Sample Question Paper - 2
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.*

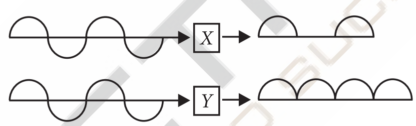
(iv) *There is no overall choice. However, an internal choice has been provided in one question of two marks and two questions of three marks. You have to attempt only one of the choices in such questions.*

(v) *You may use log tables if necessary but use of calculator is not allowed.*

SECTION - A

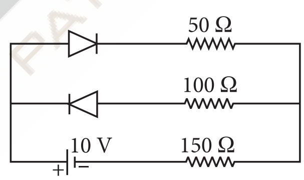
1. If the kinetic energy of a particle is reduced to one-fourth then the percentage increase in the de-Broglie wavelength of the particle.

2. An a.c. signal is fed into two circuits 'X' and 'Y' and the corresponding output in the two cases have the waveforms as shown in figure. Identify the circuits 'X' and 'Y'. Draw their labelled circuit diagrams.



OR

Assume that each diode shown in the figure has a forward bias resistance of 50 Ω and an infinite reverse bias resistance. The current through the resistance 150 Ω is



3. Define the magnifying power of a compound microscope when the final image is formed at infinity. Why must both the objective and the eyepiece of a compound microscope has short focal lengths? Explain.

SECTION - B

4. A single slit of width b is illuminated by a coherent monochromatic light of wavelength λ. If the second and fourth minima in the diffraction pattern at a distance 1 m from the slit are at 3 cm and 6 cm respectively from the central maximum, what is the width of the central maximum? (*i.e.* distance between first minimum on either side of the central maximum)

5. A plane electromagnetic wave travels in free space along X-direction. If the value of $\vec{B}$ (in tesla) at a particular point in space and time is $1.2 \times 10^{-8}\,\hat{k}$. Find the value of $\vec{E}$ at that point.

6. A nucleus at rest splits into two nuclear parts having radii in the ratio 1 : 2. Find the ratio of their velocities.

7. (a) Draw a ray diagram depicting the formation of the image by an astronomical telescope in normal adjustment.

(b) You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope? Give reason.

Lenses	Power(D)	Aperture (cm)
L_1	2	6
L_2	4	1
L_3	8	1

OR

Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses.

8. Using Bohr's postulates for hydrogen atom, show that the total energy (E) of the electron in the stationary states can be expressed as the sum of kinetic energy (K) and potential energy (U), where $U = -2K$. Hence deduce the expression for the total energy in the n^{th} energy level of hydrogen atom.

9. (a) Use Huygen's geometrical construction to show how a plane wave-front at $t = 0$ propagates and produces a wave-front at a later time.

(b) How does the angular separation between fringes in single-slit diffraction experiment change when the distance of separation between the slit and screen is doubled.

10. The threshold frequency for a certain photosensitive metal is υ_0. When it is illuminated by light of frequency $\upsilon = 2\upsilon_0$, the maximum velocity of photoelectrons is v_0. What will be the maximum velocity of the photoelectrons when the same metal is illuminated by light of frequency $\upsilon = 5\upsilon_0$?

OR

Explain giving reasons for the following:

(a) Photoelectric current in a photocell increases with the increase in the intensity of the incident radiation.

(b) The stopping potential (V_0) varies linearly with the frequency (υ) of the incident radiation for a given photosensitive surface with the slope remaining the same for different surfaces.

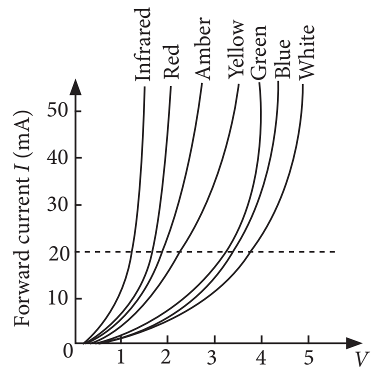
11. Define the term 'critical angle' for a pair of media.

A point source of monochromatic light 'S' is kept at the centre of the bottom of a cylinder of radius 15.0 cm. The cylinder contains water (refractive index 4/3) to a height of 7.0 cm. Draw the ray diagram and calculate the area of water surface through which the light emerges in air.

