Sample Question Paper - 12
Physics (042)
Class- XII, Session: 2021-22
TERM II

Time Allowed: 2 hours **Maximum Marks: 35**

General Instructions:

1. There are 12 questions in all. All questions are compulsory.
2. This question paper has three sections: Section A, Section B and Section C.
3. 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.
4. 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.
5. You may use log tables if necessary but use of calculator is not allowed.

Section A

1. Write two points of difference between intrinsic and extrinsic semiconductors. **[2]**

2. Define ionisation energy. How would the ionisation 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? **[2]**

OR

Define the terms (i) **cut-off voltage** and (ii) **threshold frequency** in relation to the phenomenon of photoelectric effect.

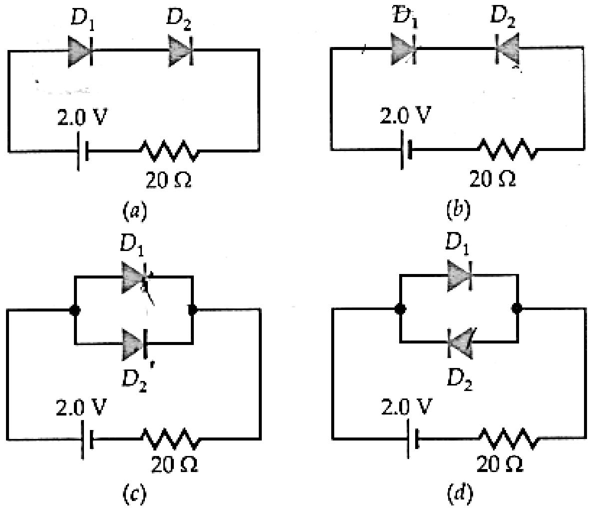
Using Einstein's photoelectric equation show how the cut-off voltage and threshold frequency for a given photosensitive material can be determined with the help of a suitable plot/graph.

3. Why is photodiode used in reverse bias? **[2]**

Section B

4. **[3]**
   i. Using Bohr's second postulate of quantisation of orbital angular momentum show that the circumference of the electron in the nth orbital state in hydrogen atom is n-times the de-Broglie wavelength associated with it.
   ii. The electron in hydrogen atom is initially in the third excited state. What is the maximum number of spectral lines which can be emitted when it finally moves to the ground state?

5. Determine the currents through the resistances of the circuits shown in figure. **[3]**



6. Calculate the binding energy per nucleon (in MeV) for ${}^{4}_{2}$He and ${}^{4}_{3}$He. Comment on the difference of these binding energies and its significance in relation to α-decay of the nuclei. [Given: mass of ${}^{1}_{1}$H =1.00783 u, mass of ${}^{1}_{0}$n= 1.00867 u, mass of ${}^{3}_{2}$He = 3.01664 u, mass of ${}^{4}_{2}$He = 4.00387 u] **[3]**

7. i. Write two points to distinguish between interference and diffraction fringes. **[3]**
   ii. In Young's double-slit experiment, fringes are obtained on a screen placed at a certain distance away from the slits. If the screen is moved by 5 cm towards the slits, the fringe width changes by 30 μm. Given that the slits are 1 mm apart, calculate the wavelength of the light used.

8. i. What is the relation between critical angle and refractive index of a material? **[3]**
   ii. Does critical angle depend on the colour of light? Explain

OR

A small candle, 2.5 cm in size is placed at 27 cm in front of a concave mirror of radius of curvature 36 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image? Describe the nature and size of the image. If the candle is moved closer to the mirror, how would the screen have to be moved?

9. The maximum kinetic energy of the photoelectrons emitted is doubled when the wavelength of light incident on the photosensitive surface changes from λ_1 to λ_2. Deduce expressions for the threshold wavelength and work function for the metal surface in terms of λ_1 and λ_2. **[3]**

10. i. Draw a ray diagram for a convex mirror showing the image formation of an object placed anywhere in front of the mirror. **[3]**
    ii. Use this ray diagram to obtain the expression for its linear magnification.

11. Answer the following questions. **[3]**
    i. Name the waves which are produced during radioactive decay of a nucleus. Write their frequency range.
    ii. Welders wear special glass goggles while working. Why? Explain.
    iii. Why are infrared waves often called as heatwaves? Give their one application.

OR

Compare the interference pattern observed in Young's double slit experiment with single slit diffraction pattern, pointing out two distinguishing features.

CASE STUDY

12. **Read the source given below and answer the following questions:** **[5]**

A prism is a portion of a transparent medium bounded by two plane faces inclined to each other at a suitable angle. A ray of light suffers two refractions on passing through a prism and hence deviates through a certain angle from its original path. The angle of deviation of a prism is, $\delta = (\mu - 1)A$, through which a ray deviates on passing through a thin prism of small refracting angle A.

