Sample Question Paper - 26
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

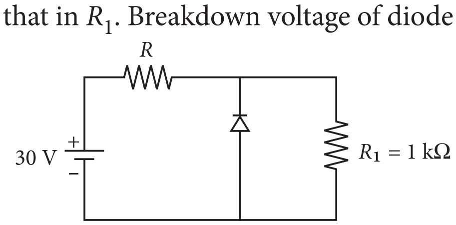
1. For a single slit of width 'a', the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$,we get a maximum for two narrow slits separated by a distance 'a'. Explain.

2. An ultraviolet light of wavelength 2000 Å irradiates a photocell made of molybdenum metal. If the stopping potential is – 1.5 V, what is the work function of the metal?
(Planck's constant = 6.6×10^{-34} J s)

3. Explain, with the help of a circuit diagram, the working of a photodiode. Write briefly how it is used to detect the optical signals.

OR

If current in diode is five times that in R_1. Breakdown voltage of diode is 6 volt. Find the value of R.



SECTION - B

4. (i) In hydrogen atom, an electron undergoes transition from 2nd excited state to the first excited state and then to the ground state. Identify the spectral series to which these transitions belong.
(ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.

5. The photoelectric threshold wavelength of silver is 3250×10^{-10} m. Find the velocity of the electron ejected from a silver surface by ultraviolet light of wavelength 2536×10^{-10} m.
[Given : $h = 4.14 \times 10^{-15}$ eV s and $c = 3 \times 10^{8}$ m s^{-1}]

6. (a) Which segment of electromagnetic waves has highest frequency? How are these waves produced? Give one use of these waves.

   (b) Which *e.m.* waves lie near the high frequency end of visible part of *e.m.* spectrum? Give its one use. In what way this component of light has harmful effects on humans?

7. Draw ray diagrams to show how specially designed prisms make use of total internal reflection to obtain inverted image of the object by deviating rays (i) through 90° and (ii) through 180°.

OR

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 at 15 cm from each other. A point object lies 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the image by the combination. Determine the nature and position of the image formed.

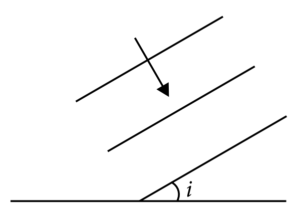
8. A slit of width *a* is illuminated by light of wavelength 6000 Å. For what value of *a* will the
   (i) First maximum fall at an angle of diffraction of 30°?
   (ii) First minimum fall at an angle of diffraction 30°?

9. The following fusion reaction takes place :

$$ {}^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + n + 3.27 \text{ MeV} $$

If 2 kg of deuterium is subjected to above reaction, the energy released is used to light a 100 W lamp, how long will the lamp glow?

10. A plane wavefront propagating in a medium of refractive index 'μ_1' is incident on a plane surface making the angle of incidence *i* as shown in the figure. It enters into a medium of refraction of refractive index 'μ_2' ($\mu_2 > \mu_1$). Use Huygens' construction of secondary wavelets to trace the propagation of the refracted wavefront. Hence verify Snell's law of refraction.



OR

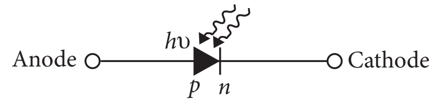
You have learnt in the text how Huygens principle leads to the laws of reflection and refraction. Use the same principle to deduce directly that a point object placed in front of a plane mirror produces a virtual image whose distance from the mirror is equal to the distance of the object from the mirror.

11. A glass slab of thickness 8 cm contains the same number of waves as 10 cm of water when both are traversed by the same monochromatic light. If the refractive index of water is 4/3, then find the refractive index of glass.

SECTION - C

12. CASE STUDY : PHOTODIODE

A photodiode is an optoelectronic device in which current carriers are generated by photons through photo-excitation *i.e.*, photo conduction by light. It is a *p-n* junction fabricated from a photosensitive semiconductor and provided with a transparent window so as allow light to fall on its function. A photodiode can turn its current ON and OFF in nanoseconds. So, it can be used as a fastest photo-detector.



