Sample Question Paper - 16
Physics (042)
Class- XII, Session: 2021-22
TERM II

Time : 2 Hours		*Max. Marks : 35*

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.

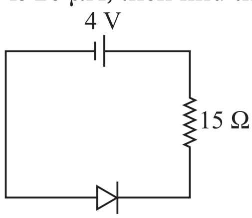
SECTION - A

1. Using Rutherford's model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron?

2. How does a light emitting diode (LED) work? Give two advantages of LED's over the conventional incandescent lamps.

OR

In the circuit shown if current for the diode is 20 μA, then find the potential difference across the diode.



3. (a) Distinguish between n-type and p-type semiconductors on the basis of energy band diagrams.

(b) Compare their conductivities at absolute zero temperature and at room temperature.

SECTION - B

4. The rms value of the electric field of the light coming from the sun is 720 N C^{-1}. Then what is the average total energy density of the electromagnetic wave?

5. What will be the ratio of the energy released by 4 kg of hydrogen at sun by fusion process to 23.5 kg of ^{235}U in the nuclear reactor by fission process? (Assume energy released per fusion is 26 MeV and that per fission is 200 MeV)

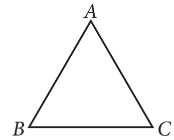
6. What is the conductivity of a semiconductor sample having electron concentration of 5×10^{18} m^{-3}, hole concentration of 5×10^{19} m^{-3}, electron mobility of 2.0 m^2 V^{-1} s^{-1} and hole mobility of 0.01 m^2 V^{-1} s^{-1}? (Take charge of electron as 1.6×10^{-19} C)

7. (a) Define the term 'critical angle' for a pair of media.

(b) 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.

8. (a) A ray of light incident on face AB of an equilateral glass prism, shows minimum deviation of 30°. Calculate the speed of light through the prism.



(b) Find the angle of incidence at face AB so that the emergent ray grazes along the face AC.

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 15 cm apart. A point object is placed 40 cm in front of the convex lens. Find the position of the image formed by this combination. Draw the ray diagram showing the image formation.

9. The photoelectric threshold for a certain metal is 3600 Å. Calculate the maximum energy of the ejected photoelectrons by a radiation of 2000 Å. (Given $h = 6.62 \times 10^{-34}$ J s)

10. Calculate the highest frequency of the emitted photon in the Paschen series of spectral lines of the Hydrogen atom.

11. Explain the following, giving reasons:

(a) When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency.

(b) When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave ?

(c) In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light?

OR

(a) Why are coherent sources necessary to produce a sustained interference pattern?

(b) In Young's double slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is $\lambda/3$.

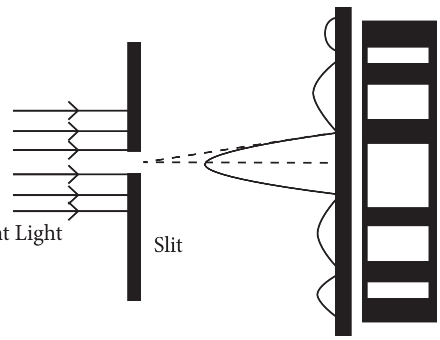
SECTION - C

12. CASE STUDY : DIFFRACTION DUE TO A SINGLE SLIT (FRAUNHOFER)

When light from a monochromatic source is incident on a single narrow slit, it gets diffracted and a pattern of alternate bright and dark fringes is obtained on screen, called "Diffraction Pattern" of single slit. In diffraction pattern of single slit, it is found that

(I) Central bright fringe is of maximum intensity and the intensity of any secondary bright fringe decreases with increase in its order.

(II) Central bright fringe is twice as wide as any other secondary bright or dark fringe.



(i) A single slit of width 0.1 mm is illuminated by a parallel beam of light of wavelength 6000 Å and diffraction bands are observed on a screen 0.5 m from the slit. The distance of the third dark band from the central bright band is

(a) 3 mm (b) 1.5 mm (c) 9 mm (d) 4.5 mm

(ii) In Fraunhofer diffraction pattern, slit width is 0.2 mm and screen is at 2 m away from the lens. If wavelength of light used is 5000 Å then the distance between the first minimum on either side the central maximum is

(a) 10^{-1} m (b) 10^{-2} m (c) 2×10^{-2} m (d) 2×10^{-1} m

(iii) Light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. The angular width of central maxima in the diffraction pattern is (measured from minimum to minimum)

(a) 6×10^{-3} rad (b) 4×10^{-3} rad (c) 2.4×10^{-3} rad (d) 4.5×10^{-3} rad

(iv) A diffraction pattern is obtained by using a beam of red light. What will happen, if the red light is replaced by the blue light?

