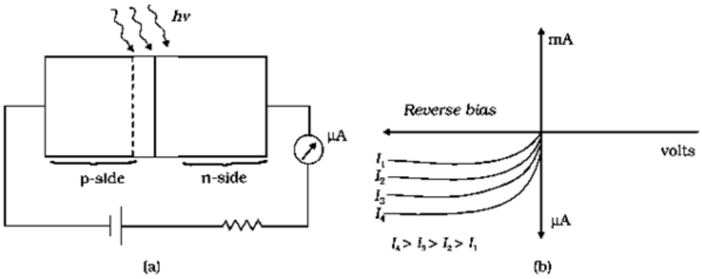
At the distance of head on approach, the entire kinetic energy of α-particle is converted into electrostatic potential energy. This distance of head on approach gives an upper limit of the size of nucleus (denoted by r_0) and is given by:

$E_k = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{r_0}$

$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{E_k}$

This is about 10^{-14}m.

5. A Photodiode is again a special purpose p-n junction diode fabricated with a transparent window to allow light to fall on the diode. It is operated under reverse bias. When the photodiode is illuminated with light (photons) with energy ($h\nu$) greater than the energy gap (E_g) of the semiconductor, then electron-hole pairs are generated due to the absorption of photons. The diode is fabricated such that the generation of e-h pairs takes place in or near the depletion region of the diode. Due to electric field of the junction, electrons and holes are separated before they recombine. The direction of the electric field is such that electrons reach n-side and holes reach p-side. Electrons are collected on n-side and holes are collected on p-side giving rise to an emf. When an external load is connected, current flows. The magnitude of the photocurrent depends on the intensity of incident light (photocurrent is proportional to incident light intensity).
The circuit diagram used for the measurement of I-V characteristics of a photodiode is shown in Fig. (a) and a typical I-V characteristics in Fig. (b).



It is easier to observe the change in the current with the change in the light intensity if a reverse bias is applied. Thus photodiode can be used as a photodetector to detect optical signals.

6. B.E. of ${}_2^4\text{He} = \left[2m_p + 2m_n - m\left({}_2^4\text{He}\right)\right] \times c^2$
= [2 × 1.00783 + 2 × 1.00867 - 4.00387] 931 MeV
= [4.03390 - 4.00387] 931 = 0.02933 931 MeV
= 27.30623 MeV
BE. per nucleon of ${}_2^4\text{He}$
$= \frac{27.30623}{4}$ = 6.83 MeV
B.E. of ${}_2^3\text{He}$
= $\left[2m_p + m_n - m\left({}^3\text{He}\right)\right] c^2$
= [2 × 1.00783 + 1.00867 - 3.01664] × 931 MeV
= 0.00769 × 931 MeV = 7.16 MeV
B.E. per nucleon of ${}_2^3\text{He}$
$= \frac{7.16}{3} = 2.39\text{MeV}$
As the binding energy per nucleon of ${}_2^4\text{He}$ is larger than that of ${}_2^3\text{He}$, so unstable heavy nuclei prefer to get stabilised through α-decay.

7. i. The distance of the mth bright fringe from the central maximum is given by
$y_m = \frac{m\lambda D}{d}$
$\therefore y_3 = \frac{3\lambda D}{d} = \frac{3\times(6500\times10^{-10})\times1.20}{2\times10^{-3}}$
$= 1.17 \times 10^{-3} m$ = 1.17 mm
ii. Let the nth bright fringe of wavelength λ_n and the mth bright fringe of wavelength λ_m coincide at a distance y from the central maximum, then
$y = \frac{m\lambda_m D}{d} = \frac{n\lambda_n D}{d}$
or $\frac{m}{n} = \frac{\lambda_m}{\lambda_n} = \frac{6500}{5200} = \frac{5}{4}$
The least integral value of m and n which satisfy the above condition are
m = 5 and n = 4

i.e. the 5 th bright fringe of wavelength 5200$\overset{o}{A}$ coincides with the 4^{th} bright fringe of wavelength 6500$\overset{o}{A}$.

