Solved Paper 2022

PHYSICS (TERM-II)

Class-XII

Time : 2 Hours **Max. Marks : 35**

General Instructions :

Read the following instructions carefully and strictly follow them:

1. *This Question paper contains **12** questions. **All** questions are compulsory.*
2. *This question paper is divided into **THREE** Section, **Section A, B** and **C**.*
3. ***Section–A—**Question number 1 to 3 are of **2** marks each.*
4. ***Section–B—**Question number 4 to 11 are of **3** marks each.*
5. ***Section–C—**Question number 12 is a case based question of **5** marks.*
6. *There is no overall choice in the question paper. However internal choice has been provided in some of the questions. Attempt **any one** of the alternatives in such questions.*
7. *Use of log tables is permitted, if necessary, but use of calculator is not permitted.*

$c = 3 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12}$ C^{2}N^{-1}m^{-2}

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$$

Mass of electron (m_e) $= 9.1 \times 10^{-31}$ kg

Mass of neutron $= 1.675 \times 10^{-27}$ kg

Mass of proton $= 1.673 \times 10^{-27}$ kg

Avogadro's number $= 6.023 \times 10^{23}$ per gram mole

Boltzmann constant $= 1.38 \times 10^{-23}$ JK^{-1}

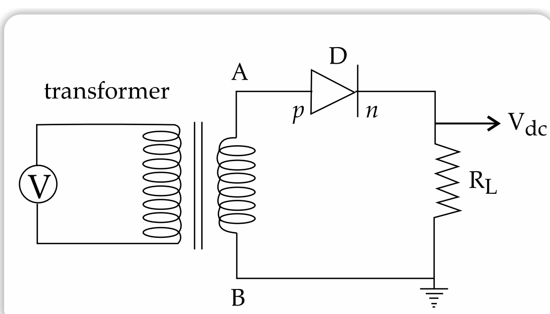
Delhi Set-I, Series: A5BAB/5, **55/5/1**

SECTION - A

1. With the help of a circuit diagram, explain briefly how a *p-n* junction diode works as a half-wave rectifier. **2**

Ans. Half-Wave rectifier: The rectifier that converts only one half of ac into dc is called half-wave rectifier.

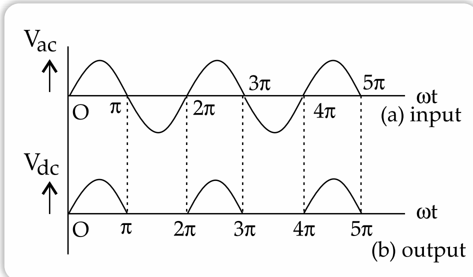
Circuit diagram:



Working: The ac input signal to be rectified is fed to the primary coil of the transformer. The secondary coil is connected to the junction diode in series with a load resistance R_L.

For positive half cycle of ac, point A of secondary coil is positive and point B is at zero potential. Since A is connected to *p*-region of the junction diode, the junction diode is forward biased. Thus, the junction diode conducts. The output voltage which varies in accordance with input half cycle is obtained across R_L.

For negative half cycle of ac, point A is negative and point B is at zero potential. So the junction diode is reverse biased. Hence the junction diode does not conduct, and therefore, no output across load resistance is obtained. The variation of output corresponding to input is as shown below:



2. (a) What results do you expect if α-particle scattering experiment is repeated using a thin sheet of hydrogen in place of a gold foil? Explain. (Hydrogen is a solid at temperature below 14 K) **2**

OR

(b) Why it is the frequency and not the intensity of light source that determines whether emission of photoelectrons will occur or not? Explain. **2**

Ans. (a) In the α-particle scattering experiment, the target atom should be much heavier than the bombarding particle. If a thin sheet of solid hydrogen is used in place of a gold foil, then the target is lighter than the bombarding particle.

As a result, the α-particles would not bounce back.

OR

(b) It is the frequency and not the intensity of light source that determines the emission as if any incident light of particular (i.e., threshold or more) frequency is incident,then it results in emission while it is independent of its intensity.

3. Why a photo-diode is operated in reverse bias whereas current in the forward bias is much larger than that in the reverse bias? Explain. Mention its two uses. **2**

Ans. The width of depletion layer increases when a diodes is reversed biased and a small reverse current flows through the diode.

When light is incident on the junction, electron-hole pairs are generated in depletion layer in a large amount due to wide depletion layer. So, in reverse bias, diode changes the incident light to current, more significantly i.e., photocurrent is significant in reverse bias as compared to the forward bias current.

Current in forward bias is more than reverse bias but the fractional change in current in reverse bias is more easily measurable than fractional change in forward bias current.