SECTION - C

12. CASE STUDY : LIGHT EMITTING DIODE

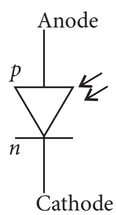
Light emitting diode is a photoelectric device which converts electrical energy into light energy. It is a heavily doped *p-n* junction diode which under forward biased emits spontaneous radiation. The general shape of the *I-V* characteristics of an LED is similar to that of a normal *p-n* junction diode, as shown. The barrier potentials are much higher and slightly different for each colour.

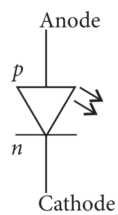


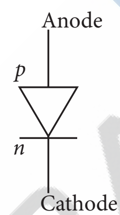
(i) The I-V characteristic of shown LED lies in

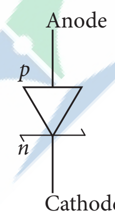
(a) visible region only
(b) infrared and visible region
(c) ultraviolet region only
(d) microwave region

(ii) The schematic symbol of light emitting diode (LED) is

(a) 

(b) 

(c) 

(d) 

(iii) An LED is constructed from a p-n junction based on a certain Ga-As-P semiconducting material whose energy gap is 1.9 eV. Identify the colour of the emitted light.

(a) Blue
(b) Red
(c) Violet
(d) Green

(iv) Which one of the following statement is not correct in the case of light emitting diodes?

(a) It is a heavily doped p-n junction.
(b) It emits light only when it is forward biased.
(c) It emits light only when it is reverse biased.
(d) The energy of the light emitted is less than the energy gap of the semiconductor used.

(v) The energy of radiation emitted by LED is

(a) greater than the band gap of the semiconductor used
(b) always less than the band gap of the semiconductor used
(c) can be greater than or less than the band gap of the semiconductor used
(d) equal to or less than the band gap of the semiconductor used.

Solution

PHYSICS - 042

Class 12 - Physics

1. de-Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$

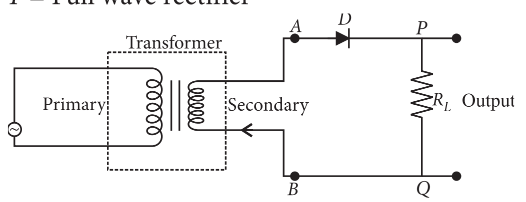
If $K' = \frac{K}{4}$; $\lambda' = \frac{h}{\sqrt{2mK'}} = \frac{h}{\sqrt{2mK/4}} = 2\lambda$

$\therefore$ Percentage increase in de-Broglie wavelength

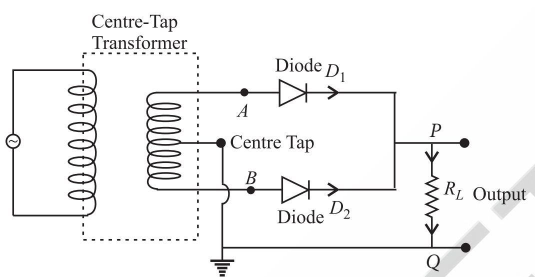
$$= \frac{\lambda' - \lambda}{\lambda} \times 100\% = \frac{2\lambda - \lambda}{\lambda} \times 100\% = 100\%$$

2. X = Half wave rectifier

Y = Full wave rectifier



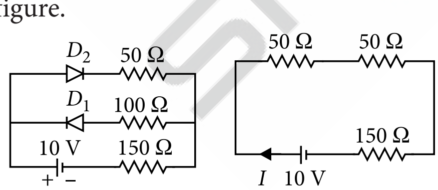
(Half wave rectifier)



(Full wave rectifier)

OR

In the circuit, diode D_1 is reverse biased and offers infinite resistance, diode D_2 is forward biased and offers 50 Ω resistance. The equivalent circuit is shown in the figure.



Total resistance of the circuit,

R = 50 Ω + 50 Ω + 150 Ω = 250 Ω

The current in the circuit, $I = \frac{V}{R} = \frac{10\text{ V}}{250\ \Omega} = 0.04$ A

So, current through the resistance 150 Ω is 0.04 A.