If μ is refractive index of the material of the prism, then prism formula is, $\mu = \frac{\sin(A+\delta_m)/2}{\sin A/2}$

i. For which colour, angle of deviation is minimum?

a. Red
b. Yellow
c. Violet
d. Blue

ii. When white light moves through vacuum

a. all colours have same speed
b. different colours have different speeds
c. violet has more speed than red
d. red has more speed than violet.

iii. The deviation through a prism is maximum when angle of incidence is

a. 45°
b. 70°
c. 90°
d. 60°

iv. What is the deviation produced by a prism of angle 6°? (Refractive index of the material of the prism is 1.644).

a. 3.864°
b. 4.595°
c. 7.259°
d. 1.252°

v. A ray of light falling at an angle of 50° is refracted through a prism and suffers minimum deviation. If the angle of prism is 60°, then the angle of minimum deviation is

a. 45°
b. 75°
c. 50°
d. 40°

Solution

PHYSICS - 042

Class 12 - Physics

Section A

1.

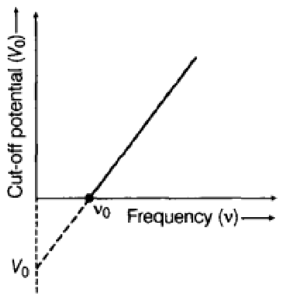
	Intrinsic Semiconductor	Extrinsic Semiconductor
1	Pure semiconductors not doped with any impurity atoms	Semiconductors are doped with trivalent or pentavalent impurity atoms.
2	$n_e = n_h$	$n_e \neq n_h$

2. The ionisation energy (IE) is defined as the amount of energy required to remove the most loosely bound electron i.e; valence electron of an isolated gaseous atom to form a cation.
Ionisation energy is given by,
$E_0 = \frac{me^4}{8\varepsilon_0^2 h^2}$
So, $E_0 \propto m$
i.e. ionisation energy is directly proportional to mass.
The ionisation energy becomes 200 times on replacing an electron by a particle of mass 200 times of the electron and of same charge.

OR

i. **Cut-off voltage:** For a particular frequency of incident radiation, the minimum negative (retarding) potential V_0 for which the photocurrent stops or becomes zero is called the cut-off or stopping potential.
ii. **Threshold frequency**: For a given material, there exists a certain minimum frequency of the incident radiation below which no emission of photo- electrons take place. This frequency is called the threshold frequency.

The variation of cut-off potential with frequency of incident radiation is shown as below.



As per Einstein's photoelectric equation,
$eV_0 = h\nu - h\nu_0$
$V_0 = \frac{h}{e}(\nu - \nu_0)$
Hence the intercept, on the Y - axis, gives ν_0. One can read V_0, for any ν, from the graph.

3. In forward bias, the current is mainly due to major carriers while in reverse bias, the current is due to minor carriers. The width of the depletion layer increases as compared to forward biased and a small reverse current flows through the diode. Now, when the light is incident on the junction, electron-hole pairs are generated in depletion layer in a big amount and these charge carriers can easily cross the barrier, hence contribute to current across the diode. We can say that in reverse bias, diode changes the incident light to current, more significantly due to broad depletion layer i.e. photocurrent is significant in reverse bias as compared to the forward bias current.

Section B

4. i. Bohr's second postulate states that the electron revolves around the nucleus in certain privileged orbit which satisfy certain quantum condition that angular momentum of an electron is an integral multiple of $h/2\pi$
i.e $L = mvr = nh/2\pi$

$2\pi r = n(h/mv)$,

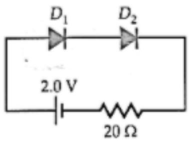
Circumference of electron in n^{th} orbit = n $\times$ de-Broglie wavelength associated with electron.

ii. Number of spectral lines obtained due to transition of electron from n = 4 (3^{d} excited state) to n = 1 (ground state) is

$N = \frac{n(n-1)}{2}$

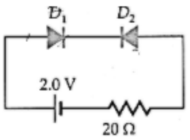
$N = \frac{(4)(4-1)}{2} = 6$

5. i. In figure (a), both the diodes D_1 and D_2 are forward biased and offer no resistance.

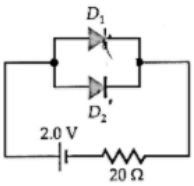


$\therefore$ Current in the circuit = $\frac{2.0\text{ V}}{20\Omega}$ = 0.1 A

ii. In Figure (b), diode D_2 is reverse biased offers infinite resistance, so the current through the series circuit = zero.

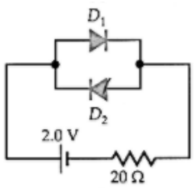


iii. In figure (c), D_1 and D_2 are forward biased and offer zero resistance.