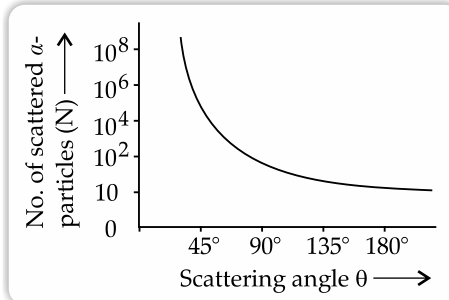
For this reason, photo diode is used in reverse bias.

Uses: In smoke detectors, in bar code scanners.

SECTION - B

4. Draw a graph showing the variation of number of particles scattered (N) with the scattering angle θ in Geiger-Marsden experiment Why only a small fraction of the particles are scattered at θ > 90°? Mention two limitations of Rutherford nuclear model of an atom. **3**

Ans. Graph showing the variation of number of particles scattered (N) with the scattering angle (θ):



Scattering of α-particles at θ > 90° is due to the strong repulsive force exerted by the positively charged nucleus. Since the nucleus is very small in size, the number of scattered α-particles is less.

Limitations of Rutherford model:

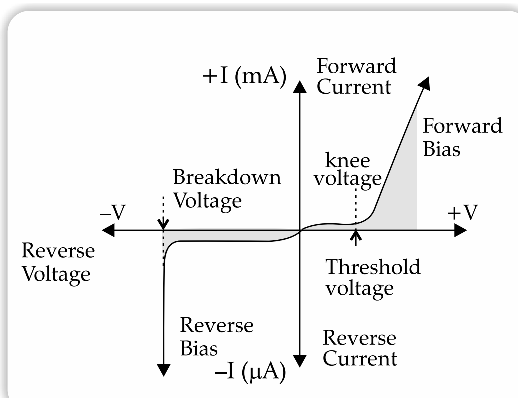
- It does not explain the stability of the atom. Electrons revolving around the nucleus (as suggested by Rutherford) will lose energy and come closer and closer to the nucleus, and finally will merge with the nucleus. This makes the atom unstable. Practically this does not happen. The electrons do not fall into the nucleus and atoms are very stable.
- It does not explain the arrangement of a electrons inside the atom.

5. (i) Draw V-I characteristics of a *p-n* Junction diode. **3**

(ii) Differentiate between the threshold voltage and the breakdown voltage for a diode.

(iii) Write the property of a junction diode which makes it suitable for rectification of ac voltages.

Ans. (i) V-I characteristics of ***p-n*** Junction diode:



(ii)

Threshold voltage	Breakdown voltage
The forward voltage at which the current through the *p-n* junction starts increasing rapidly is known as threshold voltage.	Reverse voltage at which the *p-n* junction breakdown occurs is called as breakdown voltage.
The magnitude of this voltage is lower than the breakdown voltage.	The magnitude of this voltage is higher than the threshold voltage.

(iii) The property of junction diode which makes it suitable for rectification:

It exhibits high resistance when reverse biased and low resistance when forward biased.

6. In a fission event of $^{238}_{92}U$ by fast moving neutrons, no neutrons are emitted and final products, after the beta decay of the primary fragments, are $^{140}_{58}Ce$ and $^{99}_{44}Ru$. Calculate Q for this process. Neglect the masses of electrons/ positrons emitted during the intermediate steps. **3**

Given: $m\left(^{238}_{92}U\right) = 238.05079u$;

$m\left(^{140}_{58}Ce\right) = 139.90543u$

$m\left(^{99}_{44}Ru\right) = 98.90594u$; $m\left(^{1}_{0}n\right) = 1.008665u$

Ans. $^{238}_{92}U + ^{1}_{0}n \rightarrow ^{239}_{92}U \rightarrow ^{140}_{58}Ce + ^{99}_{44}Ru + 10^{0}_{-1}e$

Δm = (238.05079 + 1.008665 – 139.90543 – 98.90549) u [neglecting mass of electron]

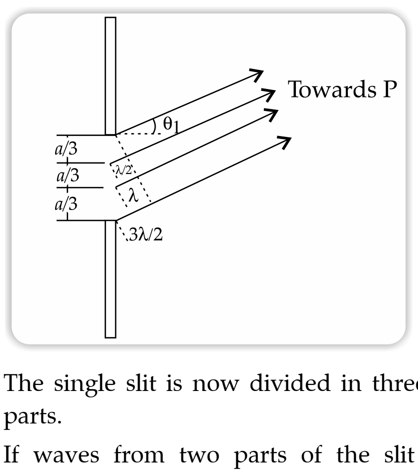
Or, $\Delta m = 0.24835$ u

$\therefore Q = 0.24835 \times 931 = 231.386085 = 231.386$ MeV

7. How can you differentiate whether a pattern is produced by a single slit or double slits? Derive the expression for the angular position of (i) bright and (ii) dark fringes produced in a single slit diffraction. **3**

Ans. If all the bands are of equal width and intensity, then pattern is produced by double slit. Bands of the pattern produced by single slit have the width and intensity both varying.

