CBSE Board
Class XII Physics
Sample Paper - 5
Term 2 – 2021-22

Time: 2 hours **Total 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 meant by the term doping of an intrinsic semiconductor? How does it affect the conductivity of a semiconductor? [2]

2. Explain how the maximum kinetic energy of electrons emitted from a metal surface varies with the frequency of incident radiation. [2]

OR

What is the ratio of radii of the orbits corresponding to the first excited state and ground state in a hydrogen atom? [2]

3. Which of the ones between silicon and germanium preferred in the manufacturing of semiconductor devices? Why? [2]

SECTION - B

4. What is the main feature of Rutherford's atom model and state the drawbacks of Rutherford's atom model? [3]

5. In Young's double-slit experiment using monochromatic light of wavelength λ, the intensity at a point on the screen where the path difference is λ is K units. What is the intensity of light at a point where the path difference is $\lambda/3$? [3]

6. Why does photoelectric emission not take place if the frequency of incident radiation is less than the threshold value? [3]

7. In the fusion reaction ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1$, the masses of deuteron, helium and neutron expressed in amu are 2.015, 3.017 and 1.009, respectively. If 1 kg deuterium undergoes complete fusion, find the amount of total energy released. [3]

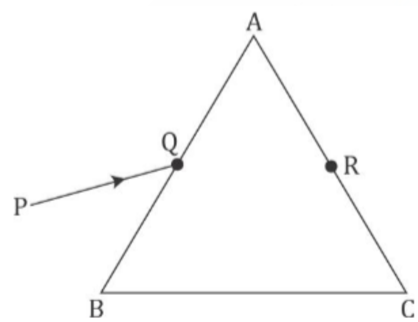
8.

a) Why does light appear to travel in a straight line despite its wave nature?

b) Two students are separated by a 7m partition wall in a room 10m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily? [3]

OR

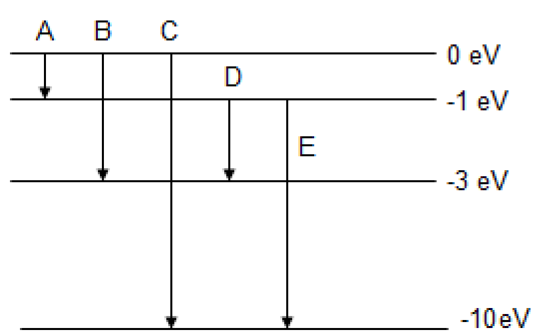
a) A ray PQ incident on the face AB of a prism ABC, as shown in the figure, emerges from the face AC such that AQ = AR.



Draw the ray diagram showing the passage of the ray through the prism.

b) If the angle of the prism is 60° and the refractive index of the material of the prism is $\sqrt{3}$, determine the values of angle of incidence and angle of deviation. [3]

9. The energy levels of an atom of an element are shown in the following diagram. Which one of the level transitions will result in the emission of photons of wavelength 620 nm? Support your answer with mathematical calculations. [3]



10. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept 15 cm apart. A point object is placed 40 cm in front of the convex lens. Find the position of the image formed by this combination. Draw the ray diagram showing the image formation. [3]

11.

a) An astronomical telescope consists of two thin lenses set 36 cm apart and has a magnifying power of 8. Calculate the focal length of the lenses.

b) A giant refracting telescope at an observatory has an objective lens of focal length 15 cm. If an eyepiece of focal length 1.0 cm is used, what is the angular magnification of the telescope? If this telescope is used to view the Moon, what is the diameter of the image of the Moon formed by the objective lens? The diameter of the Moon is 3.48×10^6 m, and the radius of the lunar orbit is 3.8×10^8 m. [3]

OR

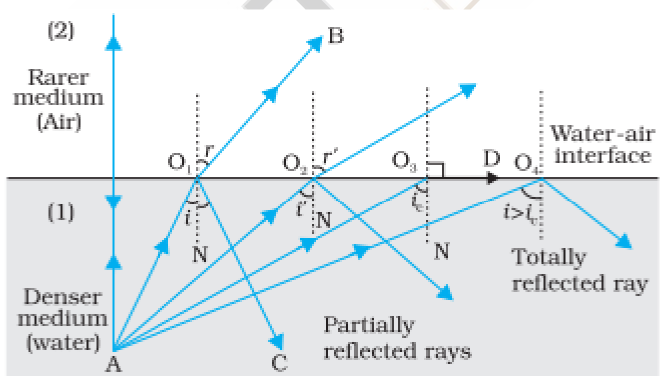
a) Explain the phenomenon of total internal reflection.

b) State two conditions that must be satisfied for total internal reflection to occur.

c) Derive the relation between the critical angle and the refractive index of the medium.

