Sample Question Paper - 4
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. In the following diagram, is the junction diode forward biased or reverse biased?

2. Three immiscible liquids of densities $d_1 > d_2 > d_3$ and refractive indices $\mu_1 > \mu_2 > \mu_3$ are put in a beaker. The height of each liquid column is $\frac{h}{3}$. A dot is made at the bottom of the beaker. For near normal vision, find the apparent depth of the dot.

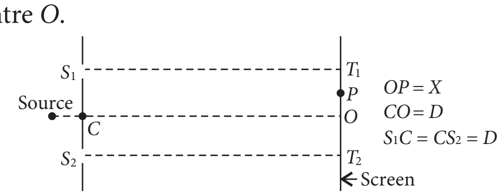
3. Two monochromatic beams A and B of equal intensity I, hit a screen. The number of photons hitting the screen by beam A is twice that by beam B. Then what inference can you make about their frequencies?

OR

A proton and an α-particle are accelerated, using the same potential difference. How are the de Broglie wavelengths λ_p and λ_α related to each other?

SECTION - B

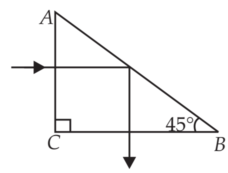
4. Consider a two slit interference arrangements such that the distance of the screen from the slits is half the distance between the slits. Obtain the value of D in terms of λ such that the first minima on the screen falls at a distance D from the centre O.



5. The wavelength of a probe is roughly a measure of the size of a structure that it can probe in some detail. The quark structure of protons and neutrons appears at the minute length scale of 10^{-15} m or less. This structure was first probed in early 1970's using high energy electron beam produced by a linear accelerator at Standford, USA. What is the rest mass energy of these electron beams.

6. In a typical nuclear reaction, *e.g.* ${}_1^2\text{H} + {}_1^2\text{H} \rightarrow {}_2^3\text{He} + {}_0^1n + 3.27\text{ MeV}$, although number of nucleons is conserved, yet energy is released. How? Explain.

7. A ray of light incident normally on one of the faces of a right angle prism is found to be totally reflected as shown in figure. What is the minimum value of the refractive index of the material of the prism?



8. Two thin lenses have a combined power of +9 D. When they are separated by a distance of 20 cm, their equivalent power becomes $+\frac{27}{5}$ D. Find their individual powers.

9. The near vision of an average person is 25 cm. To view an object with an angular magnification of 10, what should be the power of the microscope?

OR

Show that for a material with refractive index $\mu \geq \sqrt{2}$, light incident at any angle shall be guided along a length perpendicular to the incident face.

10. Show that the first few frequencies of light that is emitted when electrons fall to the n^{th} level from levels higher than n, are approximate harmonics (*i.e.* in the ratio 1 : 2 : 3...) when $n >> 1$.

11. (a) Arrange the following electromagnetic waves in the ascending order of their wavelengths :
(i) Microwaves
(ii) Infra-red rays
(iii) Ultra-violet-radiation
(iv) Gamma rays
(b) Write one use each of any two of them.

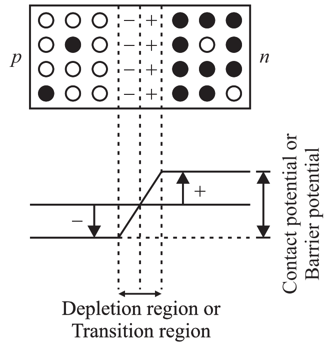
OR

A beam of light consisting of two wavelengths, 650 nm and 520 nm is used to obtain interference fringes in a Young's double-slit experiment.
(a) Find the distance of the third bright fringe on the screen from the central maximum for wavelength 650 nm.
(b) What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?
(Slit separation is 2 mm and distance between slits and screen is 1.2 m)

SECTION - C

12. CASE STUDY : DOPING IN SEMICONDUCTOR

p-n junction is a single crystal of Ge or Si doped in such a manner that one half portion of it acts as *p*-type semiconductor and other half functions as *n*-type semiconductor. As soon as a *p-n* junction is formed, the holes from the *p*-region diffuse into the *n*-region and electron from *n* region diffuse into *p*-region. This results in the development of V_B across the junction which opposes the further diffusion of electrons and holes through the junction.