(i) Derivation of expression for angular position of bright fringe produced by single slit diffraction:



The single slit is now divided in three equal parts.

If waves from two parts of the slit cancel each other, the wave from the third part will produce a maxima at a point between two minima.

So, $$\sin\theta_1 = \frac{3\lambda}{2a}$$

Similarly, if the slit is divided in five equal parts, then another maxima will be produced at

$$\sin\theta_2 = \frac{5\lambda}{2a}$$

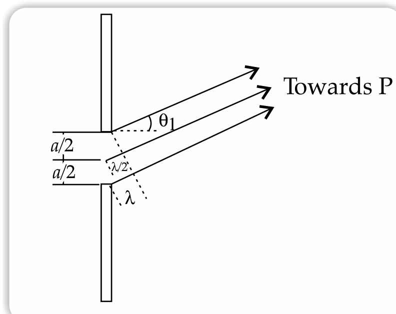
Similarly for other fringes,

$$\sin\theta_n = \frac{(2n+1)\lambda}{2a}$$

Or, $$\theta_n = \frac{(2n+1)\lambda}{2a}$$

For central maxima, $\theta = 0°$

(ii) Derivation of expression for angular position of dark fringe produced by single slit diffraction:



The single slit is divided into two equal halves. For every point in one half has a corresponding point in the other half. The path difference between two waves arriving at point P is

$$\frac{a}{2\sin\theta_1} = \frac{\lambda}{2}$$

This means the contributions are in opposite phase, so they cancel each other and the intensity falls to zero.

So, for 1st dark fringe, $\sin\theta_1 = \dfrac{\lambda}{a}$

Similarly for other dark fringes,

$$\sin\theta_n = \frac{n\lambda}{a}$$

$$\theta_n = \frac{n\lambda}{a}$$

8. (a) (i) Define SI unit of power of a lens. **3**

(ii) A plano- convex lens is made of glass of refractive index 1.5. The radius of curvature of the convex surface is 25 cm.

(iii) Calculate the focal length of the lens.

(iv) If an object is placed 50 cm in front of the lens, find the nature and position of the image formed.

OR

(b) A slit of width 0.6 mm is illuminated by a beam of light consisting of two wavelengths 600 nm and 480 nm. The diffraction pattern is observed on a screen 1.0 m from the slit. Find: **3**

(i) The distance of the second bright fringe from the central maximum pertaining to light of 600 nm.

(ii) The least distance from the central maximum at which bright fringes due to both the wavelengths coincide.

Ans. (a) (i) SI unit of power of lens: Dioptre is the SI unit of power of a lens.

The power of the lens is the reciprocal of its focal length measured in metre(m).

(ii) (iii) Refractive index = μ = 1.5

Radius of curvature of convex side = 25 cm

$= \frac{25}{100}$ m

Radius of curvature of plane side = ∞

Applying lens maker's formula,

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

Or, $$\frac{1}{f} = (1.5 - 1)\left(\frac{1}{\infty} + \frac{100}{25}\right)$$

Or, $$\frac{1}{f} = 0.5 \times \left(\frac{100}{25}\right)$$

$\therefore$ $$f = \frac{25}{50} \text{ m} = 50 \text{ cm}$$

(iv) Focal length $= f = 50$ cm

Object distance $= u = -50$ cm

When the object distance = focal length, then the image will be formed at infinity.

Image will be highly magnified, real and inverted.

OR

(b) (i) Distance of 2nd bright fringe from central maximum $= \frac{2\lambda D}{d}$

$$= \frac{2 \times 600 \times 10^{-9} \times 1}{0.6 \times 10^{-3}}$$

$$= 20 \times 10^{-4} \text{ m}$$

(ii) If n^{th} bright fringe due to 600 nm coincides with $(n+1)^{th}$ bright fringe due to 480 nm, then

$$\frac{n\lambda_1 D}{d} = \frac{(n+1)\lambda_2 D}{d}$$

Or, $$n\lambda_1 D = (n+1)\lambda_2 D$$

Or, $$\frac{n}{(n+1)} = \frac{\lambda_2}{\lambda_1}$$

Or, $$\frac{n}{(n+1)} = \frac{480}{600}$$

$\therefore$ $$n = 4$$

So, the least distance from central maximum

$$= \frac{4 \times 600 \times 10^{-9} \times 1}{0.6 \times 10^{-3}} = 40 \times 10^{-4} \text{ m}$$

9. (a) Calculate the energy and momentum of a photon in a monochromatic beam of wavelength 331.5 nm. **3**

(b) How fast should a hydrogen atom travel in order to have the same momentum as that of the photon in part (a)?