(a) Bands disappear.
(b) Bands become broader and farther apart.
(c) No change will take place.
(d) Diffraction bands become narrower and crowded together.

(v) To observe diffraction, the size of the obstacle

(a) should be $\lambda/2$, where λ is the wavelength. (b) should be of the order of wavelength.
(c) has no relation to wavelength. (d) should be much larger than the wavelength.

Solution

PHYSICS - 042

Class 12 - Physics

1. An electron revolving in an orbit of H-atom, has both kinetic energy and electrostatic potential energy. Kinetic energy of the electron revolving in a circular orbit of radius r is $E_K = \frac{1}{2}mv^2$

Since, $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$

$$\therefore \quad E_K = \frac{1}{2}\times\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \quad \text{or} \quad E_K = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r} \qquad \text{... (i)}$$

Electrostatic potential energy of electron of charge $-e$ revolving around the nucleus of charge $+e$ in an orbit of radius r is

$$E_P = \frac{1}{4\pi\varepsilon_0}\frac{+e\times -e}{r} \quad \text{or} \quad E_P = \frac{-1}{4\pi\varepsilon_0}\frac{e^2}{r} \qquad \text{... (ii)}$$

So, total energy of electron in orbit of radius r is

$$E = E_K + E_P \quad \text{or} \quad E = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r} - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$\text{or} \quad E = \frac{-1}{4\pi\varepsilon_0}\frac{e^2}{2r}$$

The –ve sign of the energy of electron indicates that the electron and nucleus together form a bound system *i.e.*, electron is bound to the nucleus.

2. A light emitting diode is simply a forward biased *p-n* junction which emits spontaneous light radiation. At the junction, energy is released in the form of photons due to the recombination of the excess minority charge carrier with the majority charge carrier.

Advantages :

(i) Low operational voltage and less power.

(ii) Fast action and no warm up time required.

OR

Since the diode is reversed biased, only drift current exists in circuit which is 20 μA.

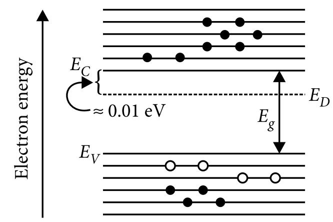
Potential drop across 15 Ω resistor, = 15 Ω × 20 μA

= 300 μV = 0.0003 V

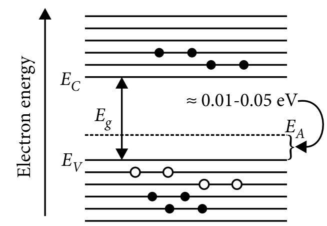
Potential difference across the diode = 4 – 0.0003

= 3.99 ≅ 4 V

3. (a) The required energy band diagrams are given below:

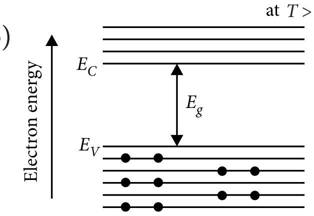


(a)
Energy band diagram of
n-type semiconductor
at $T > 0$ K



(b)
Energy band diagram of
p-type semiconductor
at $T > 0$ K

(b)



Energy band diagram of
semiconductor
at $T = 0$ K

At absolute zero temperature (0 K) conduction band of semiconductor is completely empty, *i.e.*, σ = 0. Hence the semiconductor behaves as an insulator. At room temperature, some valence electrons acquire enough thermal energy and jump to the conduction band where they are free to conduct electricity. Thus the semiconductor acquires a small conductivity at room temperature.