3. The magnification of compound microscope when the final image is formed at infinity,

$$M = \frac{L}{f_0}\left(\frac{D}{f_e}\right)$$

Both the objective and the eyepiece of a compound microscope has short focal length so as to produce large magnifying power.

4. For single slit diffraction, $\sin\theta = \frac{n\lambda}{b}$

Position of n^{th} minima from central maxima $= \frac{n\lambda D}{b}$

When $n = 2$, then $x_2 = \frac{2\lambda D}{b} = 0.03$ ...(i)

When $n = 4$, then $x_4 = \frac{4\lambda D}{b} = 0.06$ ...(ii)

From equation (i) and (ii)

$x_4 - x_2 = \frac{4\lambda D}{b} - \frac{2\lambda D}{b} = 0.03$ or $\frac{\lambda D}{b} = \frac{0.03}{2}$

then width of central maximum $= \frac{2\lambda D}{b}$

$$= 2 \times \frac{0.03}{2} = 0.03 \text{ m} = 3 \text{ cm}$$

5. Here, $\vec{B} = 1.2 \times 10^{-8}\,\hat{k}$ T

The magnitude of $\vec{E}$ is

$E = Bc = (1.2 \times 10^{-8}\text{ T})(3 \times 10^{8}\text{ m s}^{-1}) = 3.6\text{ V m}^{-1}$

$\vec{B}$ is along Z-direction and electromagnetic wave propagates along X-direction. Therefore $\vec{E}$ should be in a direction perpendicular to both X and Z axes. Using vector algebra $\vec{E} \times \vec{B}$ should be along X-direction.

Since $(+\hat{j}) \times (+\hat{k}) = \hat{i}$, $\vec{E}$ is along the Y-direction.

Thus, $\vec{E} = 3.6\hat{j}$ V m^{-1}

6. Let A_1 and A_2 be the mass numbers of the two nuclear parts. Their radii are given by

$R_1 = R_0 A_1^{1/3}$ ...(i)

and $R_2 = R_0 A_2^{1/3}$ ...(ii)

Dividing eqn. (i) by eqn. (ii), we get

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} \text{ or } \frac{A_1}{A_2} = \left(\frac{R_1}{R_2}\right)^3$$

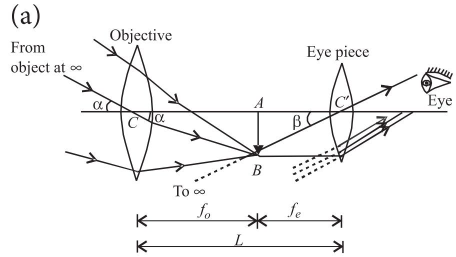
As $\frac{R_1}{R_2} = \frac{1}{2}$ (given) $\therefore$ $\frac{A_1}{A_2} = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$

Hence the ratio of their masses is, $\frac{m_1}{m_2} = \frac{1}{8}$ ...(iii)

According to law of conservation of linear momentum, magnitude of p_1 = magnitude of p_2

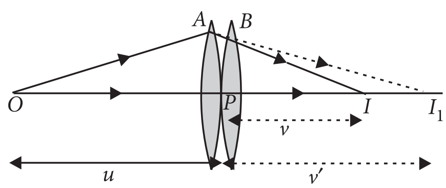
i.e., $m_1 v_1 = m_2 v_2$ or $\frac{v_1}{v_2} = \frac{m_2}{m_1} = \frac{8}{1}$ (using (iii))

7. (a)



(b) For a telescope, lens L_1 is chosen as objective, as its aperture and focal lengths are largest. The lens L_3 is chosen as eyepiece as its focal length is smallest.

OR



Consider two lenses placed close to each other. The focal lengths of lens A and B is f_1 and f_2 respectively.

For lens A,

$$\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1} \quad \text{... (i)}$$

For lens B,

$$\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2} \quad \text{...(ii)}$$

Adding (i) and (ii),

$$\frac{1}{v'} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_1} + \frac{1}{f_2} \;;\; \frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$$

Since $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ then, $\frac{1}{f_T} = \frac{1}{f_1} + \frac{1}{f_2} \left(\because P = \frac{1}{f} \right)$

Equivalent power, $P_T = P_1 + P_2$

8. According to Bohr's postulates for hydrogen atom, electron revolves in a circular orbit around the heavy positively charged nucleus. These are the stationary (orbits) states of the atom.