Ans. (a) $$\text{Energy} = E = \frac{hc}{\lambda}$$

Or, $$E = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{331.5 \times 10^{-9}}$$

$\therefore$ $$E = 6 \times 10^{-19} \text{ J}$$

$$\text{Momentum} = p = \frac{h}{\lambda}$$

Or, $$p = \frac{6.6 \times 10^{-34}}{331.5 \times 10^{-9}}$$

$\therefore$ $$p = 2 \times 10^{-27} \text{ kg.m/s}$$

(b) Momentum of Hydrogen atom

$$= p = 2 \times 10^{-27} \text{ kg.m/s}$$

$$p = mv$$

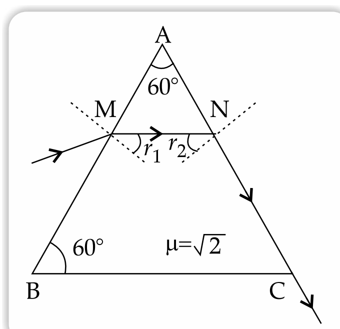
Or, $$v = \frac{p}{m}$$

Or, $$v = \frac{2 \times 10^{-27} \text{ kg.m/s}}{1 \text{ a.m.u.}}$$

Or, $$v = \frac{2 \times 10^{-27} \text{ kg.m/s}}{1.66 \times 10^{-27} \text{ kg}}$$

$\therefore$ $$v = 1.2 \text{ m/s}$$

10. A ray of light passes through a prism of refractive index $\sqrt{2}$ as shown in the figure. Find: **3**



(i) The angle of incidence ($\angle r_2$) at face AC.

(ii) The angle of minimum deviation for this prism.

Ans. (i) Since at point N, the angle of refraction is 90°, then $\angle r_2$ is the critical angle for the glass-air pair of media.

$$\sin \angle r_2 = \frac{1}{\mu} = \frac{1}{\sqrt{2}}$$

$\therefore$ $$\angle r_2 = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45°$$

(ii)
$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

Or,
$$\sqrt{2} = \frac{\sin\left(\frac{60°+\delta_m}{2}\right)}{\sin\frac{60°}{2}}$$

Or,
$$\sqrt{2} = \frac{\sin\left(30°+\frac{\delta_m}{2}\right)}{\frac{1}{2}}$$

Or,
$$0.7 = \sin\left(30°+\frac{\delta_m}{2}\right)$$

Or,
$$\sin^{-1} 0.7 = 30° + \frac{\delta_m}{2}$$

Or,
$$44.4° = 30° + \frac{\delta_m}{2}$$

$\therefore$
$$\delta_m = 28.8°$$

11. (a) (i) Arrange the following electromagnetic radiation in the ascending order of their frequencies:
X-rays, microwaves, gamma rays, radio waves 3

(ii) Write two uses of any two of these radiation.

OR

(b) With the help of a ray diagram explain the working of a reflecting telescope. Mention two advantages of a reflecting telescope over a refracting telescope. 3

Ans. (a) (i) Arranging in ascending order of frequency:

Radio waves, Microwaves, X-rays, Gamma ray

(ii) Uses of X-ray:

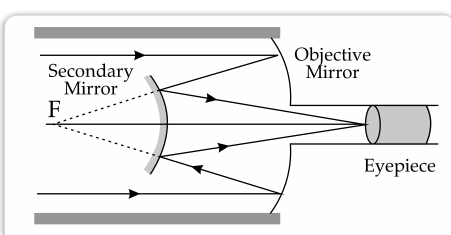
- to view bones and teeth, for diagnosing fractures.
- to check for cracks or flaws in industrial materials.

Uses of infra-red:

- In heat-sensitive thermal imaging cameras.
- In home remote controls.

OR

(b)



Parallel light rays from infinite distance initially are incident on two concave objective mirrors. After reflection they are incident on a secondary convex mirror. A virtual image is formed at F. After reflection by the convex mirror, the rays meet at a point to form a real image which is observed by the eyepiece.