4. Total average energy density of electromagnetic wave is $\frac{1}{2}\varepsilon_0 E_{rms}^2 + \frac{1}{2}\varepsilon_0 E_{rms}^2 = \varepsilon_0 E_{rms}^2$

$= 8.85 \times 10^{-12} \times (720)^2 = 4.58 \times 10^{-6}$ J m^{-3}

5. As 1 g of H-atom = N_A

∴ 1000 g of H-atom = $1000N_A$

So, 4 kg of H-atom = $4000N_A$

$$\therefore \quad \text{Number of fusion} = \frac{4000N_A}{4} = 1000N_A$$

Energy released per fusion process

= $1000N_A \times 26$ MeV

Now, 235 g of Uranium = N_A

23.5 kg of Uranium = $100N_A$
So, energy released for fission process
$= 100N_A \times 200$ MeV

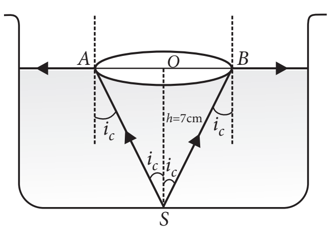
$$\therefore \frac{E_{\text{fusion}}}{E_{\text{fission}}} = \frac{1000N_A \times 26\text{ MeV}}{100N_A \times 200\text{ MeV}} = \frac{13}{10}$$

6. **(b):** Given; $n_e = 5 \times 10^{18}$ m^{-3}, $n_h = 5 \times 10^{19}$ m^{-3}, $\mu_e = 2$ m^2 V^{-1} s^{-1}, $\mu_h = 0.01$ m^2 V^{-1} s^{-1} then conductivity, $\sigma = e\,(n_e\mu_e + n_h\mu_h)$
Putting values, we get
$\sigma = 1.6 \times 10^{-19}(5 \times 10^{18} \times 2 + 5 \times 10^{19} \times 0.01)$
$= 1.6 \times 10^{-19}(10^{19} + 0.05 \times 10^{19}) = 1.68\ (\Omega\text{-m})^{-1}$

7. 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.

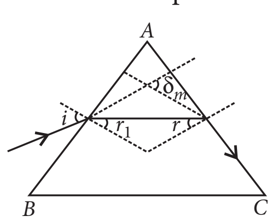
$$\text{Area of water surface} = \frac{\pi h^2}{\mu^2 - 1}$$

$$= \frac{22}{7} \times \frac{(7)^2}{(1.33)^2 - 1} = 200.28\text{ cm}^2$$



8. (a) The refractive index of the material of prism

$$\mu = \frac{\sin\left[\frac{A + \delta_m}{2}\right]}{\sin\frac{A}{2}},$$



Given : $A = 60°$, $\delta_m = 30°$

$$\therefore\ \mu = \frac{\sin 45°}{\sin 30°} = \frac{1}{\sqrt{2}}.2 \Rightarrow \mu = \sqrt{2}$$

$$\because\ \mu = \frac{c}{v} \Rightarrow v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.414} = 2.12 \times 10^8\text{ m s}^{-1}$$

(b) $\sin i_C = \frac{1}{\mu} = \frac{1}{\sqrt{2}}$

$i_C = r = 45°$
$\because\ A = r_1 + r$
$\Rightarrow r_1 = 15°$

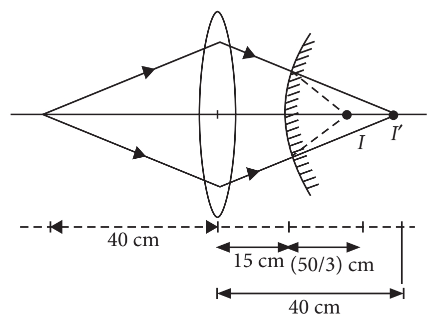
$$\frac{\sin i}{\sin r_1} = \sqrt{2}$$

$$\therefore\ \sin i = \sqrt{2}\sin 15° = \frac{(\sqrt{3} - 1)}{2\sqrt{2}} \times \sqrt{2}$$

$$\sin i = \frac{\sqrt{3} - 1}{2}$$

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

OR



For the lens

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

$u = -40$ cm, $f = +20$ cm. This gives $v = +40$ cm
This image acts as a (virtual) object for the convex mirror.
$\therefore\ u = (+40 - 15)$ cm = 25 cm

Also $f = +\frac{20}{2}$ cm $= +10$ cm

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

We get $v = \frac{50}{3}$ cm $\simeq 16.67$ cm

The final image is, therefore formed at a distance of 16.67 cm $\left(= \frac{50}{3}\text{ cm}\right)$ to the right of the convex mirror.
(at a distance of 31.67 cm $\left(= \frac{95}{3}\text{ cm}\right)$ to the right of the convex lens.