(i) Photodiode is a device
   (a) which is always operated in reverse bias
   (b) which of always operated in forward bias
   (c) in which photo current is independent of intensity of incident radiation
   (d) which may be operated in forward or reverse bias.

(ii) Photodiode can be used as a photodetector to detect
   (a) optical signals (b) electrical signals (c) both (a) and (b) (d) none of these

(iii) A *p-n* photodiode is fabricated from a semiconductor with a band gap of 2.5 eV. It can detect a signal of wavelength
   (a) 4000 nm (b) 6000 nm (c) 4000 Å (d) 6000 Å

(iv) Three photo diodes D_1, D_2 and D_3 are made of semiconductors having band gap of 2.5 eV, 2 eV and 3 eV, respectively. Which one will be able to detect light of wavelength 6000 Å ?
   (a) D_1 (b) D_2 (c) D_3 (d) D_1 and D_2 both

(v) To detect light of wavelength 500 nm, the photodiode must be fabricated from a semiconductor of minimum bandwidth of
   (a) 1.24 eV (b) 0.62 eV (c) 2.48 eV (d) 3.2 eV

Solution

PHYSICS - 042

Class 12 - Physics

1. For a single slit of width "a" the first minima of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of (λ/a) because the light from centre of the slit differs by a half of a wavelength.
Whereas a double slit experiment at the same angle of (λ/a) and slits separation "a" produces maxima because one wavelength difference in path length from these two slits is produced.

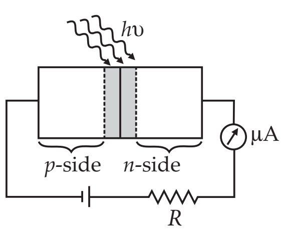
2. Frequency of incident radiation is

$$\upsilon = \frac{c}{\lambda} = \frac{3\times10^{8}}{2000\times10^{-10}} = 1.5\times10^{15}\text{ Hz}$$

The work function of the metal is

$$\phi_0 = h\upsilon - eV_s$$
$$= 6.6\times10^{-34}\times1.5\times10^{15} - 1.6\times10^{-19}\times1.5 = 7.5\times10^{-19}\text{J}$$

3. Working of photodiode : A junction diode made from light sensitive semiconductor is called a photodiode. A photodiode is a p-n junction diode arranged in reverse biasing.



The number of charge carriers increases when light of suitable frequency is made to fall on the p-n junction, because new electron holes pairs are created by absorbing the photons of suitable frequency. Intensity of light controls the number of charge carriers. Due to this property photodiodes are used to detect optical signals.

OR

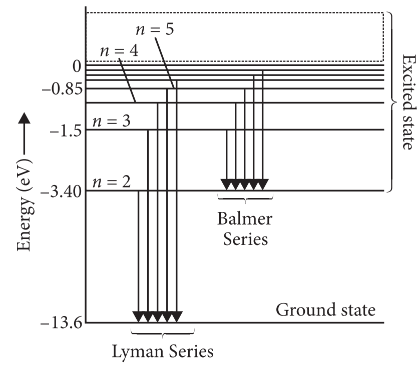
Current in diode is 5 times that in R_1.
Current through R_1 is

$$I_1 = \frac{V}{R_1} = \frac{6}{1\times10^{3}}\text{ A} = 6\text{ mA}$$

So total current drawn from battery
= 6 mA + 30 mA = 36 mA
Potential difference across R = 24 volt
So $V = IR$; $24 = 36\times10^{-3}R$; $R = 2000/3\ \Omega$

4. (i) An electron undergoes transition from 2nd excited state to the first excited state is Balmer series and then to the ground state is Lyman series.

(ii) The wavelength of the emitted radiations in the two cases.