Advantages of a reflecting telescope over a refracting telescope:

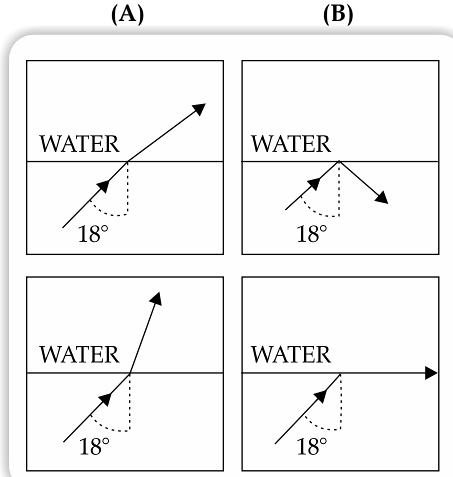
- Mirrors can be made larger in size than lenses.
- There is no chromatic aberrations.

SECTION - C

12. A ray of light travels from a denser to a rarer medium. After refraction, it bends away from the normal. When we keep increasing the angle of incidence, the angle of refraction also increases till the refracted ray grazes along the interface of two media. The angle of incidence for which it happens is called critical angle. If the angle of incidence is increased further the ray will not emerge and it will be reflected back in the denser medium. This phenomenon is called total internal reflection of light. 5

(i) A ray of light travels from a medium into water at an angle of incidence of 18°. The refractive index of the medium is more than that of water and the critical angle for the interface between the two media is 20°. Which one of the following figures best represents the correct path of the ray of light?

(A) **(B)**



(C) **(D)**

(ii) A point source of light is placed at the bottom of a tank filled with water, of refractive index μ, to a depth *d*. The area of the surface of water through which light from the source can emerge, is:

(A) $\dfrac{\pi d^2}{2(\mu^2-1)}$ **(B)** $\dfrac{\pi d^2}{(\mu^2-1)}$

(C) $\dfrac{\pi d^2}{\sqrt{2}\sqrt{\mu^2-1}}$ **(D)** $\dfrac{2\pi d^2}{(\mu^2-1)}$

(iii) For which of the following media, with respect to air, the value of critical angle is maximum?

(A) Crown glass **(B)** Flint glass

(C) Water **(D)** Diamond

(iv) The critical angle for a pair of two media A and B of refractive indices 2.0 and 1.0 respectively is:

(A) 0° **(B)** 30°

(C) 45° **(D)** 60°

(v) The critical angle of pair of a medium and air is 30°. The speed of light in the medium is:

(A) 1×10^8 m s^{-1} **(B)** 1.5×10^8 m s^{-1}

(C) 2.2×10^8 m s^{-1} **(D)** 2.8×10^8 m s^{-1}

Ans. (i) Option (A) is correct.

Explanation: The angle of incidence is less than the critical angle. So, there will be normal refraction from denser to rarer medium and the refracted ray will move away from the normal.

(ii) Option (B) is correct.

Explanation:

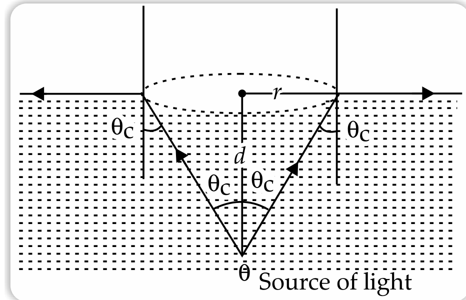
$$r = d \tan \theta_c$$

$$\sin \theta_c = \frac{1}{\mu}$$

$$\therefore \quad \cos \theta_c = \sqrt{1 - \frac{1}{\mu^2}}$$

$$\therefore \quad r = d\,\frac{1/\mu}{\frac{\sqrt{\mu^2 - 1}}{\mu}} = \frac{d}{\sqrt{\mu^2 - 1}}$$

$$\therefore \quad \text{area} = \pi r^2 = \frac{\pi d^2}{\mu^2 - 1}$$



(iii) Option (C) is correct

Explanation: Critical angle of glass is around 42°.

Critical angle of water is around 49°.

Critical angle of diamond is around 24°.

(iv) Option (B) is correct.

Explanation: $\sin \theta_C = \frac{1}{2}$

$\therefore \quad \theta_C = 30°$

(v) Option (B) is correct.

Explanation: $\theta_C = 30°$

$$\therefore \quad \mu = \frac{1}{\sin \theta_C} = \frac{1}{\sin 30°} = 2$$

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in the medium}}$$

$$\text{or,} \quad 2 = \frac{3 \times 10^8}{\text{velocity of light in the medium}}$$

$\therefore$ Velocity of light in the medium

$= 1.5 \times 10^8$ ms^{-1}.

Delhi Set-II, Series: A5BAB/5, 55/5/2

Note: Except these all other Questions are from Delhi Set-I & Set-II

SECTION - A

1. Two crystals C_1 and C_2, made of pure silicon, are doped with arsenic and aluminium respectively. **2**

(i) Identify the extrinsic semiconductors so formed.

