Sample Question Paper - 3
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. Identify the electromagnetic waves whose wavelengths vary as

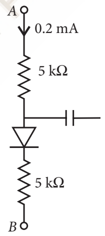
(a) 10^{-12} m $< \lambda <$ 10^{-8} m (b) 10^{-3} m $< \lambda <$ 10^{-1} m

Write one use for each.

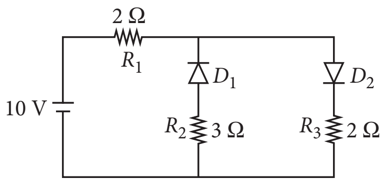
2. An LED is constructed from a *p-n* junction diode using GaAsP. The energy gap is 1.9 eV. What will be the wavelength of the light emitted?

OR

In the circuit shown in figure, if the diode forward voltage is 0.3 V, find the voltage difference between *A* and *B*.

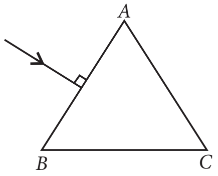


3. The given circuit has two ideal diodes connected as shown in the figure. Find the current flowing through the resistance R_1.



SECTION - B

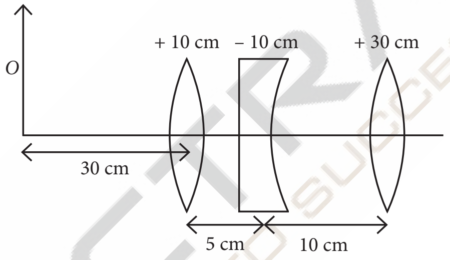
4. The figure shows a ray of light falling normally on the face *AB* of an equilateral glass prism having refractive index $\frac{3}{2}$, placed in water of refractive index $\frac{4}{3}$. Will this ray suffer total internal reflection on striking the face *AC*? Justify your answer.



5. A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is obtained on a screen 1 m away. If the first minimum is formed at a distance of 2.5 mm from the centre of the screen, find the (i) width of the slit, and (ii) distance of first secondary maximum from the centre of the screen.

6. Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations and write the range of their frequency.

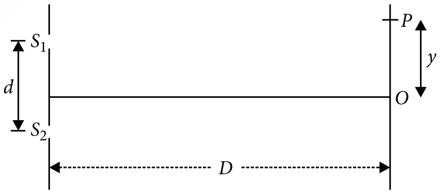
7. Three lenses of focal lengths +10 cm, –10 cm and +30 cm are arranged coaxially as in the figure given below. Find the position of the final image formed by the combination.



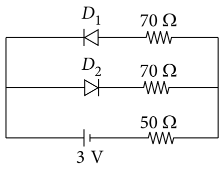
OR

(a) Write the necessary conditions for the phenomenon of total internal reflection to occur.
(b) Write the relation between the refractive index and critical angle for a given pair of optical media.

8. The intensity at the central maxima (*O*) in Young's double slit experiment is I_0. If the distance *OP* equals one-third of the fringe width of the pattern, show that the intensity at point *P* would be $\frac{I_0}{4}$.



9. The circuit shown in the diagram contains two diodes, each with a forward resistance of 60 Ω and infinite reverse resistance. If the battery is of 3 V, then find the voltage drop across 50 Ω resistance.



10. Calculate the neutron separation energy from the following data

$m\left({}^{40}_{20}\text{Ca}\right) = 39.962591\text{ u}; m\left({}^{41}_{20}\text{Ca}\right) = 40.962278\text{ u};$

$m_n = 1.00865, 1\text{ u} = 931.5\text{ MeV}/c^2$

11. In the ground state of hydrogen atom, its Bohr radius is given as 5.3×10^{-11} m. The atom is excited such that the radius becomes 21.2×10^{-11} m. Find (i) the value of the principal quantum number and (ii) the total energy of the atom in this excited state.

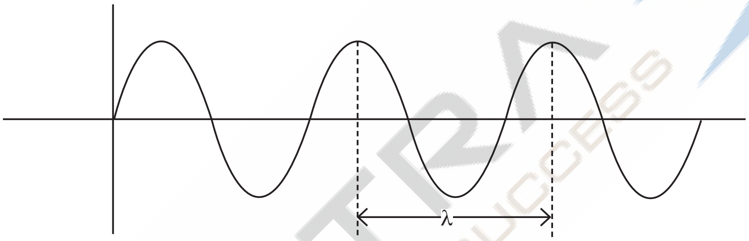
OR

The energy of a hydrogen atom in the ground state is –13.6 eV. Prove that the energy of a He^+ ion in the first excited state will be some as Hydrogen atom in ground state.

SECTION - C

12. CASE STUDY : DE-BROGLIE WAVELENGTH

According to de-Broglie, a moving material particle sometimes acts as a wave and sometimes as a particle or a wave associated with moving material particle which controls the particle in every respect. The wave associated with moving particle is called matter wave or de-Broglie wave where wavelength called de-Broglie wavelength, is given by $\lambda = \frac{h}{mv}$.