For $n_2 \to n_1$
$\Delta E = (-3.40 + 13.6) = 10.20$ eV

$$\lambda_2 = \frac{6.626\times10^{-34}\times3\times10^{8}}{10.2\times1.6\times10^{-19}}$$

$$\lambda_2 = \frac{19.878\times10^{-7}}{10.2\times1.6} = 1.218\times10^{-7}\text{ m} = 1218\text{ Å}$$

For $n_3 \to n_2$
$\Delta E = (-1.5 + 3.4) = 1.9$ eV

$$\lambda_1 = \frac{19.878\times10^{-7}}{1.9\times1.6} = 6.538\times10^{-7}\text{ m} = 6538\text{ Å}$$

The ratio $\dfrac{\lambda_1}{\lambda_2} = \dfrac{6538}{1218} = 5.36$

5. The maximum kinetic energy is given as

$$K_{\max} = h\upsilon - \phi_0 = h\upsilon - h\upsilon_o = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

where λ_0 = threshold wavelength

or $\dfrac{1}{2}mv^2 = \dfrac{hc}{\lambda} - \dfrac{hc}{\lambda_0}$

Here, $hc = 4.14\times10^{-15}\text{ eV s}\times3\times10^{8}\text{ m s}^{-1} = 12420\text{ eV Å}$

$$\therefore\quad \frac{1}{2}mv^2 = 12420\left[\frac{1}{2536} - \frac{1}{3250}\right]\text{eV} = 1.076\text{ eV}$$

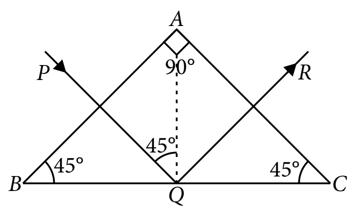
$$v^2 = \frac{2.152\text{ eV}}{m} = \frac{2.152\times1.6\times10^{-19}}{9.1\times10^{-31}}$$

$\therefore\quad v \approx 6\times10^{5}\text{ m s}^{-1}$

6. (a) Gamma rays has the highest frequency in the electromagnetic waves. These rays are of the nuclear origin and are produced in the disintegration of radioactive atomic nuclei and in the decay of certain subatomic particles. They are used in the treatment of cancer and tumours.
(b) Ultraviolet rays lie near the high-frequency end of visible part of $e.m.$ spectrum. These rays are used to

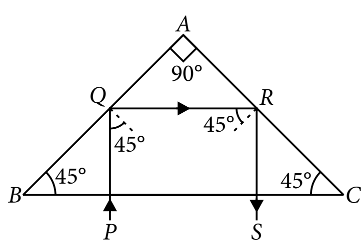
preserve food stuff. The harmful effect from exposure to ultraviolet (UV) radiation can be life threatening, and include premature aging of the skin, suppression of the immune systems, damage to the eyes and skin cancer.

7. (i) To deviate a ray of light through 90° :



A totally reflecting prism is used to deviate the path of the ray of light through 90°, when it is inconvenient to view the direct light. In Michelson's method to find velocity of light, the direct light from the octagonal mirror is avoided from direct viewing by making use of totally reflecting prism.

(ii) To deviate a ray of light through 180° : When the ray of light comes to meet the hypotenuse face *BC* at right angles to it, it is refracted out of prism as such along the path *RS*. The path of the ray of light has been turned through 180° due to two total internal reflections.



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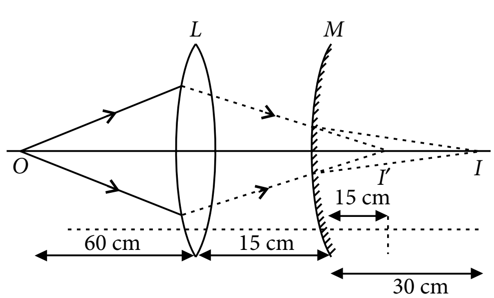


For the convex lens,

$u = -60$ cm, $f = +20$ cm

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \text{ gives } v = +30 \text{ cm}$$

For the convex mirror

$$u = +(30 - 15) \text{ cm} = 15 \text{ cm}, f = +\frac{20}{2} \text{ cm} = 10 \text{ cm}$$

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \text{ gives } v = +30 \text{ cm}$$

Final image is formed at the distance of 30 cm from the convex mirror (or 45 cm from the convex lens) to the right of the convex mirror.