For a particular orbit, electron moves there, so it has kinetic energy.

Also, there is potential energy due to charge on electron and heavy positively charged nucleus.

Hence, total energy (E) of atom is sum of kinetic energy (K) and potential energy (U).

i.e., $E = K + U$

Let us assume that the nucleus has positive charge Ze.

An electron moving with a constant speed v along a circle of radius r with centre at the nucleus.

Force acting on electron due to nucleus is given by

$$F = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$$

The acceleration of electron $= \frac{v^2}{}$ (towards the centre).

If m = mass of an electron, then from Newton's second law

$$F = m\left(\frac{v^2}{r}\right)$$

$$\Rightarrow \frac{Ze^2}{4\pi\varepsilon_0 r^2} = m\left(\frac{v^2}{r}\right) \Rightarrow r = \frac{Ze^2}{4\pi\varepsilon_0 m v^2} \quad \text{...(i)}$$

From Bohr's quantisation rules,

$$mvr = n\frac{h}{2\pi} \quad \text{...(ii)}$$

Where, n is a positive integer

Substituting the value of r from eq. (i), we get

$$mv.\frac{Ze^2}{4\pi\varepsilon_0 (mv^2)} = n\frac{h}{2\pi}, \; v = \frac{Ze^2}{2\varepsilon_0 hn} \quad \text{...(iii)}$$

So, kinetic energy, $K = \frac{1}{2}mv^2 = \frac{Z^2e^4m}{8\varepsilon_0^2 h^2 n^2}$ ...(iv)

Potential energy of the atom, $U = -\frac{Ze^2}{4\pi\varepsilon_0 r}$ ...(v)

Using eq. (iii) in eq. (i), we get

$$r = \frac{Ze^2}{4\pi\varepsilon_0 m \frac{(Ze^2)^2}{(2\varepsilon_0 hn)^2}} = \frac{4\varepsilon_0^2 h^2 n^2}{(4\pi\varepsilon_0) mZe^2} \;;\; r = \frac{\varepsilon_0 h^2 n^2}{\pi m Z e^2}$$

Using value of r in eq. (v), we get

$$U = \frac{-Ze^2}{4\pi\varepsilon_0 \left(\frac{\varepsilon_0 h^2 n^2}{\pi m Z e^2}\right)} = \frac{-Z^2 e^4 m}{4\varepsilon_0^2 h^2 n^2} \quad \text{...(vi)}$$

From (iv) and (vi), $U = -2K$

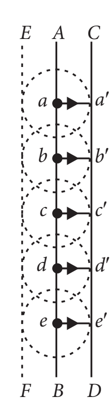
So, the total energy, $E = K + U$

$$= +\frac{mZ^2e^4}{8\varepsilon_0^2 h^2 n^2} - \frac{mZ^2e^4}{4\varepsilon_0^2 h^2 n^2} = -\frac{Z^2 e^4 m}{8\varepsilon_0^2 h^2 n^2}$$

For H-atom $Z = 1$, so the total energy of the n^{th} energy level of H-atom.

$$E_n = -\frac{me^4}{8n^2\varepsilon_0^2 h^2}$$

9. (a) Consider a plane wavefront moving towards right. Let AB be its position at any instant of time. The region on its left has received the wave while region on the right is undisturbed.



Huygens' geometrical construction for the propagation of plane wavefront.

According to Huygens' principle, each point on AB becomes a source of secondary disturbance, which takes with the same speed c. To find the new wavefront after time t, we draw spheres of radii ct, from each point on AB.

The forward envelope or the tangential surface *CD* of the secondary wavelets gives the new wavefront after time *t*.

The lines *aa′*, *bb′*, *cc′*, etc., are perpendicular to both *AB* and *CD*. Along these lines, the energy flows from *AB* to *CD*. So these lines represent the rays. Rays are always normal to wavefronts.

