Sample Question Paper - 23
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

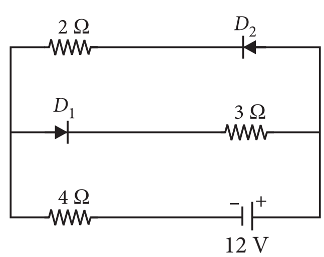
1. The current in the forward bias is known to be more (~mA) than the current in the reverse bias (~ μA). What is the reason, then, to operate the photodiode in reverse bias?

2. Calculate the orbital period of the electron in the first excited state of hydrogen atom.

OR

Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge?

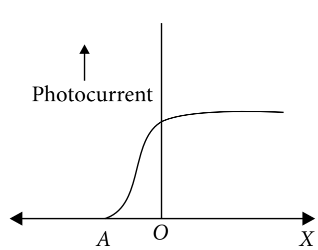
3. The circuit shown in the figure has two oppositely connected ideal diodes connected in parallel. Find the current flowing through each diode in the circuit.



SECTION - B

4. Draw the circuit diagram of a half wave rectifier and explain its working. Also, give the input and output waveforms.

5. The following graph shows the variation of photocurrent for a photosensitive metal:



(a) Identify the variable X on the horizontal axis.
(b) What does the point A on the horizontal axis represent?
(c) Draw this graph for three different values of frequencies of incident radiation υ_1, υ_2 and υ_3 ($\upsilon_1 > \upsilon_2 > \upsilon_3$) for same intensity.
(d) Draw this graph for three different values of intensities of incident radiation I_1, I_2 and I_3 ($I_1 > I_2 > I_3$) having same frequency.

6. Using Bohr's postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels.

7. (a) How is the size of a nucleus experimentally determined? Write the relation between the radius and mass number of the nucleus. Show that the density of nucleus is independent of its mass number.

(b) The nuclear radius of $^{27}_{13}\text{Al}$ is 3.6 fermi. Find the nuclear radius of $^{64}_{29}\text{Cu}$.

8. Two wavelengths of sodium light 590 nm and 596 nm are used, in turn to study the diffraction taking place at a single slit of aperture 2×10^{-4} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases.

9. A person can see clearly objects only when they lie between 50 cm and 400 cm from his eyes. In order to increase the maximum distance of distinct vision to infinity, person has to use what type and power of the correcting lens?

OR

In Young's double experiment, a monochromatic light of wavelength 5400 Å produces a fringe width of 3 mm. If this source is replaced by another source of monochromatic light of wavelength 6300 Å, then find the fringe width.

10. An object placed at a distance of 16 cm from a convex lens produces an image of magnification $m (m > 1)$. If the object is moved towards the lens by 8 cm then again an image of magnification m is obtained. What is the numerical value of the focal length of the lens?

11. A double convex lens is made of a glass of refractive index 1.55, with both faces of the same radius of curvature. Find the radius of curvature required, if the focal length is 20 cm.

OR

In a single slit diffraction experiment, the width of the slit is reduced to half its original width. How would this affect the size and intensity of the central maximum?

SECTION - C

12. CASE STUDY : SPEED OF AN ELECTROMAGNETIC WAVE

Maxwell showed that the speed of an electromagnetic wave depends on the permeability and permittivity of the medium through which it travels. The speed of an electromagnetic wave in free space is given by $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$.
The fact led Maxwell to predict that light is an electromagnetic wave. The emergence of the speed of light from purely electromagnetic considerations is the crowning achievement of Maxwell's electromagnetic theory. The speed of an electromagnetic wave in any medium of permeability μ and permittivity ε will be $\frac{c}{\sqrt{K\mu_r}}$ where K is the dielectric constant of the medium and μ_r is the relative permeability.