SECTION – C

12. Consider a ray of light that travels from a denser medium to a rarer medium. As the angle of incidence increases in the denser medium, the angle of refraction in the rarer medium increases. The angle of incidence for which the angle of refraction becomes 90^0 is called the critical angle.



$$\frac{\text{Sinc}}{\text{Sin}90^0} = \frac{\mu_1}{\mu_2} \Rightarrow \text{SinC} = \frac{\text{Refractive index of rarer medium}}{\text{Refractive index of rarer medium}}$$

When the angle of incidence of a ray travelling from a denser medium to a rarer medium is greater than the critical angle, no refraction occurs. The incident ray is totally reflected back into the same medium. Here, the laws of reflection hold good. Some light is also reflected before the critical angle is achieved but not totally. [5]

1. Find the maximum angle that can be made in glass medium (μ=1.5) if a light ray is refracted from glass to vacuum

a. $\text{Sin}^{-1}\frac{3}{2}$
b. $\text{Sin}^{-1}\frac{4}{3}$
c. $\text{Sin}^{-1}\frac{2}{3}$
d. None of these

2. Following are the application of Total Internal Reflection, **EXCEPT**:
   a. Brilliance of diamond
   b. Phenomenon Mirage
   c. Transmission of signals using optical fibre
   d. Dispersion produced by a thin prism

3. Which of the following is the necessary condition for the Phenomenon of Total Internal Reflection?
   a. Light must incident on the interface from a denser medium.
   b. The angle of incidence must be greater than the critical angle.
   c. The angle of incidence is such that the angle of refraction is 90^0
   d. Both a and b

4. Considering the figure shown in the passage, when light travels from denser medium to rarer medium, the ray becomes parallel to the surface after refraction when
   a. $i=i_c$
   b. $i=90^0$
   c. $i=r$
   d. $i>i_c$

5. Considering the figure shown in the passage, when light travels from denser medium to rarer medium, the maximum deviation of the ray is achieved at
   a. $i=i_c$
   b. $i=90^0$
   c. $i=r$
   d. None of these

Solution

SECTION-A

Ans 1.
Doping of an Intrinsic Semiconductor: The mixing of a small amount of pentavalent (e.g., phosphorus) or trivalent (e.g., aluminium) substance as an impurity in a pure semiconductor (e.g., Ge, Si) is called doping.
Doping increases, the conductivity of a semiconductor.

Ans 2.
According to Einstein, when a photon of incident light strikes a bound electron of metal, its energy is used in two ways:
(i) In overcoming the work function of the metal to free metallic electrons
(ii) In imparting kinetic energy to this freed electron,
i.e., $h\nu = w + E_k$
When $E_k = 0$, $\nu = \nu_0$ (threshold frequency),
$h\nu_0 = w + 0$
$w = h\nu_0$
Therefore, $h\nu = h\nu_0 + E_k$
$E_k = h(\nu - \nu_0)$
So, as the frequency of incident radiation ν increases, the maximum KE of photoelectrons also increases.

OR

The radius of the nth orbit is given as
$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h^2}{2\pi}\right)\frac{4\pi\epsilon_0}{e^2}$
For the ground state, n=1
For excited state, n=2
So the ratio between radii of the first orbital and the ground state radii is 4.

Ans 3.
Silicon is preferred to germanium in the manufacture of semiconductor devices (e.g., semiconductor diode, transistor, etc.) due to the following reasons: -
i. The leakage current in silicon is very small as compared to that of germanium.
ii. The working temperature of silicon is more than that of germanium. The structure of germanium will be destroyed at a temperature of about 1000C.
However, silicon can be operated up to about 200 °C.

SECTION - B

Ans 4.

