# Sample Question Paper - 5
# Physics (042)
# Class- XII, Session: 2021-22
# TERM II

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

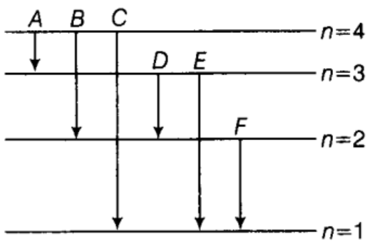
**General Instructions:**

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. Write two points of difference between intrinsic and extrinsic semiconductors. **[2]**

2. The figure shows energy level diagram of hydrogen atom. **[2]**




i. Find out the transition which results in the emission of a photon of wavelength 496 nm.
ii. Which transition corresponds to the emission of radiation of maximum wavelength? Justify your answer.

OR

Given: $m_n = 1.675 \times 10^{-27} kg$. Obtain the de-Broglie wavelength associated with thermal neutrons at room temperature (27°C). Hence explain why a fast neutron beam needs to be thermalised with the environment before it can be used for neutron diffraction experiments?

3. A semiconductor has equal electron and hole concentration of $6 \times 10^8$ m$^{-3}$. On doping with certain impurity, electron concentration increases to $9 \times 10^{12}$ m$^{-3}$. **[2]**

i. Identify the new semiconductor obtained after doping.
ii. Calculate the new hole concentration.
iii. How does the energy gap vary with doping?

**Section B**

4. The ground state energy of hydrogen atom is -13.6eV **[3]**

i. What is the potential energy of an electron in the 3rd excited state?

ii. If the electron jumps to the ground state from the 3rd excited state, calculate the wavelength of the photon emitted.

5. State the reason, why the photodiode is always operated under reverse bias. Write the working principle of operation of a photodiode. The semiconducting material used to fabricate a photodiode, has an energy gap of 1.2 eV. Using calculations, show whether it can detect light of wavelength of 400 nm incident on it. **[3]**

6. i. Why is the binding energy per nucleon found to be constant for nuclei in the range of mass number (A) lying between 30 and 170? **[3]**

ii. When a heavy nucleus with mass number A = 240 breaks into two nuclei, A = 120, energy is released in the process.

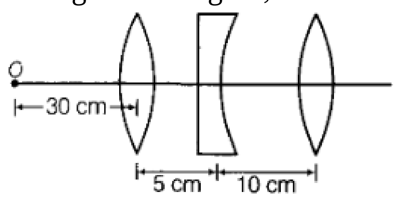
iii. In β-decay, the experimental detection of neutrinos (or antineutrinos) is found to be extremely difficult.

7. White light is incident on a soap film at an angle of $\sin^{-1}\frac{4}{5}$ and the reflected light on examination by the spectroscope shows dark bands. The consecutive dark bands correspond to wavelengths 6100 $\overset{\circ}{A}$ and 6000 $\overset{\circ}{A}$. If the refractive index of the film is $\frac{4}{3}$, calculate its thickness. **[3]**

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

OR

Find the position of the image formed of the object O by the lens combination is given in the figure having focal lengths, f = +10 cm, -10 cm, and 30 cm respectively.




9. i. Why photoelectric effect cannot be explained on the basis of wave nature of light? Give reasons. **[3]**

ii. Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

10. a. With the help of a ray diagram, show how a concave mirror is used to obtain an erect and magnified image of an object. **[3]**

b. Using the above ray diagram, obtain the mirror formula and the expression for linear magnification.

11. Name the parts of the electromagnetic spectrum which is **[3]**

i. suitable for RADAR systems in aircraft navigations.

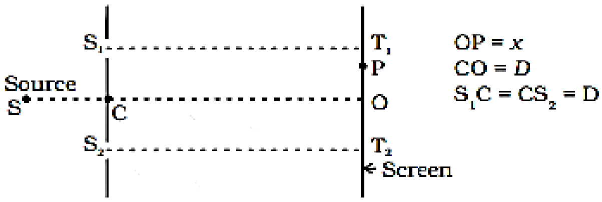
ii. used to treat muscular strain.

iii. used as a diagnostic tool in medicine.

Write in brief, how these waves can be produced.