(i) If a proton and an electron have the same de Broglie wavelength, then
- (a) kinetic energy of electron < kinetic energy of proton
- (b) kinetic energy of electron = kinetic energy of proton
- (c) momentum of electron = momentum of proton
- (d) momentum of electron < momentum of proton.

(ii) Which of these particles having the same kinetic energy has the largest de Broglie wavelength?
- (a) Electron
- (b) Alpha particle
- (c) Proton
- (d) Neutron

(iii) Two particles A_1 and A_2 of masses m_1, m_2 ($m_1 > m_2$) have the same de Broglie wavelength. Then
- (a) their momenta are the same
- (b) their energies are the same
- (c) momentum of A_1 is less than the momentum of A_2
- (d) energy of A_1 is more than the energy of A_2.

(iv) When the velocity of an electron increases, its de Broglie wavelength
- (a) increases
- (b) decreases
- (c) remains same
- (d) may increase or decrease.

(v) Proton and α-particle have the same de-Broglie wavelength. What is same for both of them?
- (a) Time period
- (b) Energy
- (c) Frequency
- (d) Momentum

Solution

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1. (a) X-rays - used to study atomic structure.

(b) Microwaves - used in radar application.

2. Given, energy gap = 1.9 eV

Now, for the LED to operate, electrons need to cross this energy gap.

$\therefore$ Wavelength of light emitted,

$$\lambda = \frac{1242\,\text{eV-nm}}{1.9\text{ eV}} = 654\text{ nm}$$

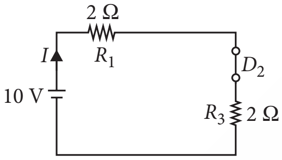
OR

Let V be the potential difference between A and B, then

$V - 0.3 = (5 + 5) \times 10^3 \times (0.2 \times 10^{-3}) = 2$

or $V = 2 + 0.3 = 2.3$ V

3. Diode D_1 is reverse biased so, it will block the current and diode D_2 is forward biased so, it will pass the current.



Hence, equivalent circuit becomes as shown in the figure.

Current in the circuit = Current flowing through the resistance $R_1 = \frac{10}{2+2} = 2.5$ A

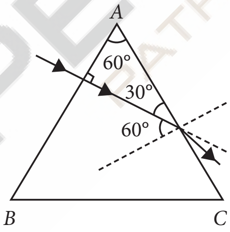
4. Critical angle for the given pair of media

$$\theta_c = \sin^{-1}\left(\frac{\mu_w}{\mu_g}\right)$$

$$= \sin^{-1}\left(\frac{4/3}{3/2}\right)$$

$$= \sin^{-1}\left(\frac{8}{9}\right)$$

$$\sin\theta_c = \frac{8}{9} = 0.89$$



Now, $\sin 60° = \frac{\sqrt{3}}{2} = 0.86$

On face AC, angle of incidence is less than that of critical angle, so there will be no total internal reflection.

5. Given $\lambda = 500 \times 10^{-9}$ m, $D = 1$ m, $y_{\min} = 2.5$ mm

$$\therefore \quad y_{\min} = \frac{n\lambda D}{d} = \frac{1 \times 500 \times 10^{-9} \times 1}{d} \Rightarrow d = 0.2\text{ mm}$$

Now the distance between first secondary maximum from centre of the screen,

$$y_{\max} = \frac{\left(n + \frac{1}{2}\right)\lambda D}{d} = \frac{3}{2}\frac{\lambda D}{d} = 3.75\text{ mm}$$

6. Ultraviolet radiations produced during welding are harmful to eyes. Special goggles or face masks are used to protect eyes from UV radiations. UV radiations have a range of frequency between 10^{14} Hz – 10^{16} Hz.

7. For lens L_1 : $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

where, $f = +\,10$ cm

$$\frac{1}{v_1} = \frac{1}{10} - \frac{1}{30}$$

$$\frac{1}{v_1} = \frac{3-1}{30} = \frac{2}{30} \Rightarrow v_1 = 15\text{ cm}$$

For lens L_2 :

$v_1 = 15$ cm, $u = 10$ cm, $f = -10$ cm

Position of final image,

$$\frac{1}{v_2} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{10} \Rightarrow v_2 = \infty$$

$\therefore$ For third lens L_3 object is at infinity, hence final image is formed at focus of L_3 at a distance of 30 cm.

OR

(a) Essential conditions for total internal reflection :

(i) Light should travel from a denser medium to a rarer medium.

(ii) Angle of incidence in denser medium should be greater than the critical angle for the pair of media in contact.

(b) ${}^a\mu_b = \frac{1}{\sin C}$, where a and b are the rarer and denser media respectively and C is the critical angle for the given pair of optical media.