Rutherford's atom is an electrically neutral sphere consisting of a very small, massive and positively charged nucleus at the centre surrounded by revolving electrons in their respective orbits. The electrostatic force provides the required centripetal force.

The main drawbacks are given below:

- He could not explain properly the distribution of the electrons around the nucleus.
- An electron revolving in a circular orbit is an example of accelerated motion. As per classical physics, a particle in accelerated motion must radiate energy. Consequently, the energy of electrons goes on decreasing and ultimately falls into the nucleus. Hence, he couldn't explain the stability of the atom.
- According to it, we should obtain radiation of all possible wavelengths whereas in actual practice atomic spectrum is line spectrum. He couldn't explain the origin of the line spectrum.

Ans 5.

Intensity is $I = 4I_0 \cos^2 \Phi/2$

When the path difference is λ, the phase difference is 2π.

$I = 4I_o \cos^2\pi = 4 I_o = K$

When path difference is $\Delta = \lambda /3$, then the phase difference will be

$\phi' = 2\pi\frac{\Delta}{\lambda}$

$= 2 \pi \times \lambda/3\lambda = 2\pi/3$

Hence, the intensity at a point where the path difference is λ/3 is

$I' = 4I_0 \cos^2 2\pi /6$ …. $(\because K = 4I_0)$

$= K \cos^2 \pi/3 = K \times \{1/2\}2 = (¼) K$

Ans 6.

According to Einstein's photoelectric equation,

$(1/2)\ mv^2_{max} = h\ f - h\ f_0$

where m = mass of the electron

f = frequency of incident radiation

f_0 = threshold frequency

If the frequency of incident radiation is less than the threshold value ($f < f_0$), the KE of the emitted electron is negative, i.e. photoelectric emission will not take place no matter how large the intensity of incident radiation.

Ans 7.

1 amu = 931.5 MeV

$\Delta m = 2(2.015) - (3.017 + 1.009) = 0.004$ amu

Hence, energy released per deuteron = $\frac{0.004\times931.5}{2} = 1.863\ MeV$

The number of deuterons in 1 kg $=\frac{N_A}{2} = \frac{6.023}{2}\times10^{26}$

Energy released = $(3.01 \times 10^{26}) \times (1.863 \times 10^{6}) \times (1.6 \times 10^{-19})$ J = 9.0×10^{13} J

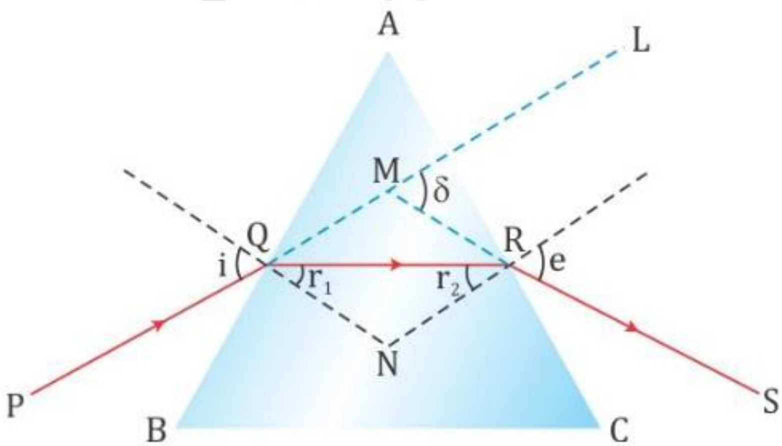
Ans 8.

a) When a portion of a wave is obstructed by an obstacle or aperture, diffraction occurs, which depends upon the size of the obstacle or aperture which in turn is related to the wavelength of the wave. If the aperture or obstacle is large compared with the wavelength, the bending of waves is not noticeable and the wave propagates in the straight line. Since the wavelength of light (4000 $\overset{0}{\mathrm{A}}$ to 8000 $\overset{0}{\mathrm{A}}$) is very small as compared with the size of ordinary objects and apertures, diffraction of light is not easily noticeable and hence light appears to travel in a straight line.

b) For a diffraction effect size of the aperture or object should be comparable to the wavelength of the wave. In the present example, the size of the obstacle is of the order of a few meters whereas the wavelength of light is about 6000 A $=6 \times 10^{-7}$m.
Therefore, the diffraction of light is almost zero. However, for audible sound waves of frequency 1 kHz, the wavelength is $\lambda = \frac{v}{\nu} = \frac{332\ \mathrm{m\,s^{-1}}}{1000\ \mathrm{Hz}} = 0.332\mathrm{m}$. As a result, the sound waves can bend around the partition and students sitting on opposite sides of the partition wall can converse freely.