OR

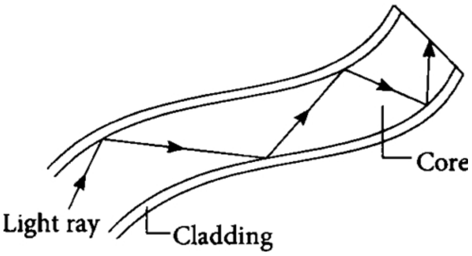
Consider a two-slit interference arrangements (Figure) such that the distance of the screen from the slits is half the distance between the slits. Obtain the value of D in terms of λ such that the first minima on the screen fall at a distance D from the center O.




**CASE STUDY**

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

An optical fibre is a thin tube of transparent material that allows light to pass through, without being refracted into the air or another external medium. It make use of total internal reflection. These fibres are fabricated in such a way that light reflected at one side of the inner surface strikes the other at an angle larger than critical angle. Even, if fibre is bent, light can easily travel along the length.

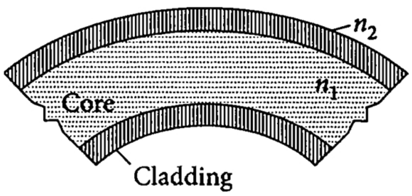



i. Which of the following is based on the phenomenon of total internal reflection of light?
   a. Sparkling of diamond
   b. Optical fibre communication
   c. Instrument used by doctors for endoscopy
   d. All of these

ii. A ray of light will undergo total internal reflection inside the optical fibre, if it
   a. goes from rarer medium to denser medium
   b. is incident at an angle less than the critical angle
   c. strikes the interface normally
   d. is incident at an angle greater than the critical angle

iii. If in core, angle of incidence is equal to critical angle, then angle of refraction will be
   a. 0°
   b. 45°
   c. 90°
   d. 180°

iv. In an optical fibre (shown), correct relation for refractive indices of core and cladding is




   a. $n_1 = n_2$
   b. $n_1 > n_2$

c. $n_1 < n_2$

d. $n_1 + n_2 = 2$

v. If the value of critical angle is 30° for total internal reflection from given optical fibre, then speed of light in that fibre is

a. $3 \times 10^8 \text{ m s}^{-1}$
b. $1.5 \times 10^8 \text{ m s}^{-1}$
c. $6 \times 10^8 \text{ m s}^{-1}$
d. $4.5 \times 10^8 \text{ m s}^{-1}$

# Solution

## PHYSICS - 042

## Class 12 - Physics

### Section A

1.

| | Intrinsic Semiconductor | Extrinsic Semiconductor |
|---|---|---|
| 1 | Pure semiconductors not doped with any impurity atoms | Semiconductors are doped with trivalent or pentavalent impurity atoms. |
| 2 | $n_e = n_h$ | $n_e \neq n_h$ |

2. i. According to the question,
   Given, $\lambda$ = 496 nm = $496 \times 10^{-9}$ m
   $\because E = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{496 \times 10^{-9}}$J$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{496 \times 10^{-9} \times 1.6 \times 10^{-19}} = 2.5$eV
   This equals (nearly) the difference ($E_4$ - $E_2$). Hence, the required transition is (n = 4) to (n = 2)
   ii. Energy of emitted photon is given by,
   $E = \frac{hc}{\lambda} \therefore \lambda_{\max} \propto \frac{1}{E_{\mathrm{mm}}}$
   The transition n = 4 to n = 3 corresponds to emission of radiation of maximum wavelength. It is so because this transmission gives out the photon of least energy.

OR

Here, T = 27 + 273 = 300 K
Boltzmann's constant, k $= 1.38 \times 10^{-23} J\ mol^{-1} K^{-1}$
We know, average K.E. of neutron at absolute temperature T is given by $E = \frac{3}{2} kT$ where k is the Boltzmann's constant.
Now, $\lambda = \frac{h}{\sqrt{2m_n E}} = \frac{h}{\sqrt{3m_n kT}}$
$\therefore \lambda = \frac{6.63 \times 10^{-34}}{\sqrt{3 \times 1.675 \times 10^{-27} \times 1.38 \times 10^{-23} \times 300}} = 1.45 \times 10^{-10} m$
Since this wavelength is comparable to interatomic spacing $(\sim 1\overset{o}{A})$ in a crystal, therefore, thermal neutrons are a suitable probe for diffraction experiments. So a high energy neutron beam should be first thermalised before using it for diffraction.