8. Fringe width $(\beta) = \frac{\lambda D}{d}$

$$y = \frac{\beta}{3} = \frac{\lambda D}{3d}$$

Path difference $(\Delta p) = \frac{yd}{D} \Rightarrow \Delta p = \frac{\lambda D}{3d} \cdot \frac{d}{D} = \frac{\lambda}{3}$

$$\Delta\phi = \frac{2\pi}{\lambda} \cdot \Delta p = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{3} = \frac{2\pi}{3}$$

Intensity at point $P = I_0 \cos^2 \Delta\phi$

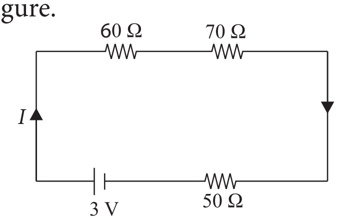
$$= I_0\left[\cos\frac{2\pi}{3}\right]^2 = I_0\left(\frac{1}{2}\right)^2 = \frac{I_0}{4}$$

Here $D = 120$ cm $= 1.20$ m
and $d = 2$ mm $= 2 \times 10^{-3}$ m
$\therefore$ Least distance,

$$y_{\min} = \frac{nD\lambda_1}{d} = \frac{4\times1.2\times650\times10^{-9}}{2\times10^{-3}}\ \text{m}$$

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

9. Here, diode D_1 is reverse biased and diode D_2 is forward biased. Equivalent circuit can be drawn as shown in figure.



Net resistance of the circuit, $R_N = 60\ \Omega + 70\ \Omega + 50\ \Omega$ $= 180\ \Omega$

$\therefore$ Current in the circuit, $I = \frac{V}{R_N} = \frac{3\,\text{V}}{180\,\Omega} = \frac{1}{60}$ A

So, voltage drop across 50 Ω resistance,

$$V_{50\Omega} = IR = \frac{1}{60}\ \text{A} \times 50\,\Omega = 0.84\ \text{V}$$

10. When a neutron is separated from $^{41}_{20}$Ca, we are left $^{40}_{20}$C. So, $^{41}_{20}\text{Ca} \longrightarrow {}^{40}_{20}\text{Ca} + {}^{1}_{0}n$

Mass defect, $\Delta M = \left(m(^{40}_{20}\text{Ca}) + m_n - m(^{41}_{20}\text{Ca})\right)$
$= 39.962591 + 1.00865 - 40.962278 = 0.008963$ u
Neutron separation energy $= \Delta Mc^2$
$= 0.008963 \times 931.5$ MeV $= 8.35$ MeV

11. (i) Since, $r \propto n^2$; $\frac{r_n}{r_g} = \frac{n^2}{1^2}$

$$\frac{21.2\times10^{-11}}{5.3\times10^{-11}} = \frac{n^2}{1}$$

$$\frac{212}{53} = n^2 \Rightarrow\ n^2 = 4 \quad \text{or} \quad n = \sqrt{4} = 2$$

(ii) We know that $E = \frac{-13.6}{n^2} = \frac{-13.6}{4} = -3.4$ eV

OR

Energy of an hydrogen like atom like He$^+$ in an n^{th} orbit is given by

$$E_n = -\frac{13.6Z^2}{n^2}\ \text{eV}$$

For hydrogen atom, $Z = 1$

$$\therefore \quad E_n = -\frac{13.6}{n^2}\text{eV}$$

For ground state, $n = 1$

$$\therefore\ E_1 = -\frac{13.6}{1^2}\ \text{eV} = -13.6\ \text{eV}$$

For He$^+$ ion, $Z = 2$

$$E_n = -\frac{4\,(13.6)}{n^2}\ \text{eV}$$

For first excited state, $n = 2$

$$\therefore\ E_2 = -\frac{4\,(13.6)}{(2)^2}\ \text{eV} = -13.6\ \text{eV}$$

Hence, the energy in He$^+$ ion in first excited state is same that of energy of the hydrogen atom in ground state *i.e.*, – 13.6 eV.

12. (i) **(c) :** de Broglie wavelength, $\lambda = \frac{h}{p}$

where p is the momentum of the particle

For electron, $\lambda_e = \frac{h}{p_e}$

For proton, $\lambda_p = \frac{h}{p_p}$

As $\lambda_e = \lambda_p \Rightarrow p_e = p_p$ (Given)
or Momentum of electron = Momentum of proton

(ii) **(a) :** As $\lambda = \frac{h}{\sqrt{2mK}}$ so $\lambda \propto \frac{1}{\sqrt{m}}$

Out of the given particles m is least for electron, therefore electron has the largest value of de Broglie wavelength.

(iii) **(a) :** As $\lambda = \frac{h}{p}$ or $p = \frac{h}{\lambda}$ or $p \propto \frac{1}{\lambda}$

$$\therefore \quad \frac{p_1}{p_2} = \frac{\lambda_2}{\lambda_1} = \frac{\lambda}{\lambda} = 1 \text{ or } p_1 = p_2$$

Also $E = \frac{1}{2}\frac{p^2}{m} = \frac{1}{2m}\frac{h^2}{\lambda^2}$ $\left(\because\ p = \frac{h}{\lambda}\right)$

or $E \propto \frac{1}{m}$ $\therefore$ $\frac{E_1}{E_2} = \frac{m_2}{m_1} < 1$ or $E_1 < E_2$

(iv) **(b) :** The de Broglie wavelength is given by

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

So if the velocity of the electron increases, the de Broglie wavelength decreases.

(v) **(d) :** $\lambda = \frac{h}{p}$, when λ is same, p is also same.