The smallest value of y at which this happens is:

$y_{min} = \frac{m\lambda_m D}{d} = \frac{5\times(5200\times10^{-10})\times1.20}{2\times10^{-3}}$

$= 1.56 \times 10^{-3} m$ = 1.56 mm

8. Here, u_0 = -0.9 cm, f_0 = 0.8 cm

As, $\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$

$\therefore \frac{1}{v_0} = \frac{1}{f_0} + \frac{1}{u_0} = \frac{1}{0.8} - \frac{1}{0.9} = \frac{1}{7.2}$

or v_0 = 7.2 cm

Now for the eyepiece, we have

f_e = 2.5 cm, v_e = -25 cm, u_e = ?

$\therefore \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = -\frac{1}{25} - \frac{1}{2.5} = -\frac{11}{25}$

or $u_e = -\frac{25}{11} = -2.27cm$

Separation between the two lenses

$= v_0 + |u_e|$

= 7.2 + 2.27 = 9.47 cm

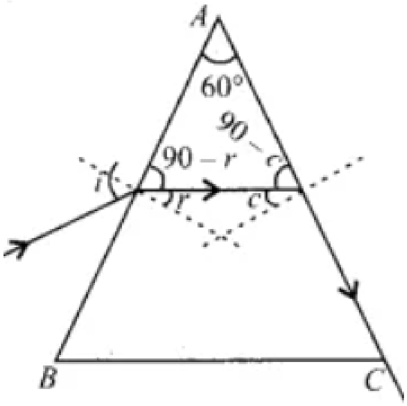
Magnifying power, $M = M_0 \times M_e$

$M = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right) = \frac{7.2}{0.9}\left(1 + \frac{25}{2.5}\right)$

$= 8 \times 11 = 88$

OR

The beam should be incident at critical angle or more than critical angle, for total internal reflection at second surface of the prism.



Let us first find critical angle for air glass interface.

We know

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

$C = \sin^{-1}\left(\frac{1}{a\mu_g}\right) = \sin^{-1}\left(\frac{1}{1.524}\right)$

Critical angle C = 41^o

Now we can calculate 'r', as the refracted ray in the prism is incident on the second face at critical angle i_c. thus,

$60^o + (90^o - r) + (90^o - C) = 180^o$

or , r = 19^o

Using Snell's law, required angle of incidence i at first surface can be calculated.

${}^a\mu_g = \frac{\sin i}{\sin r}$ or $1.524 = \frac{\sin i}{\sin 19^\circ}$

sin i = 1.524 (sin 19^o)

sin i = 1.524 $\times$ 0.3256 $\Rightarrow i \cong 29.75^\circ$

9. i. From de-Broglie equation,

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$

As, $p=\sqrt{2mK}$ and K = qV

$\Rightarrow \quad \lambda=\frac{h}{\sqrt{2mqV}}$ ....(i)

$\lambda \propto \frac{1}{\sqrt{mq}}$

Ratio of wavelengths of electron and proton,

$\frac{\lambda_e}{\lambda_p}=\sqrt{\left(\frac{m_p}{m_e}\right)\left(\frac{q_p}{q_e}\right)}$

Ratio of mass of proton and electron,

$\frac{m_p}{m_e}=1836$ (constant)

$\frac{q_p}{q_e}=1$ (Both electron and proton have same charge)

$\Rightarrow \quad \frac{\lambda_e}{\lambda_p}=\sqrt{1836\times 1}$

$\lambda_e \approx 42.8\lambda_p$ nearly

Electron have greater wavelength associated with it than that of proton.

ii. $\because \quad \lambda=\frac{h}{p}$ (de-Broglie equation)

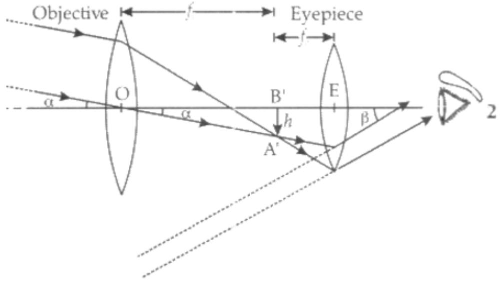
$\Rightarrow \quad p=\frac{h}{\lambda}\Rightarrow p\propto\frac{1}{\lambda}\Rightarrow\frac{p_e}{p_p}=\frac{\lambda_p}{\lambda_e}$

Now,

$\frac{\lambda_p}{\lambda_e}=\frac{1}{42.8}\Rightarrow \quad \frac{p_e}{p_p}=\frac{\lambda_p}{\lambda_e}=\frac{1}{42.8}$

Momentum of proton is nearly 42.8 times to that of momentum of electron. Thus, electron will have less momentum.