3. i. As the electron concentration increases after doping, so the new semiconductor obtained is of n-type.
   ii. As $n_e\ n_h = n_i^2$
   $\therefore n_h = \frac{n_i^2}{n_e} = \frac{(6 \times 10^8)^2}{9 \times 10^{12}} = 4 \times 10^4\ m^{-3}$
   iii. The energy gap decreases with doping.

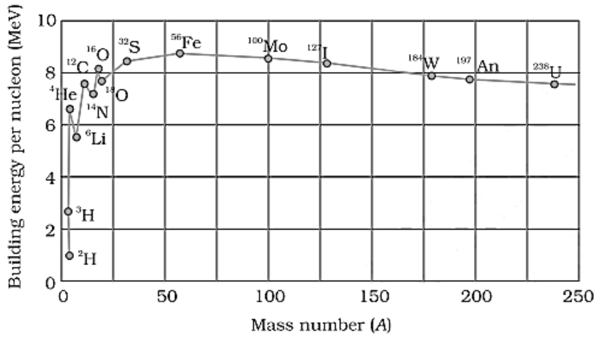
### Section B

4. The energy of an electron in nth orbit is given by
   $E_n = -\frac{13.6}{n^2} eV$
   i. For 3 rd excite state, n = 4
   $\therefore E_4 = -\frac{13.6}{4^2} = -\frac{13.6}{16} = -0.85 eV$
   ii. Required energy to jump electron to the ground state from the 3 rd excited state
   E = $E_4$ - $E_1$
   $= -\frac{13.6}{4^2} - \left(-\frac{13.6}{1^2}\right)$
   = - 0.85 + 13.6 = 12.75 eV
   $\therefore$ Wavelength of the photon emitted as
   $\lambda = \frac{hc}{E} \left(As,\ E = \frac{hc}{\lambda}\right)$
   $\Rightarrow \lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{12.75 \times 1.6 \times 10^{-19}}$

$= \frac{19.878\times10^{-7}}{20.4} = 0.974 \times 10^{-7}$
$= 974\overset{o}{A}$

5. Because photodiodes conduct in reverse biased condition only when the light of suitable frequency falls on it is used to detect the variation of intensity of light. The fractional change, due to photo effects, on the minority charge carrier dominates reverse bias current, which is much more than the fractional change in the forward bias current and can be easily detected Hence, the photodiode is used in reverse bias.
   **Working principle of photodiode:**
   i. Generation of electron-hole pairs due to light close to the junction.
   ii. Separation of electrons and holes due to the electric field of the depletion region.

   Detection is possible if $E_p > E_g$
   $E_p = \frac{hc}{\lambda}$
   $= \frac{hc}{e\lambda}\mathrm{eV}$
   $= \frac{6.63\times10^{-3}\times3\times10^{8}}{1.6\times10^{-5}\times400\times10^{-9}}$
   = 3.1 eV ($>E_g$)
   ∴It can detect this light.
6. Figure is a plot of the binding energy per nucleon $E_{bn}$ versus the mass number A for a large number of nuclei.




   i. Larger the binding energy per nucleon, the greater the work that must be done to remove the nucleon from the nucleus, the more stable the nucleus.
   The binding energy per nucleon for the nucleus of range, 30 < A < 170 is close to its maximum value. So, the nucleus belongs to this region is highly stable and does not show radioactivity.
   ii. Binding energy per nucleon is smaller for heavier nuclei than the middle ones, i.e. heavier nuclei are less stable. When a heavier nucleus such as a nucleus of mass number 240 splits into lighter nuclei (mass number 120), the BE/nucleon changes from about 7.6 MeV to 8.4 MeV. Greater BE of the product nuclei results in the liberation of energy.
   iii. Neutrinos are neutral particles with very small mass compared to electrons. They have only weak interaction with other particles, therefore, they are very difficult to detect, since they can penetrate large quantity of matter without any interaction.
7. Here i = $\sin^{-1} \frac{4}{5}$
   ∴ sin i = $\frac{4}{5}$
   As $\mu = \frac{\sin i}{\sin r}$
   ∴ sin r = $\frac{\sin i}{\mu} = \frac{4/5}{4/3} = \frac{3}{5}$ = 0.6
   cos r = $\sqrt{1-\sin^2 r} = \sqrt{1-(0.6)^2}$ = 0.8
   For a dark fringe in the reflected light,
   2 $\mu$t cos r = $n\lambda$n = 0, 1, 2, 3, ….
   Suppose nth and (n + 1)th dark bands correspond to wavelengths 6100 $\overset{\circ}{A}$ and 6000 $\overset{\circ}{A}$ respectively. Then
   In first case,
   $2 \times \frac{4}{3} \times t \times 0.8 = n \times 6100 \times 10^{-10}$ ...(i)
   In second case,