(ii) Why is doping of intrinsic semiconductors necessary?

Ans. (i) Arsenic is pentavalent. So, C_1 doped with arsenic will form *n*-type semiconductor.

Aluminium is trivalent. So, C_2 doped with aluminium will form *p*-type semiconductor.

(ii) Doping is necessary to increase the conductivity of semiconductor at normal temperature.

SECTION - B

4. How will the interference pattern in Young's double-slit experiment be affected if **3**

(i) The screen is moved away from the plane of the slits.

(ii) The source slit is moved away from the plane of the slits.

(iii) The phase difference between the light waves emanating from the two slits S_1 and S_2 changes from 0 to π and remains constant.

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

(i) As, D increases, the fringe width increases.

(ii) If the source slit is moved away from the plane of the slits, there will be no change in fringe width.

(iii) If the phase difference becomes π, then the central fringe will be a dark fringe, since

$$I = 4I_0 \cos^2 \frac{\theta}{2}$$

$$= 4I_0 \cos^2 \frac{\pi}{2}$$

$$= 0$$

5. An alpha particle is accelerated through a potential difference of 100 V. Calculate : 3

(i) The speed acquired by the alpha particle, and

(ii) The de-Broglie wavelength associated with it.

(Take mass of alpha particle = 6.4 x 10^{-27} kg)

Ans. (i) $\frac{1}{2} mv^2 = qV$

or, $\frac{1}{2} mv^2 = 2e \times 100$

or, $mv^2 = 400$ eV

or, $v = \sqrt{\frac{400\ eV}{m}}$

or, $v = \sqrt{\frac{400 \times 1.6 \times 10^{-19}}{6.4 \times 10^{-27}}}$

$\therefore$ $v = 10^5$ m/s

(ii) de-Broglie wavelength

$= \lambda = \frac{h}{\sqrt{2mqV}}$

or, $\lambda = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 6.4 \times 10^{-27} \times 2 \times 1.6 \times 10^{-19} \times 100}}$

$\therefore$ $\lambda = 1.03 \times 10^{-12}$ m

9. (a) Use Bohr's postulate to prove that the radius of n^{th} orbit in a hydrogen atom is proportional to n^2. 3

(b) How will the energy of a hydrogen atom change if n increases from 1 to ∞?

Ans. (a) The necessary centripetal force for the rotation of electron is supplied by the electrostatic force between the electron and nucleus.

$$\frac{mv^2}{r} = \left(\frac{1}{4\pi\varepsilon_0}\right)\left(\frac{e^2}{r^2}\right) \quad \text{[putting Z =1]}$$

Or, $mv^2 = \frac{e^2}{4\pi\varepsilon_0 r}$ ...(i)

From Bohr's theory,

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

$\therefore$ $v = \frac{nh}{2\pi mr}$

Putting in equation (i)

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{e^2}{4\pi\varepsilon_0 r}$$

Or, $r = \frac{\varepsilon_0 n^2 h^2}{\pi me^2}$

In general,

$$r_n = \frac{\varepsilon_0 n^2 h^2}{\pi me^2}$$

$\therefore$ $r_n \propto n^2$

(b) $E_n \propto \frac{-1}{n^2}$

Energy is minimum at $n = 1$.

As n increases, the energy becomes less negative, which means energy increases.

Delhi Set-III, Series: A5BAB/5, 55/5/3

Note: Except these all other Questions are from Delhi Set-I & Set-II.

SECTION - A

1. Give two differences between a half wave rectifier and a full wave rectifier. 2

Ans. Difference between half-wave and full wave rectifier:

Half wave rectifier	Full wave rectifier
Only one diode is used.	Two or four diodes are used.
Only one half cycle of input ac is rectified.	Both the half cycles of input ac are rectified.

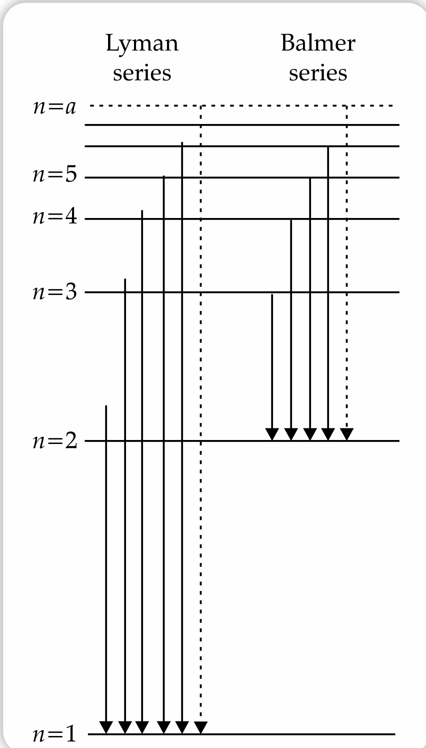
SECTION - B

5. An electron in a hydrogen atom makes transitions from orbits of higher energies to orbits of lower energies. 3

(i) When will such transitions result in (a) Lyman (b) Balmer series?