$\therefore$ Current in the circuit = $\frac{2.0\text{ V}}{20\Omega}$ = 0.1 A

iv. In figure (d), no current flows through D_2 as it is reverse biased.



$\therefore$ Current in the remaining circuit = $\frac{2.0\text{ V}}{20\Omega}$ = 0.1 A

6. B.E. of ${}_2^4\text{He} = \left[2m_p + 2m_n - m\left({}_2^4\text{He}\right)\right] \times c^2$

= [2 $\times$ 1.00783 + 2 $\times$ 1.00867 - 4.00387] 931 MeV

= [4.03390 - 4.00387] 931 = 0.02933 931 MeV

= 27.30623 MeV

BE. per nucleon of ${}_2^4\text{He}$

$= \frac{27.30623}{4}$ = 6.83 MeV

B.E. of ${}_2^3\text{He}$

= $\left[2m_p + m_n - m\left({}^3\text{He}\right)\right] c^2$

= [2 $\times$ 1.00783 + 1.00867 - 3.01664] $\times$ 931 MeV

= 0.00769 $\times$ 931 MeV = 7.16 MeV

B.E. per nucleon of ${}_2^3\text{He}$

$= \frac{7.16}{3} = 2.39\text{MeV}$

As the binding energy per nucleon of ${}_2^4\text{He}$ is larger than that of ${}_2^3\text{He}$, so unstable heavy nuclei prefer to get stabilised through α-decay.

7. i. Any two points of difference

Interference	**Diffraction**
Fringes are equally spaced.	Fringes are not equally spaced.

Intensity is same for all maxima.	Intensity falls as we go to successive maxima away from the centre.
Superposition of two waves originating from two narrow slits.	Superposition of a continuous family of waves originating from each point on a single slit.

ii. Let D be the distance of the screen from the plane of the slits.

We have d= 1mm $=10^{-3}$ m.
Fringe width, $\beta = \frac{\lambda D}{d}$
In the first case $\beta = \frac{\lambda D}{d}$ or $\beta d = \lambda D$ ...(i)
In the second case $\left(\beta - 30 \times 10^{-6}\right) = \frac{\lambda(D-0.05)}{d}$
or $\left(\beta - 30 \times 10^{-6}\right) d = \lambda(D - 0.05)$ ...(ii)
Subtracting (ii) from (i) we get
$30 \times 10^{-6} \times d = \lambda \times 0.05$
$\therefore \lambda = \frac{30 \times 10^{-6} \times 10^{-3}}{5 \times 10^{-2}} \mathrm{m}$
$\therefore \lambda = 6 \times 10^{-7} \mathrm{m}$ = 600 nm

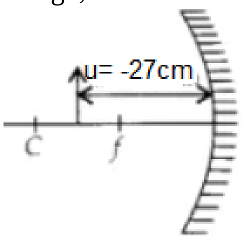
8. i. $\mu = \sin i_c$ or $n_{21} = \sin i_c$

where n_{21} is the refractive index of rarer medium 1 with respect to denser medium 2.

ii. As μ depends on wavelength, therefore, critical angle for the same pair of media in contact will be different for different colours.

OR

The object is kept between f and C. So the image should be real, inverted and beyond C. To locate the sharp image, the screen should be placed at the position of the image.



Radius of curvature of the concave mirror, R = -36 cm
The focal length $f = \frac{-R}{2} = -18 \mathrm{cm}$
Object distance u = -27 cm
Using mirror formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$
or $\frac{1}{v} + \frac{1}{-27} = \frac{1}{-18}$ or $\frac{1}{v} = -\frac{1}{18} + \frac{1}{27}$
$\frac{1}{v} = \frac{-3+2}{54} \Rightarrow \frac{1}{v} = -\frac{1}{54}$
v = -54 cm
Size of image can be calculated magnification
$m = -\frac{v}{u} = \frac{-I}{O}$ or $\frac{-I}{O} = -\frac{v}{u}$
$\frac{I}{+2.5} = -\frac{-54}{-27} \Rightarrow I = -5 \mathrm{cm}$
So, the image is inverted and magnified. Thus in order to locate the sharp image, the screen should be kept 54 cm in front of the concave mirror, and the image on the screen will be observed real, inverted, and magnified. If the candle is moved closer to the mirror, the real image will move away from the mirror hence the screen has to be shifted away from the mirror to locate the sharp image.