$2 \times \frac{4}{3} \times t \times 0.8 = (n + 1) \times 6000 \times 10^{-10}$

$\therefore n \times 6100 \times 10^{-10} = (n + 1) \times 6000 \times 10^{-10}$

or n = 60

Putting the value of n in equation (i), we get

$2 \times \frac{4}{3} \times t \times 0.8 = 60 \times 6100 \times 10^{-10}$

or $t = 1.716 \times 10^{-5}$ m

8. The refractive index of a transparent medium is inversely proportional to the wavelength of the incident light. The relationship between the two is given by,

$\mu = \lambda_0/\lambda$

where,

$\mu$ = Refractive index of the medium

$\lambda_0$= Wavelength of incident light in vacuum

$\lambda$= Wavelength of incident light in the medium

Above relationship can also be expressed in terms of speed of light in a vacuum to the speed of the light in the medium, i.e.

$\mu = c/v$

where c = speed of the light in vacuum

and $v =$ speed of the light in the medium

Given,

Velocity of light in air (vacuum), $c = 3 \times 10^8$ m/sec and Velocity of light in glass, $v_g = 2 \times 10^8$ m/sec

The refractive index of glass is given by, $\mu_g = \frac{c}{v_g}$, where c is the 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 ${}^a\mu_g = 1/\sin C$

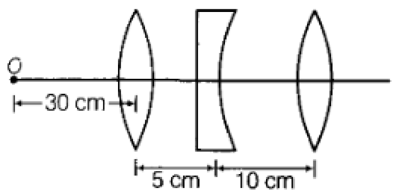
where C is the critical angle for the interface

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

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

$\therefore$ Critical angle, C = $41.3^o$

OR




From the given diagram, for first (left side) convex lens, we have

f = +10 cm and u = -30 cm

Therefore, by using lens formula, we have

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{10} = \frac{1}{v} - \frac{1}{(-30)}$ ..........................(i)

$\Rightarrow \quad v = 15\text{cm}$

The image formed by the first lens acts as a virtual object for the plano-concave lens.

For plano-concave lens, we have

u = +10 cm, f = -10 cm and v = ?

Again by using lens formula, we have

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow -\frac{1}{10} = \frac{1}{v} - \frac{1}{10}$

$1/v = 0 \Rightarrow v = \infty.$

The refracted ray becomes parallel to the principal axis for a second convex lens (right side) of focal length 30 cm. Here,

$u = -\infty, v = ?, f = 30\text{cm}$

Thus, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{30} = \frac{1}{v} - \frac{1}{(-\infty)}$

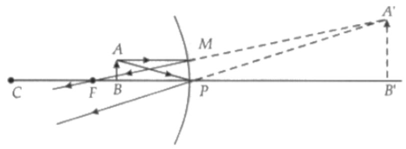
$\Rightarrow \quad v = 30\text{cm}$

Thus, the final image is formed at a distance of 30 cm from the second convex lens on the other side of it.

9. i. The photoelectric effect cannot be explained on the basis of wave nature of light because wave nature of radiation cannot explain the following:
      a. The instantaneous ejection of photoelectrons.
      b. The existence of threshold frequency for a metal surface.
      c. The fact that kinetic energy of the emitted electrons is independent of the intensity of light and depends upon its frequency.

   ii. Photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based on particle nature of light Its basic features are given as below:
      a. In interaction of radiation with matter, radiation behaves as if it is made up of particles called photons.
      b. Each photon has energy E (= h$\nu$ = $\frac{hc}{\lambda}$ ) and momentum p(= E/c).
      c. All photons of light of a particular frequency $\nu$ or wavelength $\lambda$ have the same energy E (= h$\nu$ = $\frac{hc}{\lambda}$ ) and momentum p (= E/c) whatever the intensity radiation may be.
      d. By increasing the intensity of light of given wavelength, there is only an increase in the number of photons per second crossing a given area with each photon having the same energy. Thus, photon energy is independent of the intensity of radiation.