9. According to Einstein's photoelectric equation,

$$K_{\text{max}} = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$$

$$= 6.62 \times 10^{-34} \times 3 \times 10^8\left[\frac{1}{20 \times 10^{-8}} - \frac{1}{36 \times 10^{-8}}\right]$$

$$= \frac{6.62 \times 10^{-34} \times 3 \times 10^8 \times 4}{180 \times 10^{-8} \times 1.6 \times 10^{-19}}\text{ eV} = 2.76\text{ eV}$$

10. The frequencies of the emitted photon in the Paschen series are given by

$$\upsilon = Rc\left(\frac{1}{3^2} - \frac{1}{n^2}\right),\text{ where } n = 4, 5, 6, ...$$

The highest frequency corresponds to $n = \infty$

$$\therefore \quad \upsilon_{highest} = \frac{Rc}{9} = \frac{1.097\times10^{7}\ m^{-1}\times3\times10^{8}\ m/s}{9}$$

$$= 0.37 \times 10^{15}\ s^{-1} = 3.7 \times 10^{14}\ Hz$$

11. (a) Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence frequency remains unchanged.

(b) Energy carried by a wave depends on the frequency of the wave, not on the speed of wave propagation.

(c) For a given frequency, intensity of light in the photon picture is determined by

$$I = \frac{\text{Energy of photons}}{\text{area} \times \text{time}} = \frac{n\times h\upsilon}{A\times t}$$

where n is the number of photons incident normally on crossing area A in time t.

OR

(a) Coherent sources are necessary to produce a sustained interference pattern otherwise the phase difference changes very rapidly with time and hence no interference will be observed.

(b) Intensity at a point, $I = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$

$$\text{Phase difference} = \frac{2\pi}{\lambda}\times \text{ Path difference}$$

At path difference λ,

$$\text{Phase difference, } \phi = \frac{2\pi}{\lambda}\times\lambda = 2\pi$$

$$\therefore \quad \text{Intensity, } K = 4I_0\cos^2\left(\frac{2\pi}{2}\right)$$

[$\because$ Given $I = K$, at path difference λ]

$$K = 4I_0 \qquad \text{...(i)}$$

If path difference is $\frac{\lambda}{3}$, then phase difference will be

$$\phi' = \frac{2\pi}{\lambda}\times\frac{\lambda}{3} = \frac{2\pi}{3}$$

$$\therefore \quad \text{Intensity, } I' = 4I_0\cos^2\left(\frac{2\pi}{6}\right) = \frac{K}{4} \quad \text{(Using (i))}$$

12. (i) **(c) :** Here, $d = 0.1$ mm, $\lambda = 6000$ Å, $D = 0.5$ m

For third dark band, $d\sin\theta = 3\lambda$; $\sin\theta = \frac{3\lambda}{d} = \frac{y}{D}$

$$y = \frac{3D\lambda}{d} = \frac{3\times0.5\times6\times10^{-7}}{0.1\times10^{-3}} = 9\times10^{-3}\ m = 9\ mm$$

(ii) **(b) :** Given $d = 0.2$ mm $= 0.2 \times 10^{-3}$ m, $D = 2$ m

$\lambda = 5000$ Å $= 5 \times 10^{-7}$ m

The distance between the first minimum on other side of the central maximum

$$x = \frac{2\lambda D}{d} = \frac{2\times5\times10^{-7}\times2}{0.2\times10^{-3}} \Rightarrow x = 10^{-2}\ m$$

(iii) **(a) :** Here, $\lambda = 600$ nm $= 6 \times 10^{-7}$ m

$a = 0.2$ mm $= 2 \times 10^{-4}$ m, $\theta = ?$

Angular width of central maxima,

$$\theta = \frac{2\lambda}{a} = \frac{2\times6\times10^{-7}}{2\times10^{-4}} = 6\times10^{-3}\ rad$$

(iv) **(d) :** When red light is replaced by blue light ($\lambda_B < \lambda_R$) the diffraction pattern bands becomes narrow and crowded together.

(v) **(b) :** To observe diffraction, the size of the obstacle should be of the order of wavelength.