(i) In an unbiased *p*-*n* junction electrons diffuse from *n*-region to *p*-region because
- (a) holes in *p*-region attract them
- (b) electrons travel across the junction due to potential difference
- (c) electron concentration in *n*-region is more as compared to that in *p*-region
- (d) only electrons move from *n* to *p* region and not the *vice-versa*

(ii) Electron hole recombination in *p*-*n* junction may lead to emission of
- (a) light
- (b) ultraviolet rays
- (c) sound
- (d) radioactive rays

(iii) In an unbiased *p*-*n* junction
- (a) potential at *p* is equal to that at *n*
- (b) potential at *p* is +ve and that at *n* is –ve
- (c) potential at *p* is more than that at *n*
- (d) potential at *p* is less than that at *n*.

(iv) The potential of depletion layer is due to
- (a) electrons
- (b) holes
- (c) ions
- (d) forbidden band

(v) In the depletion layer of unbiased *p*-*n* junction,
- (a) it is devoid of charge carriers
- (b) has only electrons
- (c) has only holes
- (d) *p*-*n* junction has a weak electric field.

Solution

PHYSICS - 042

Class 12 - Physics

1. Voltage at p side is less than voltage at n side of the diode so it is in reverse bias.

2. We know that, $\mu = \dfrac{\text{Apparent depth}}{\text{Real depth}}$.

Real depth of dot under liquid of density d_1 is $\dfrac{h}{3}$.

$$\text{Apparent depth of dot} = \left(\frac{h/3}{\mu_1} + \frac{h/3}{\mu_2} + \frac{h/3}{\mu_3}\right).$$

$$= \frac{h}{3}\left(\frac{1}{\mu_1} + \frac{1}{\mu_2} + \frac{1}{\mu_3}\right).$$

3. Let n_1, n_2 be the number of photons hitting the screen per second by beam A and B respectively

Intensity of beam of photon, $I = nh\upsilon$

$\therefore \quad n_1\upsilon_1 = n_2\upsilon_2$

$$\frac{n_1}{n_2} = \frac{\upsilon_2}{\upsilon_1}$$

As $\dfrac{n_1}{n_2} = 2 \quad \therefore \quad \dfrac{\upsilon_2}{\upsilon_1} = 2,\ \upsilon_2 = 2\upsilon_1$

i.e, frequency of beam B is twice of that of beam A.

OR

We know that,

$$\lambda = \frac{h}{mv} \quad \text{and} \quad qV = \frac{1}{2}mv^2$$

$$\therefore \quad \lambda = \frac{h}{m\sqrt{2qV/m}} = \frac{h}{\sqrt{2mqV}}$$

$$\lambda \propto \frac{1}{\sqrt{mq}} \qquad \text{(for constant } V\text{)}$$

$$\therefore \quad \frac{\lambda_p}{\lambda_\alpha} = \frac{\sqrt{m_\alpha q_\alpha}}{\sqrt{m_p q_p}} = \frac{\sqrt{4m_p \times 2e}}{\sqrt{m_p \times e}} = \sqrt{8}$$

4. From diagram

$T_1P = T_1O - OP = (D - x)$

$T_2P = T_2O + OP = (D + x)$

Now $S_1P = \sqrt{(S_1T_1)^2 + (T_1P)^2}$

$= \sqrt{D^2 + (D-x)^2}$

$S_2P = \sqrt{(S_2T_2)^2 + (T_2P)^2} = \sqrt{D^2 + (D+x)^2}$

Path difference, $S_2P - S_1P = \dfrac{\lambda}{2}$; for first minimum to occur

$$\sqrt{D^2 + (D+x)^2} - \sqrt{D^2 + (D-x)^2} = \frac{\lambda}{2}$$

The first minimum falls at a distance D from the center, *i.e.*, $x = D$.

$$[D^2 + 4D^2]^{1/2} - D = \frac{\lambda}{2}$$

$$D(\sqrt{5} - 1) = \frac{\lambda}{2}$$

$$D(2.236 - 1) = \frac{\lambda}{2};\ D = \frac{\lambda}{2.472}$$

5. $\therefore$ Momentum of electron associated with given wavelength

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}\ \text{J s}}{10^{-15}\ \text{m}} = 6.63 \times 10^{-19}\ \text{kg m s}^{-1}$$