10. a. Ray Diagram:




   b. From similar triangles A'B'F and MPF, we have

$\frac{B'A'}{PM} = \frac{B'F}{FP}$

or, $\frac{B'A'}{BA} = \frac{B'F}{FP}$ (Since PM = BA)

From similar triangles A'B'P and ABP, we have

$\frac{B'A'}{BA} = \frac{B'P}{BP}$

Hence, $\frac{B'F}{FP} = \frac{B'P}{BP}$

Now, B'F = B'P + PF

= (+ v) + (- f )

= v - f

and BP = - u

$\therefore \frac{v-f}{-f} = \frac{+v}{-u}$

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

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

This is the mirror formula.

Linear magnification is given by = $\frac{B'A'}{BA}$

From similar triangle A'B'P' and ABP, we get

$\frac{B'A'}{BA} = \frac{B'P}{BP}$

$\therefore$ Linear magnification is given by:-

$m = \frac{B'P}{BP} = \frac{+v}{-u} = -\frac{v}{u}$

11. i. The EM waves suitable for radar systems are microwaves. These rays are produced by special vacuum tubes, namely klystrons, magnetrons and Gunn diodes.
   ii. Infrared waves are used to treat muscular strain. These rays are produced by hot bodies and vibration of molecules and atoms. For example, hot charcoal emits infrared radiation not the visible light to give the sensation of heat.
   iii. X-rays are used as a diagnostic tool in medicine. These rays are produced when high energy electrons emitted from cathode are stopped suddenly on a metal (anode) of high atomic number in an X-ray tube.

OR

According to $\theta$
d = D (Given) ...(i)
$D = \frac{1}{2}d$ (Given) ...(ii)
d = 2D
Path difference at P = $S_2P$ - $S_1P$
Path difference $p = \sqrt{D^2 + \left(x + \frac{d}{2}\right)^2} - \sqrt{D^2 + \left(x - \frac{d}{2}\right)^2}$
Substitute the value of d and x from (i) and (ii)
$= \sqrt{D^2 + (D) + D)^2} - \sqrt{D^2 + (D - D)^2}$
$= \sqrt{5D^2} - \sqrt{D^2}$
$p = D(\sqrt{5} - 1)$
The path difference for nth dark fringe from central maxima O is $(2n-1)\frac{\lambda}{2}$
$\therefore$ For 1st minima $p = \frac{\lambda}{2}$
Put the value of p in (iii)
$\frac{\lambda}{2} = D(\sqrt{5} - 1)$
$D = \frac{\lambda}{2(\sqrt{5}-1)}$
Rationalizing the denominator, we get,
$D = \frac{\lambda}{2(\sqrt{5}-1)} \times \frac{(\sqrt{5}+1)}{(\sqrt{5}+1)} = \frac{(2.236+1)}{2\times(5-1)}\lambda = \frac{3.236}{2\times 4}\lambda$
$= \frac{3.236}{8}\lambda = 0.404\lambda$

**CASE STUDY**

12. i. (d): Total internal reflection is the basis for following phenomenon:
    1. Sparkling of diamond.
    2. Optical fibre communication.
    3. Instrument used by doctors for endoscopy.

    ii. (d): Total internal reflection (TIR) is the phenomenon that involves the reflection of all the incident light off the boundary. TIR only takes place when both of the following two conditions are met:
    The light is in the more denser medium and approaching the less denser medium.
    The angle of incidence is greater than the critical angle.

    iii. (c): If incidence of angle, i = critical angle C, then angle of refraction, r = 90°

    iv. (b): In optical fibres, core is surrounded by cladding, where the refractive index of the material of the core is higher than that of cladding to bound the light rays inside the core.

    v. (b): From Snell's law, $\sin C = {}_1n_2 = \frac{v_1}{v_2}$
    where, C = critical angle =30° and $v_1$ and $v_2$ are speed of light in medium and vacuum, respectively.

    We know that, $v_2 = 3 \times 10^8$ m $s^{-1}$
    $\therefore \sin 30^\circ = \frac{v_1}{3\times 10^8}$
    $\Rightarrow v_1 = 3 \times 10^8 \times \frac{1}{2} \Rightarrow v_1 = 1.5 \times 10^8 \text{ ms}^{-1}$