9. Given that

Initial kinetic energy of photoelectrons is given by = K_1
Final kinetic energy of photoelectrons is given by $K_2 = 2K_1$
Wavelength of light changes from λ_1 to λ_2
Let the threshold frequency is ν_0 and work function is ϕ_0
Now, we know that:-
$\frac{\mathrm{hc}}{\lambda} = \phi_0$ + KE

$\frac{hc}{\lambda_1}$ = ϕ_0 + K_1 ...(i)
$\frac{hc}{\lambda_2}$ = ϕ_0 + K_2 ...(ii)
$K_2 = 2K_1$
$\frac{hc}{\lambda_2}$ = ϕ_0 + $2K_1$ ...(iii)
$\frac{2hc}{\lambda_1}$ = $2\phi_0$ + $2K_1$ (eq (i) $\times$ 2)
$\frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2} = \phi_0$
$\Rightarrow \phi_0 = hc\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$
We know
work function is given by $\phi_0 = \frac{hc}{\lambda_0}$
$\frac{hc}{\lambda_0} = hc\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$
$\frac{1}{\lambda_0} = \frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}$
$\lambda_0 = \frac{\lambda_1\lambda_2}{2\lambda_2 - \lambda_1}$

10. i. The complete ray diagram which shows the image formation of the object in convex mirror is given below:

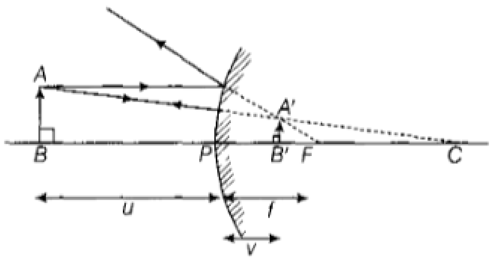


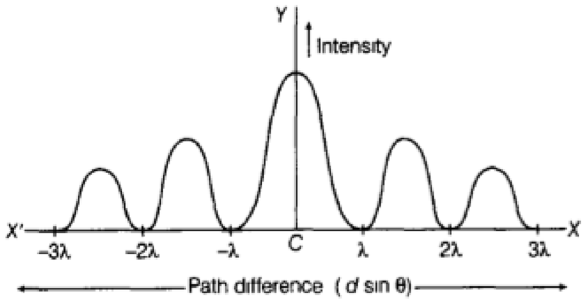
Figure shows the formation of image A'B' of a finite object AB by a convex mirror. The image is vritual, erect and diminished.

ii. Now, $\Delta ABP \sim \Delta A'B'P$
$\therefore \frac{A'B'}{AB} = \frac{PB'}{PB}$
Applying the new cartesian sign convention,
A'B' = h_2, AB = h_1, PB' = v, PB = -u
$\therefore \frac{h_2}{h_1} = \frac{v}{-u}$
Linear magnification, m = $\frac{h_2}{h_1} = -\frac{v}{u}$

11. i. γ-rays are produced during radioactive decay of a nucleus. Its frequency range is from $3\text{x}10^{18}$ Hz to $5\text{x}10^{22}$ Hz.
ii. Welders wear special glass goggles while working to protect their eyes from radiation hazards of ultraviolet rays(UV rays). The range of UV rays is 10^{15} Hz to 10^{17} Hz.
iii. Infrared waves are called heat waves because they cause the atoms and molecules to vibrate when they encounter a substance. This increases the velocity and hence internal energy of atoms and molecules. Thereby, increasing the temperature of the substance as the heat produced in the matter is directly proportional to the internal energy of atoms and molecules. They are used in physical therapy and weather forecasting.

OR

In case of single slit, the diffraction pattern obtained on the screen consists of a central bright band having alternate dark and weak bright band of decreasing intensity on both sides.
The diffraction pattern can be graphically represented as



Points to compare the intensity distribution between interference and diffraction are:

a. In the interference,it is produced due to two different wave fronts, but in diffraction, it is produced due to different parts of same wave fronts.
b. In the interference, fringe width is same size, but in diffraction, central fringe is twice as wide as other fringes.
c. In the interference, all bright fringes have same intensity, but in diffraction, all the bright fringes are not of the same intensity.
d. In interference, the widths of all the fringes are same but in diffraction, fringes are of different widths. The point C corresponds to the position of central maxima and the position $-3\lambda, 2\lambda, -\lambda, \lambda, 2\lambda, 3\lambda.....$ are secondary minima. The above conditions for diffraction maxima and minima are exactly reverse of mathematical conditions for interference maxima and minima.

CASE STUDY

12. i. (a): Angle of deviation is minimum for the red colour.
ii. (a): In vacuum all colours have same speed, because there is no dispersion of light in vacuum.
iii. (c) : The deviation is maximum when angle is 90°.
iv. (a): A = 6°; μ = 1.644
f = (μ - 1) A
f = (1.644 - 1)6 = 0.644 $\times$ 6
δ = 3.864°
v. (d): i_1 = 50°; A = 60°, δ_m = ?
A + δ_m = i_1 + i_2 = 50° + 50° = 100°
δ_m = 100° - A = 100 - 60° = 40°