(i) The dimensions of $\frac{1}{2}\varepsilon_0 E^2$ (ε_0 : permittivity of free space; E = electric field) is

(a) $[MLT^{-1}]$ (b) $[ML^2T^{-2}]$ (c) $[ML^{-1}T^{-2}]$ (d) $[ML^2T^{-1}]$

(ii) Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of the vacuum. If M = mass, L = length, T = time and A = electric current, then

(a) $[\varepsilon_0] = [M^{-1}L^{-3}T^2A]$ (b) $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$

(c) $[\varepsilon_0] = [MLT^{-2}A^{-2}]$ (d) $[\varepsilon_0] = [ML^2T^{-1}]$

(iii) An electromagnetic wave of frequency 3 MHz passes from vacuum into a dielectric medium with permittivity $\varepsilon = 4$. Then

(a) wavelength and frequency both remain unchanged
(b) wavelength is doubled and the frequency remains unchanged
(c) wavelength is doubled and the frequency becomes half
(d) wavelength is halved and the frequency remains unchanged.

(iv) Which of the following are not electromagnetic waves?

(a) cosmic rays (b) γ-rays (c) β-rays (d) X-rays

(v) The electromagnetic waves travel with

(a) the same speed in all media
(b) the speed of light, $c = 3 \times 10^8$ m s^{-1} in free space
(c) the speed of light, $c = 3 \times 10^8$ m s^{-1} in solid medium
(d) the speed of light, $c = 3 \times 10^8$ m s^{-1} in fluid medium.

Solution

PHYSICS - 042

Class 12 - Physics

1. Consider the case of an n-type semiconductor. The majority carrier density (n) is considerably larger than the minority hole density p (*i.e.,* $n >> p$). On illumination, let the excess electrons and holes generated be Δn and Δp, respectively :

$$n' = n + \Delta n \;;\; p' = p + \Delta p$$

Here n' and p' are the electron and hole concentrations at any particular illumination and n and p are carrier concentration when there is no illumination. Remember $\Delta n = \Delta p$ and $n >> p$. Hence, the fractional change in the majority carriers (*i.e.*, $\Delta n/n$) would be much less than that in the minority carriers (*i.e.*, $\Delta p/p$). In general, we can state that the fractional change due to the photo-effects on the minority carrier dominated reverse bias current is more easily measurable than the fractional change in the forward bias current. Hence, photodiodes are preferably used in the reverse bias condition for measuring light intensity.

2. As $T = \dfrac{2\pi r_n}{v_n}$ or, $T = \dfrac{n^3h^3}{4\pi^2 mk^2e^4}$

For first excited state of hydrogen atom, $n = 2$

$$\therefore\quad T = \frac{8\times(6.63\times10^{-34})}{4\times10\times9.1\times10^{-31}\times(9\times10^{9})^2\times(1.6\times10^{-19})^4}$$

$= 1.2 \times 10^{-15}$ s

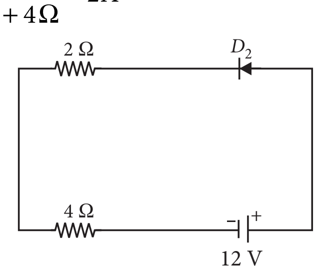
OR

The minimum energy, required to free the electron from the ground state of the hydrogen atom, is known as ionization energy of that atom.

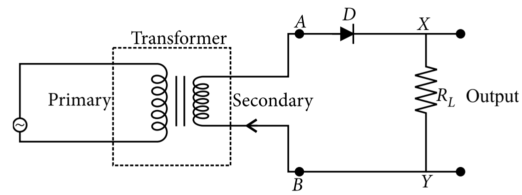
$E_0 = \dfrac{me^4}{8\varepsilon_0^2h^2}$ *i.e,.* $E_0 \propto m$, so when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron, ionization energy increases by 200 times.