OR

a) Given that side AQ = AR. This implies that ∠AQR = ∠ARQ.
The ray diagram for the refraction of ray PQ passing through the prism ABC is as shown below.



As the ray PQ after refraction from surface AB emerges from face AC at point R of the prism, it implies that the refracted ray QR travels parallel to the base of the prism. This happens at the minimum deviation position.
So, according to the angle of minimum deviation formula, we have

$$\mu = \frac{\sin\frac{(A+\delta m)}{2}}{\sin\frac{A}{2}}$$

Where A is the angle of the prism, δ_m is the angle of minimum deviation and μ is the refractive index of prism.

b)

Given,

A = 60°

n = $\sqrt{3}$

Now,

$\mu = \frac{\sin\frac{(A+\delta_m)}{2}}{\sin\frac{A}{2}} \Rightarrow \sqrt{3} = \frac{\sin\frac{(60°+\delta_m)}{2}}{\sin\frac{60°}{2}}$

$\therefore \sqrt{3} \times \sin 30° = \sin\frac{(60°+\delta_m)}{2}$

$\sin^{-1}\frac{\sqrt{3}}{2} = \frac{(60°+\delta_m)}{2}$

$120° = (60° + \delta_m)$

$\therefore \delta_m = 60°$

Thus, the angle of minimum deviation = 60°.

At the minimum deviation position,

$i = \frac{A+\delta_m}{2}$

We know, A = 60°, δ_m = 60°

Substituting we get:

$i = \frac{60+60}{2} = 60°$

Ans 9.

The energy of the photon of wavelength λ is $E = \frac{hc}{\lambda}$

Here, λ = 620 nm = 620 x 10^{-9} m

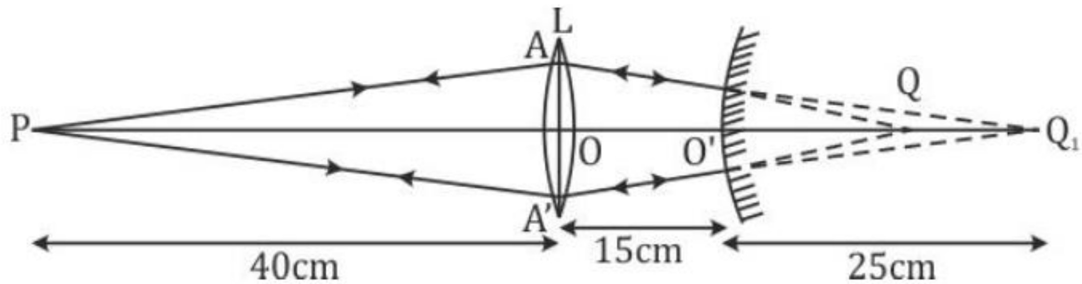
$$E = \frac{hc}{\lambda} = \frac{6.62 \text{x} 10^{-34} \text{x} 3 \text{x} 10^{8}}{620 \text{x} 10^{-9}} \text{J}$$

$$= \frac{6.62 \text{x} 10^{-34} \text{x} 3 \text{x} 10^{8}}{620 \text{x} 10^{-9} \text{x} 1.6 \text{x} 10^{-19}} \text{eV} = 2\text{eV}$$

Transition D will result in the emission of photons of wavelength 620 nm.

Ans 10.

The ray diagram for the image formed by the combination of lens and mirror is shown below.



For the convex lens, we have

u = -40 cm and f = +20 cm

Now,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$\therefore \frac{1}{v}=\frac{1}{20}-\frac{1}{40}=\frac{1}{40}$$

i.e., v = +40 cm

If only the lens was present, then the image would have formed at Q1. But now this image acts as a virtual object for the convex mirror such that

$O'Q_1$ = distance of virtual object from convex mirror = $OQ_1 - OO'$ = 40 – 15 = 25 cm.