Rest mass energy of electron,

$E_0 = m_0 c^2$

$m_0 = 9.11 \times 10^{-31}$ kg

So, $E_0 = 9.11 \times 10^{-31}\ \text{kg}\ (3 \times 10^8\ \text{m/s})^2 = 8.19 \times 10^{-14}\ \text{J}$

$$E_0 = \frac{8.19 \times 10^{-14}}{1.6 \times 10^{-19}}\ \text{eV} \qquad [\because 1\ \text{ev} = 1.6 \times 10^{-19}\ \text{J}]$$

$= 0.511 \times 10^6$ eV

$= 0.511$ MeV

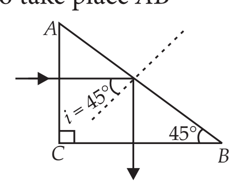
6. In a given nuclear reaction, the sum of the masses of the target nucleus $\left({}_1^2\text{H}\right)$ and the bombarding particle $\left({}_1^2\text{H}\right)$ may be greater than the product nucleus $\left({}_2^3\text{He}\right)$ and the outgoing neutron ${}_0^1n$. So from the law of conservation of mass-energy some energy (3.27 MeV) is released due to mass defect in the nuclear reaction. This energy is called Q-value of the nuclear reaction.

7. For total internal reflection to take place AB

$i > C$ or $\sin i > \sin C$

where, i = Angle of incidence

C = Critical angle



Here, $i = 45°$ and $\sin C = \dfrac{1}{\mu}$

$$\therefore \quad \sin 45° > \frac{1}{\mu} \Rightarrow \frac{1}{\sqrt{2}} > \frac{1}{\mu} \quad \text{or} \quad \mu > \sqrt{2}$$

$\therefore \quad \mu_{min} = \sqrt{2}$

8. When two thin lenses of powers P_1 and P_2 are held in contact with each other, the power of the combination is given by

$$P = P_1 + P_2 \qquad \therefore \quad 9 = P_1 + P_2 \qquad ...(i)$$

When two thin lenses of power P_1 and P_2 are separated by a distance d, the equivalent power is given by

$$P = P_1 + P_2 - dP_1P_2$$

$$\therefore \quad \frac{27}{5} = P_1 + P_2 - \frac{20}{100}P_1P_2$$

$$\frac{27}{5} = 9 - \frac{20}{100}P_1P_2 \qquad \text{(Using (i))}$$

$$P_1P_2 = 18 \qquad \text{...(ii)}$$

On solving (i) and (ii), we get

$$P_1 = 3\text{ D}, P_2 = 6\text{ D}$$

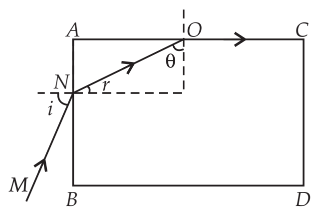
9. Given, $d = 25$ m, $m = 10$

Angular magnification, $m = \dfrac{d}{f} = \dfrac{25}{10} = 2.5$ cm

Power of microscope $P = \dfrac{100}{f} = \dfrac{100}{2.5} = 40$ D

OR

MN is guided along AC at angle i. Let ray makes an angle θ with AC such that $\theta \geq ic$



$\sin\theta \geq \sin i_c \geq \dfrac{1}{\mu}$ or, $\sin(90° - r) \geq \dfrac{1}{\mu}$

$$\therefore \quad \cos r \geq \frac{1}{\mu}$$

Squaring and subtracting both sides by 1, we get

$1 - \cos^2 r \leq 1 - \dfrac{1}{\mu^2}$ or, $\sin^2 r \leq 1 - \dfrac{1}{\mu^2}$

or $\dfrac{\sin^2 i}{\mu^2} \leq 1 - \dfrac{1}{\mu^2}$ $\qquad \left(\because \dfrac{\sin i}{\sin r} = \mu\right)$

or, $\sin^2 i \leq (\mu^2 - 1)$

When $i = \dfrac{\pi}{2}$, θ has its smallest value.