3. Diode D_1 is reverse biased, so it offers an infinite resistance. So no current flows in the branch of diode D_1. Diode D_2 is forward biased, and offers negligible resistance in the circuit. So current in the branch

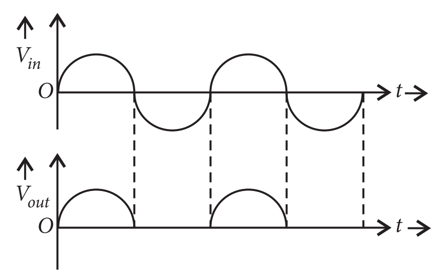
$$I = \frac{V}{R_{eq}} = \frac{12\,\text{V}}{2\,\Omega + 4\,\Omega} = 2\text{A}$$



4. Half wave rectifier:



It consists of a diode D connected in series with load resistor R_L across the secondary windings of a step-down transformer. Primary of transformer is connected to a.c. supply. During positive half cycle of input a.c., end A of the secondary winding becomes positive and end B negative. Thus, diode D becomes forward biased and conducts the current through it. So, current in the circuit flows from A to B through load resistor R_L.

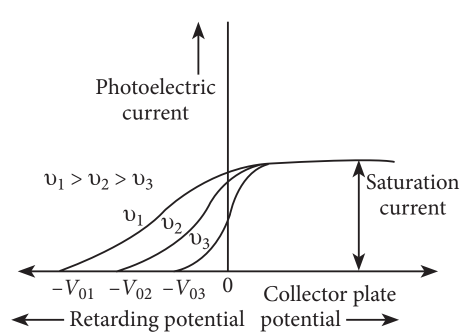


During negative half cycle of input a.c., end A of the secondary winding becomes negative and end B positive. Thus, diode D becomes reverse biased and does not conduct any current. So, no current flows in the circuit. Since electric current through load R_L flows only during positive half cycle, in one direction only *i.e.*, from A to B, so d.c. is obtained across R_L.

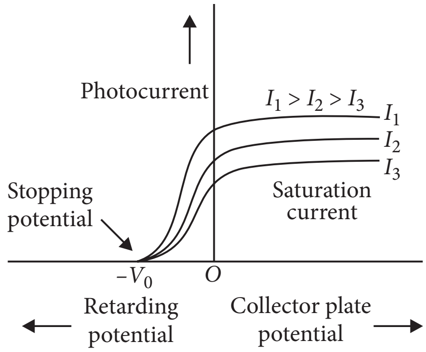
5. (a) : The variable X on the horizontal axis is collector plate potential.

(b) The point A on the horizontal axis represents stopping potential.

(c)



(d)



6. According to Bohr's postulates, in a hydrogen atom, as single electron revolves around a nucleus of charge $+e$. For an electron moving with a uniform speed in a circular orbit of a given radius, the centripetal force is provided by coulomb force of attraction between the electron and the nucleus. The gravitational attraction may be neglected as the mass of electron and proton is very small.

So, $\dfrac{mv^2}{r} = \dfrac{ke^2}{r^2}$ $\left(\text{Where, } k = \dfrac{1}{4\pi\varepsilon_0}\right)$

or $mv^2 = \dfrac{ke^2}{r}$ ...(i)

Where, m = mass of electron
r = radius of electron orbit
v = velocity of electron
Again, by Bohr's second postulates

$$mvr = \frac{nh}{2\pi}$$

Where, n = 1, 2, 3...... or $v = \dfrac{nh}{2\pi mr}$

Putting the value of v in eq. (i)

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{ke^2}{r} \Rightarrow r = \frac{n^2h^2}{4\pi^2kme^2} \quad \text{...(ii)}$$

Kinetic energy of electron,

$$E_k = \frac{1}{2}mv^2 = \frac{ke^2}{2r} \quad \left(\because \frac{mv^2}{r} = \frac{ke^2}{r^2}\right)$$

Using eq. (ii) we get

$$E_k = \frac{ke^2}{2}\frac{4\pi^2kme^2}{n^2h^2} = \frac{2\pi^2k^2me^4}{n^2h^2}$$