The final image formed is a virtual image.

8. $\lambda = 6000$ Å $= 6000 \times 10^{-10}$ m $= 6 \times 10^{-7}$ m, $\theta_1 = 30°$, $m = 1$

(i) For first maximum, $\sin\theta_m = \dfrac{\left(m+\frac{1}{2}\right)\lambda}{a}$

$$\sin\theta_1 = \frac{3\lambda}{2a} \text{ or } a = \frac{3\lambda}{2\sin\theta_1} = \frac{3\times6\times10^{-7}}{2\times\sin30°}$$

$= 1.8 \times 10^{-6}$ m $= 1.8$ μm

(ii) For first minimum,

$$\sin\theta_m = \frac{m\lambda}{a} \therefore \sin\theta_1 = \frac{\lambda}{a}$$

$$\Rightarrow a = \frac{\lambda}{\sin\theta_1} = \frac{6\times10^{-7}}{\sin30°} = 1.2\times10^{-6} \text{ m} = 1.2 \text{ μm}$$

9. Number of atoms in 2 g of deuterium $= 6.023 \times 10^{23}$

$\therefore$ Number of atoms in 2 kg (= 2000 g) of deuterium

$$= \frac{6.023 \times 10^{23}}{2} \times 2000 = 6.023 \times 10^{26}$$

Energy released in the fusion of two deuterium nuclei = 3.27 MeV

$\therefore$ Total released in the fusion of 2 kg of deuterium

$$E = \frac{3.27}{2} \times 6.023 \times 10^{26} \text{ MeV}$$

$$= \frac{3.27 \times 6.023 \times 10^{26} \times 1.6 \times 10^{-13}}{2} \text{J} = 15.75 \times 10^{13} \text{ J}$$

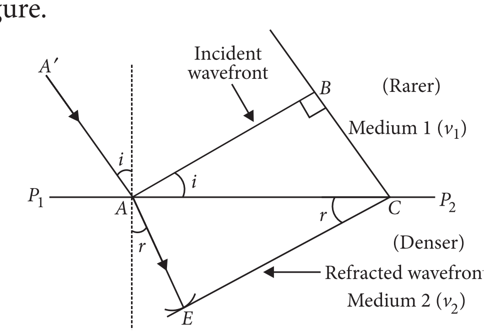
Power of bulb, $P = 100$ W $= 100$ J/s

$\therefore$ Time for which the bulb will glow is

$$t = \frac{E}{P} = \frac{15.75 \times 10^{13} \text{ J}}{100 \text{ J/s}} = 15.75 \times 10^{11} \text{ s}$$

$$= \frac{15.75 \times 10^{11}}{60 \times 60 \times 24 \times 365} \text{ years} = 5 \times 10^4 \text{ years}$$

10. Snell's law of refraction : Let P_1P_2 represents the surface separating medium 1 and medium 2 as shown in figure.



Let v_1 and v_2 represents the speed of light in medium 1 and medium 2 respectively. We assume a plane wavefront *AB* propagating in the direction *A′A* incident on the interface at an angle i. Let t be the time taken by the wavefront to travel the distance BC.

$\therefore \quad BC = v_1 t \qquad$ [$\because$ distance = speed × time]

In order to determine the shape of the refracted wavefront, we draw a sphere of radius $v_2 t$ from the point A in the second medium (the speed of the wave in second medium is v_2).

Let CE represents a tangent plane drawn from the point C. Then

$AE = v_2 t$

$\therefore$ CE would represent the refracted wavefront.

In ΔABC and ΔAEC, we have

$$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC} \text{ and } \sin r = \frac{AE}{AC} = \frac{v_2 t}{AC}$$

where i and r are the angles of incident and refraction respectively.