$$\sin^2\left(\frac{\pi}{2}\right) \leq (\mu^2 - 1)$$

or, $\mu^2 \geq 2$ or, $\mu \geq \sqrt{2}$

10. As $\dfrac{1}{\lambda} = RZ^2\left[\dfrac{1}{n_f^2} - \dfrac{1}{n_i^2}\right]$,

$$\upsilon = cRZ^2\left[\frac{1}{n^2} - \frac{1}{(n+p)^2}\right]$$

[as $c = \upsilon\lambda$, $n_f = n$, $n_i = (n+p)$, where $p = 1, 2, 3...$]

$$\text{or} \quad \upsilon = cRZ^2\left[\frac{(n+p)^2 - n^2}{n^2(n+p)^2}\right]$$

$$= cRZ^2\left[\frac{(n^2 + p^2 + 2pn) - n^2}{n^2(n+p)^2}\right]$$

$$\text{or} \quad \upsilon \approx cRZ^2\left(\frac{2pn}{n^4}\right) \approx \left(\frac{2cRZ^2}{n^3}\right)p$$

$$(\because n >> 1, p << n)$$

obviously $\upsilon \propto p$, *i.e.*, the values of υ are approximately in the ratio 1 : 2 : 3.

11. (a) Ascending order of wavelengths for given electromagnetic waves is:

(i) Gamma rays ($< 10^{-12}$) m

(ii) Ultra-violet radiation ($10^{-9} - 4 \times 10^{-7}$) m

(iii) Infra-red rays ($7.5 \times 10^{-7} - 10^{-3}$) m

(iv) Microwaves ($10^{-3} - 10^{-1}$) m

(b) Microwaves :

Frequency range $\rightarrow 3 \times 10^8$ Hz -3×10^{11} Hz. These are suitable for the radar system, used in aircraft navigation.

Gamma rays :

Frequency range $\rightarrow\, > 3 \times 10^{21}$ Hz.

These wave are used for the treatment of cancer cells.

OR

Here, $d = 2$ mm, $D = 1.2$ m,

$\lambda_1 = 650$ nm $= 650 \times 10^{-9}$ m,

$\lambda_2 = 520$ nm $= 520 \times 10^{-9}$ m

(a) Distance of third bright fringe from the central maximum for the wavelength 650 nm.

$$y_3 = \frac{3\lambda D}{d} = \frac{3(650 \times 10^{-9})1 \cdot 2}{2 \times 10^{-3}} = 1.17 \text{ mm.}$$

(b) Let at linear distance 'y' from center of screen the bright fringes due to both wavelength coincides. Let n_1 number of bright fringe with wavelength λ_1 coincides with n_2 number of bright fringe with wavelength λ_2.

We can write

$$y = n_1\beta_1 = n_2\beta_2$$

$$n_1\frac{\lambda_1 D}{d} = n_2\frac{D\lambda_2}{d} \quad \text{or} \quad n_1\lambda_1 = n_2\lambda_2 \qquad \text{...(i)}$$

Also at first position of coincide, the n^{th} bright fringe of one will coincide with $(n + 1)^{th}$ bright fringe of other.

If $\lambda_2 < \lambda_1$,

So, then $n_2 > n_1$

then $n_2 = n_1 + 1 \qquad$ ...(ii)

Using equation (ii) in equation (i)

$n_1\lambda_1 = (n_1 + 1)\lambda_2$

$n_1 (650) \times 10^{-9} = (n_1 + 1)\, 520 \times 10^{-9}$

$65\, n_1 = 52\, n_1 + 52$ or $12\, n_1 = 52$ or $n_1 = 4$

Thus, $y = n_1\beta_1 = 4\left[\dfrac{(6.5\times10^{-7})(1.2)}{2\times10^{-3}}\right]$

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

So, the fourth bright fringe of wavelength 520 nm coincides with 5th bright fringe of wavelength 650 nm.

12. (i) **(c) :** Electron concentration in *n*-region is more as compared to that in *p*-region. So electrons diffuse from *n*-side to *p*-side.

(ii) **(a) :** When an electron and a hole recombine, the energy is released in the form of light.

(iii) **(a) :** In an unbiased *p*-*n* junction, potential at *p* is equal to that at *n*.

(iv) **(c) :** The potential of depletion layer is due to ions.

(v) **(a) :** In the depletion layer of unbiased *p*-*n* junction, there is no charge carriers.