Potential energy of electron,

$$E_p = -\frac{k(e)\times(e)}{r} = -\frac{ke^2}{r}$$

Using eq. (ii), we get

$$E_p = -ke^2 \times \frac{4\pi^2kme^2}{n^2h^2} = -\frac{4\pi^2kme^4}{n^2h^2}$$

Hence, total energy of the electron in the n^{th} orbit

$$E = E_p + E_k$$

$$= -\frac{4\pi^2k^2me^4}{n^2h^2} + \frac{2\pi^2k^2me^4}{n^2h^2}$$

$$= -\frac{2\pi^2k^2me^4}{n^2h^2} = -\frac{13.6}{n^2}\text{ eV}$$

When the electron in a hydrogen atom jumps from higher energy level to the lower energy level, the difference of energies of the two energy levels is emitted as a radiation of particular wavelength. It is called a spectral line.

In H-atom, when an electron jumps from the orbit n_i to orbit n_f, the wavelength of the emitted radiation is given by

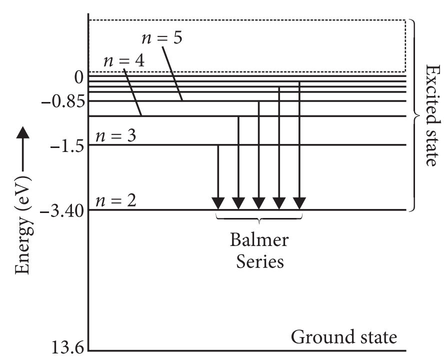
$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]; \; R = 1.09 \times 10^7 \text{ m}^{-1}$$

For Balmar series, n_f = 2 and n_i = 3, 4, 5, ...

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n_i^2}\right)$$

where, n_i = 3, 4, 5, ...

These spectral lines lie in the visible region.



7. (a) Nucleus was first discovered in 1911 by Lord Rutherford and his associates by experiments on scattering of α-particle by atoms. He found that the scattering result could be explained, if atoms consists of a small, central, massive and positive core surrounded by orbiting electron. The experiment results indicated that the size of the nucleus is of the order of 10^{-14} metres and thus 10,000 times smaller than the size of atom.

Relation between the radius and mass number of the nucleus $R = R_0 A^{1/3}$

If m is the average mass of a nucleon and R is the nuclear radius, then mass of nucleus = mA, where A is the mass number of the element.

Volume of the nucleus, $V = \dfrac{4}{3}\pi R^3$

$$\therefore \quad V = \frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3$$

$$\Rightarrow \quad V = \frac{4}{3}\pi R_0^3 A$$

Density of nuclear matter, $\rho = \dfrac{mA}{V}$

$$\Rightarrow \quad \rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} \Rightarrow \rho = \frac{3m}{4\pi R_0^3}$$

This shows that the nuclear density is independent of A.

(b) $R = R_0 A^{\frac{1}{3}} \Rightarrow \frac{R_{Al}}{R_{Cu}} = \left(\frac{A_{Al}}{A_{Cu}}\right)^{\frac{1}{3}}$

$\Rightarrow R_{Cu} = R_{Al}\left(\frac{A_{cu}}{A_{Al}}\right)^{\frac{1}{3}} = 3.6\left(\frac{64}{27}\right)^{\frac{1}{3}} = 4.8$ fermi

8. Given that: Wavelength of the light beam,
$\lambda_1 = 590$ nm $= 5.9 \times 10^{-7}$ m
Wavelength of another light beam,
$\lambda_2 = 596$ nm $= 5.96 \times 10^{-7}$ m
Distance of the slits from the screen = D = 1.5 m
Slits width = a = 2 × 10–4 m
For the first secondary maxima,