(ii) Find the ratio of the longest wavelength in Lyman series to the shortest wavelength in Balmer series.

Ans. (i) Emission spectrum of Hydrogen atom: Lyman and Balmer series:



Lyman Series: When electrons will jump from higher energy orbit to $n = 1$ orbit.

Balmer Series: When electrons will jump from higher energy orbit to $n = 2$ orbit.

(ii) Longest wavelength of Lyman series:

$$\frac{1}{\lambda_L} = R_H\left[\frac{1}{1^2}-\frac{1}{2^2}\right] = R_H\left[\frac{3}{4}\right]$$

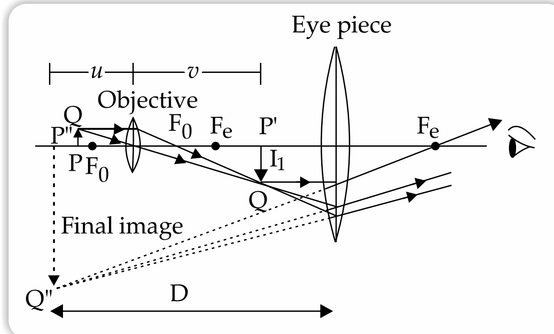
Shortest wavelength of Balmer series:

$$\frac{1}{\lambda_B} = R_H\left[\frac{1}{2^2}-\frac{1}{\infty^2}\right] = R_H\left[\frac{1}{4}\right]$$

Now, $$\frac{\lambda_L}{\lambda_B} = \frac{\left[\frac{1}{4}\right]}{\left[\frac{3}{4}\right]} = \frac{1}{3}$$

6. With the help of a ray diagram, show how a compound microscope forms a magnified image of a tiny object, at least distance of distinct vision. Hence derive an expression for the magnification produced by it. **3**

Ans. Image formation by compound microscope at the least distance of distinct vision:



Expression for magnification:

For objective,

$$\text{Magnification } = m_o = \frac{P'Q'}{PQ} = \frac{-v}{u}$$

When the image is formed at the least distance of distinct vision, then

$$\text{Magnification } = m_e = 1+\frac{D}{f_e}$$

So, final magnification $= m = m_o \times m_e = \frac{v}{u}\left(1+\frac{D}{f_e}\right)$

7. (a) Give an example each of a metal from which photoelectric emission takes place when irradiated by (i) UV light (ii) visible light. **3**

(b) The work function of a metal is 4.50 eV. Find the frequency of light to be used to eject electrons from the metal surface with a maximum kinetic energy of 6.06×10^{-19} J. **3**

Ans. (a) (i) Photoelectric emission takes place when Zn is irradiated with UV radiation.

(ii) Photoelectric emission takes place when Na is irradiated with visible light.

(b) Maximum kinetic energy of photoelectron = Energy of incident photon – Work function

Or, $6.06 \times 10^{-19} = h\nu - 4.5 \times 1.6 \times 10^{-19}$

Or, $h\nu = 13.26 \times 10^{-19}$

Or, $\nu = \frac{(13.26\times10^{-19})}{(6.6\times10^{-34})}$

$\therefore$ $\nu = 2 \times 10^{15}$ Hz

Outside Delhi Set-I, Series: A4BAB/3, 55/3/1

SECTION - A

1. What is meant by doping of an intrinsic semiconductor? Name the two types of atoms used for doping of Ge/Si. **2**

Ans. Doping of an Intrinsic Semiconductor: The mixing of a small amount of pentavalent (e.g. phosphorus) or trivalent (e.g., aluminium) substance as impurity in a pure semiconductor (e.g., Ge, Si) is called doping.

Doping increases the conductivity of a semiconductor.

For doping pure Si, Ge, pentavalent phosphorus is used to convert it to n-type semiconductor.

Trivalent aluminium is used to convert pure Si, Ge to p-type semiconductor.

2. (a) (i) Distinguish between isotopes and isobars. **2**

(ii) Two nuclei have different mass numbers A_1 and A_2. Are these nuclei necessarily the isotopes of the same element? Explain.

OR

(b) (i) Name the factors on which photoelectric emission from a surface depends.

(ii) Define the term 'threshold frequency' for a photosensitive material.