(b) In a single slit diffraction separation between fringes, $\theta \propto \frac{n\lambda}{a}$

Where a is the slit width.

So, there is no effect on angular separation 2θ by changing of the distance of separation '*D*' between slit and the screen.

10. As υ_0 is the threshold frequency,

$\therefore$ Work function, $\phi_0 = h\upsilon_0$

According to Einstein photoelectric equation

$$\frac{1}{2}mv_{max}^2 = h\upsilon - \phi_0$$

where $h\upsilon$ is the incident energy, ϕ_0 is the work function of the metal and $\frac{1}{2}mv_{max}^2$ is the maximum kinetic energy of the emitted photoelectron.

As per question

$$\frac{1}{2}mv_0^2 = h(2\upsilon_0) - h\upsilon_0 = h\upsilon_0 \quad \text{...(i)}$$

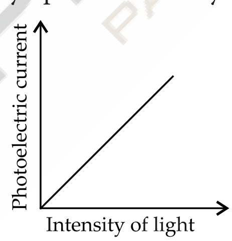
and $$\frac{1}{2}mv'^2 = h(5\upsilon_0) - h\upsilon_0 = 4h\upsilon_0 \quad \text{...(ii)}$$

Divide (ii) by (i), we get

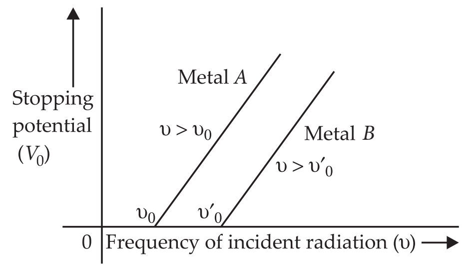
$$\frac{v'^2}{v_0^2} = \frac{4}{1} \quad \text{or} \quad v'^2 = 4v_0^2 \quad \text{or} \quad v' = 2v_0$$

OR

(a) The number of photoelectrons emitted, *i.e.*, photoelectric current depends only upon its intensity. The photo current is directly proportional to the number of photoelectrons emitted per second. This implies that the number of photoelectrons emitted per second is directly proportional to the intensity of incident radiation.



(b) The energy of the emitted electrons depends on the frequency of the incident radiations. The stopping potential is more negative for higher frequencies of incident radiation. Stopping potentials are in order $V_{03} > V_{02} > V_{01}$ if the frequencies are in the order of $\upsilon_3 > \upsilon_2 > \upsilon_1$. This implies that greater the frequency of incident light, greater is the maximum kinetic energy of the photoelectrons.

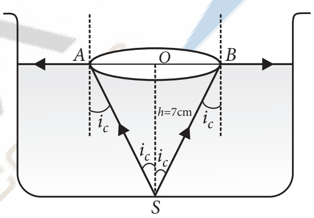


Slope of V_0 vs v graph gives $\frac{h}{e}$. This is same for different surfaces.

11. The angle of incidence in denser medium for which the angle of refraction in rarer medium is 90° is called the critical angle (i_c) for the pair of media. The light rays emerge through a circle of radius *r*.

$$\text{Area of water surface} = \frac{\pi h^2}{\mu^2 - 1} = \frac{22}{7} \times \frac{(7)^2}{(1.33)^2 - 1}$$

$$= 200.28 \text{ cm}^2$$



12. (i) **(b) :** The *I-V* characteristics of shown LED is similar to that of a Si junction diode and lies in infrared and visible regions.

(ii) **(b) :** LED is a heavily doped forward biased *p-n* junction which spontaneously converts electrical energy into optical energy.

(iii) **(b) :** As $E_g = \frac{hc}{\lambda}$ $\therefore \lambda = \frac{hc}{E_g}$

Here, $E_g = 1.9$ eV, $hc = 1240$ eV nm

$$\therefore \quad \lambda = \frac{1240 \text{ eV nm}}{1.9 \text{ eV}} = 652.6 \text{ nm}$$

Hence, the emitted light is of red colour.

(iv) **(c) :** A light emitting diode is a heavily doped *p-n* junction diode which emits light only when it is forward biased.

(v) **(d):** Energy of radiation emitted by LED is equal or to less than the band gap of semiconductor used.