10. **Ray diagram:**



Drawbacks:

i. Large-sized lenses area heavy and difficult to support.
ii. Large-sized lenses suffer from chromatic and spherical aberration.
iii. It is difficult and expensive to make such large-sized lenses.

11. i. Given, E_0 = 120 NC^{-1}, ν = 50.0 MHz = 50 × 10^6 Hz

a. $B_0=\frac{E_0}{c}=\frac{120}{3\times10^8}$ = 4 × 10^{-7} T = 400 nT

b. $\omega=2\pi\nu$ = 2 × 3.14 × 50 × 10^6 = 3.14 × 10^8 rad s^{-1}

c. $k=\frac{2\pi}{\lambda}=\frac{2\pi\nu}{c}=\frac{3.14\times10^8}{3\times10^8}$ = 1.047 rad m^{-1}

d. $\lambda=\frac{2\pi}{k}=\frac{2\times3.14}{1.047}$ = 6 m

ii. Let electromagnetic wave travel along x-axis, where $\vec{E}$ and $\vec{B}$ are along y-axis and z-axis respectively.

Then $E_y=E_0\sin(kx-\omega t)$

= 120 sin (1.05x - 3.14 × 10^8t) NC^{-1}

$B_z=B_0\sin(kx-\omega t)$

= 400 sin (1.05x - 3.14 × 10^8t) NC^{-1}

where x and t are in metre and second respectively.

OR

i. In single slit diffraction pattern, first minimum occurs at $d\sin\theta=\lambda$ [θ and λ are diffraction angle and wavelength of the light used]

$\therefore$ Slit width, $d=\frac{\lambda}{\sin\theta}$....(a)

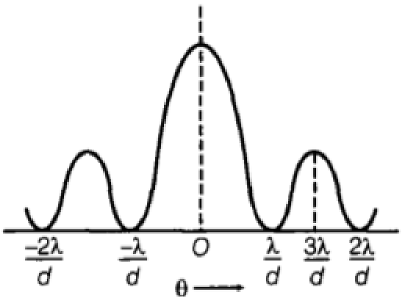
Given, $\lambda=650\times10^{-9}\text{m}\ and\ \theta=30^\circ$

Now from equation (a) we get slit width, $d = \frac{650\times10^{-9}}{\sin 30^\circ} = \frac{650}{(1/2)} \times 10^{-9}$

$= 1300 \times 10^{-9}$ m

$\therefore d = 1.3 \times 10^{-6}\text{m} = 1.3\ \mu m$

ii. In single slit diffraction pattern, maximum and minima occurs as per the below diagram -



Now for first maximum,

$d\sin\theta = \frac{3\lambda}{2}\left[using,\ d\sin\theta = (2n+1)\frac{\lambda}{2}\right]$

where, n = 1(for first maximum)

$\Rightarrow \quad d = \frac{3\lambda}{2\sin\theta}$

where, $\theta = 30^\circ, \lambda = 650 \times 10^{-9}\text{m}$

$\therefore d = \frac{3\lambda}{2\sin\theta}$

$= \frac{3\times650\times10^{-9}}{2\times\sin 30^\circ}$

$= 1950 \times 10^{-9}\text{m}$

$\therefore d = 1.95 \times 10^{-6}\text{m} = 1.95\ \mu m$

CASE STUDY

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

$C = \sin^{-1}(0.6667) = 41.8^\circ$

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

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 ${}^w\mu_g < {}^a\mu_w < {}^a\mu_g; \therefore \theta > \theta_2 > \theta_1$