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{v_1 t}{AC} \cdot \frac{AC}{v_2 t}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

If c represents the speed of light in vacuum, then

$$\mu_1 = \frac{c}{v_1} \text{ and } \mu_2 = \frac{c}{v_2}$$

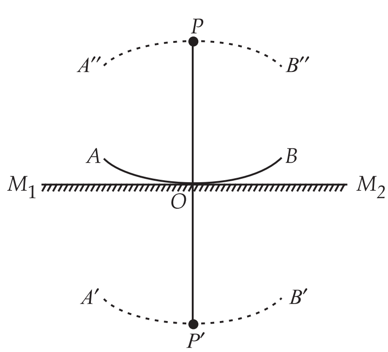
$$\Rightarrow \quad v_1 = \frac{c}{\mu_1} \text{ and } v_2 = \frac{c}{\mu_2}$$

where μ_1 and μ_2 are the refractive indices of medium 1 and medium 2.

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{c/\mu_1}{c/\mu_2} \Rightarrow \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 \sin i = \mu_2 \sin r$$

This is the Snell's law of refraction.

OR



In figure, P is a point object placed at a distance r from a plane mirror M_1M_2. With P as centre and $PO = r$ as radius, draw a spherical arc; AB. This is the spherical wavefront from the object, incident on M_1M_2.

If mirrors were not present, the position of wavefront AB would be $A'B'$ where $PP' = 2r$. In the presence of the mirror, wave front AB would appear as $A''PB''$, according to Huygen's construction. As it is clear from the figure $A'B'$ and $A''B''$ are two spherical arcs located symmetrically on either side of M_1M_2. Therefore, $A'P'B'$ can be treated as reflected image of $A''PB''$. From simple geometry, we find $OP = OP'$, which was to be proved.

11. Frequency of light in both mediums remains constant, *i.e.*, $\upsilon_g = \upsilon_w$

$$\text{or} \quad \frac{v_g}{\lambda_g} = \frac{v_w}{\lambda_w} \qquad \left(\because \upsilon = \frac{v}{\lambda}\right)$$

$$\text{or} \quad \frac{c}{\mu_g \lambda_g} = \frac{c}{\mu_w \lambda_w} \qquad \left(\because v = \frac{c}{\mu}\right)$$

$$\text{or} \quad \mu_g \lambda_g = \mu_w \lambda_w \qquad \text{...(i)}$$

Let there be n waves in 8 cm thickness of glass slab, then

$$\lambda_g = \frac{8 \text{ cm}}{n}$$

Similarly, $\lambda_w = \dfrac{10 \text{ cm}}{n}$

Putting these values in eqn. (i), we get

$$\mu_g \times \frac{8 \text{ cm}}{n} = \frac{4}{3} \times \frac{10 \text{ cm}}{n} \qquad \left(\because \mu_w = \frac{4}{3} \text{ (given)}\right)$$

$$\text{or} \quad \mu_g = \frac{5}{3}$$

12. (i) **(a) :** Photodiode is a device which is always operated in reverse bias.

(ii) **(a):** A photodiode is a device which is used to detect optical signals.

(iii) **(c) :** $\lambda_{max} = \dfrac{hc}{E} = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{2.5 \times 1.6 \times 10^{-19}}$

$= 5000$ Å

$\therefore \quad \lambda = 4000$ Å $< \lambda_{max}$

(iv) **(b) :** Energy of incident photon, $E = \dfrac{hc}{\lambda}$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{6 \times 10^{-7} \times 1.6 \times 10^{-19}} = 2.06 \text{ eV}$$

The incident radiation can be detected by a photodiode if energy of incident photon is greater than the band gap.

As $D_2 = 2$ eV, therefore D_2 will detect these radiations.

(v) **(c) :** Let E_g be the required bandwidth. Then

$$E_g = \frac{hc}{\lambda}$$

Here, $hc = 1240$ eV nm, $\lambda = 500$ nm

$$\therefore \quad E_g = \frac{1240 \text{ eV nm}}{500 \text{ nm}} = 2.48 \text{ eV}$$