$\sin\theta = \frac{3\lambda_1}{2a} = \frac{x_1}{D}$

$x_1 = \frac{3\lambda_1 D}{2a}$ and $x_2 = \frac{3\lambda_2 D}{2a}$

∴ Separation between the positions of first secondary maxima of two sodium lines,

$x_2 - x_1 = \frac{3D}{2a}(\lambda_2 - \lambda_1)$

$= \frac{3\times1.5}{2\times2\times10^{-4}}(5.96 \times 10^{-7} - 5.9 \times 10^{-7})$

$= 6.75 \times 10^{-5}$ m

9. Here, $v = -400$ cm $= -4$ m, $u = -\infty, f = ?$

Using lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

or, $-\frac{1}{4} - \left(\frac{-1}{\infty}\right)$ or, $f = -4$ m

Lens should be concave.

Power of lens $= \frac{1}{f} = \frac{1}{-4} = -0.25$ D

OR

Fringe width, $\beta = \frac{\lambda D}{d}$

where D is the distance of the screen from the slits, d is the distance between the slits.

For the same D, d ; $\beta \propto \lambda$

∴ $\frac{\beta'}{\beta} = \frac{\lambda'}{\lambda} = \frac{6300\text{ Å}}{5400\text{ Å}} = \frac{7}{6}$

$\beta' = \beta \times \frac{7}{6} = 3\text{ mm} \times \frac{7}{6} = 3.5$ mm

10. Linear magnification, $m = \frac{f}{f-u}$

Here, u = 16 cm

∴ $m = \frac{f}{f-16}$

When object is moved towards the lens by 8 cm. Then,

$m = \frac{-f}{f-16+8} = \frac{-f}{f-8}$

According to question $\frac{f}{f-16} = \frac{-f}{f-8} \Rightarrow f = 12$ cm

11. Given : $\mu = 1.55, f = 20$ cm
$|R_1| = |R_2| = R$ (let)
For double convex lens as $R_1 > 0$ and $R_2 < 0$
So, $R_1 = R$ and $R_2 = -R$
Using lens maker's equation,

$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$, we get

$\frac{1}{20} = (1.55 - 1)\left(\frac{1}{R} + \frac{1}{R}\right) \Rightarrow \frac{1}{20} = 0.55 \times \frac{2}{R}$

$\Rightarrow R = 0.55 \times 2 \times 20$ cm $= 22$ cm

∴ The radius of curvature is 22 cm.

OR

The width of central maximum is given by

$\beta_0 = \frac{2D\lambda}{a}$

(a) If width of slit is reduced to half then the size of central maxima will become double.

(b) If width of slit is reduced to half its original width then the intensity of central maximum will be one-fourth.

12. (i) **(c) :** $\frac{1}{2}\varepsilon_0 E^2 = \text{energy density} = \frac{\text{Energy}}{\text{Volume}}$

∴ $\left[\frac{1}{2}\varepsilon_0 E^2\right] = \frac{ML^2T^{-2}}{L^3} = [ML^{-1}T^{-2}]$

(ii) **(b):** As $\varepsilon_0 = \frac{q_1 q_2}{4\pi F R^2}$ (from Coulomb's law)

$\varepsilon_0 = \frac{C^2}{Nm^2} \quad \frac{[AT]^2}{MLT^{-2}L^2} = M^{-1}L^{-3}T^4A^2$

(iii) **(d):** The frequency of the electromagnetic wave remains same when it passes from one medium to another.

Refractive index of the medium, $n = \sqrt{\frac{\varepsilon}{\varepsilon_0}} = \sqrt{\frac{4}{1}} = 2$

Wavelength of the electromagnetic wave in the medium,

$\lambda_{med} = \frac{\lambda}{n} = \frac{\lambda}{2}$

(iv) **(c) :** β-rays consists of electrons which are not electromagnetic in nature.

(v) **(b):** The velocity of electromagnetic waves in free space (vacuum) is equal to velocity of light in vacuum (*i.e.*, 3×10^8 m s^{-1}).