Hence for the convex mirror

u_2 = +25 cm and R = +20 cm

Now, by using mirror formula we get

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{v}=\frac{2}{R}-\frac{1}{u}\ldots\left(\because f=\frac{R}{2}\right)$$

$$\frac{1}{v}=\frac{2}{20}-\frac{1}{20}=\frac{1}{20}$$

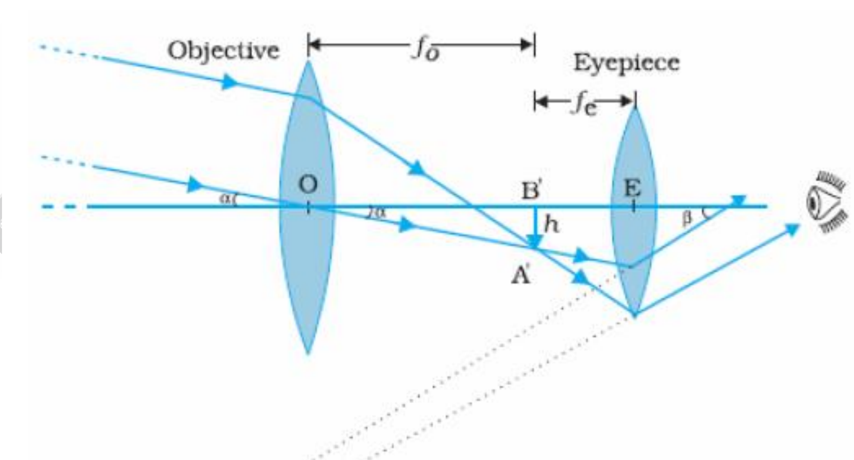
$$\therefore v=+20\ cm$$

Hence, the final image is formed at Q which is 20 cm behind the mirror.

Ans 11.

a)

Given:



Magnification, m = f_o /f_e and length of the tube, $f_o + f_e$ = L

8 = f_o / f_e and $f_o + f_e$ = 36

Hence, $8f_e + f_e$ = 36

Or f_e = 4 cm

Therefore, f_o = 32 cm

b)

Angular magnification

$$m = \frac{15}{0.01} = 1500$$

Let diameter of image be d. Then,

$$\frac{d}{1500} = \frac{3.48\times10^6}{3.8\times10^8}$$

$$\Rightarrow d = 13.7cm$$

OR

a) Total Internal Reflection: It is the phenomenon of the reflection of light rays back to the denser medium when they are incident on the boundary of a denser and rarer medium at an angle of incidence greater than the critical angle.

b) **Conditions for total internal reflection:**

- Light rays should go from the denser medium to the rarer medium.
- The angle of incidence should be greater than the critical angle i_c where

$$\text{Sin } i_c = \frac{1}{\mu}$$

c) Then the rays are internally reflected.

for angle $i = i_c$

$r = 90^0$

$${}_2\mu_1 = \frac{\sin i}{\sin r} = \frac{\sin i_c}{\sin 90^0}$$

$$\Rightarrow \quad {}_1\mu_2 = \frac{1}{\sin i_c}$$

SECTION – C

Ans 12.

1. Correct answer c: $\text{Sin}^{-1}\frac{2}{3}$

The maximum angle of refraction from denser medium to rarer medium is the critical angle Hence,

$1.5\times\sin C = 1x \text{ Sin}90^0$

$\sin C = \frac{2}{3}$

$C = Sin^{-1}\left(\frac{2}{3}\right)$

2. Correct answer d: Dispersion produced by thin prism

This phenomenon arises because the refractive index varies with wavelength. It has been observed for a prism that μ decreases with an increase in the wavelength $\mu_{blue} > \mu_{red}$.

3. Correct answer d: Both a and b.

The necessary condition for the Phenomenon of Total Internal Reflection: Light must incident on the interface from a denser medium. The angle of incidence must be greater than the critical angle.

4. Correct answer a: $i=i_c$

The rays become parallel to the surface when the angle of incidence is equal to the critical angle for that given pair of media.

5. Correct answer a: $i=i_c$

The figure shows the deviation of light travelling from denser medium to rarer medium. As the angle of incidence increases the deviation δ would increase and it reaches its maxima at $i=i_c$.