Ans. (a) (i)

Isotope	Isobar
Same element.	Different element.
Same atomic number.	Different atomic number.
Different mass number.	Same mass number.
Numbers of protons are same in isotopes.	Numbers of protons are different in isobars.

(ii) No, Only when the two nuclei have same atomic number then they are known as isotopes.

Otherwise they may be isobars also. Isobars have same mass numbers.

OR

(b) (i) Factors on which photoelectric emission from a surface depends:

- Frequency of light
- Intensity of light
- Photosensitivity of the material

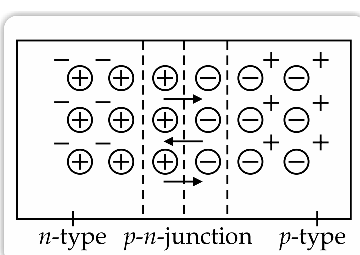
(ii) Threshold frequency: For a given photosensitive material, the minimum frequency of the incident radiation for which emission of photoelectrons takes place is called threshold frequency.

3. Explain the formation of the barrier potential in a p-n junction. **2**

Ans. Formation of barrier potential: A p-n junction is formed by bringing p-type and n-type semiconductors together in a very close proximity.

At the instant of p-n-junction, movement of free electrons from n-side and free holes from p-side diffuse across the junction and combine and thus leave −ve ions in p-side and +ve ions in n-side.

These two layers of +ve and −ve ions form the depletion region and the potential difference thus sets up is called potential barrier.



SECTION - B

4. State Bohr's postulate to explain stable orbits in a hydrogen atom. Prove that the speed with which the electron revolves in nth orbit is proportional to $\left(\frac{1}{n}\right)$. **3**

Ans. Bohr's postulate to explain stable orbits in a hydrogen atom:

The stationary orbits are those orbits for which the angular momentum of the electron is an integral multiple of $\frac{h}{2\pi}$, where h is Planck's constant.

Electron in an atom revolves because of the balance of Coulomb force of attraction between the protons and electrons and the centripetal force.

In n^{th} orbit, $$\frac{mv_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n^2}$$

$$\therefore \quad v_n = \frac{e}{\sqrt{4\pi\varepsilon_0 m r_n}} \quad \text{...(i)}$$

Again, $$r_n = \frac{\varepsilon_0 h^2 n^2}{e^2 \pi m} \quad \text{...(ii)}$$

Putting in equation (i)

$$v_n = \frac{e}{\sqrt{4\pi\varepsilon_0 m \frac{\varepsilon_0 h^2 n^2}{e^2 \pi m}}}$$

$$= \frac{e^2}{2\varepsilon_0 h n}$$

$$\therefore \quad v_n \propto \frac{1}{n}$$

5. Briefly explain how emf is generated in a solar cell. Draw its I-V characteristics. **3**

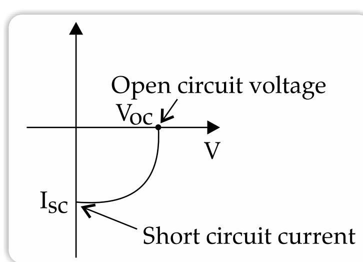
Ans. Process of emf generation in a solar cell:

(i) Light falls on the junction. Electron-hole pairs are generated.

(ii) The electron and hole move in opposite direction due to junction field. Electrons move towards n-side and holes move towards p-side of the junction.

(iii) The two sides of the junction become oppositely charged and a photo voltage is generated.

I-V characteristics of solar cell:



6. A narrow beam of protons, each having 4.1 MeV energy is approaching a sheet of lead (Z= 82). Calculate:

(i) the speed of a proton in the beam, and

(ii) the distance of its closest approach 3

Ans. (i) KE of 4.1 MeV proton

$$= 4.1 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$$

Mass of proton $= 1.67 \times 10^{-27}$ kg

$$v^2 = \frac{2\text{KE}}{m}$$

Or, $$v^2 = \frac{2 \times 4.1 \times 10^6 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}}$$

Or, $v^2 = 7.85 \text{ x } 10^{14}$

$\therefore$ $v = 2.8 \text{ x } 10^7$ m/s

(ii) Energy of proton = 4.1 MeV

Atomic number(Z) of lead = 82

When the proton is at distance of closest approach (r), then

KE of the system = 0

PE of the system $= \frac{k\text{Ze}^2}{r}$

So, from the conservation of energy principle,

$$4.1 \text{ MeV} = 0 + \frac{k\text{Ze}^2}{r}$$

Or, $$r_0 = \frac{k\text{Ze}^2}{(4.1 \times 10^6 e)}$$

Or, $$r_0 = \frac{9 \times 10^9 \times 82 \times e^2}{4.1 \times 10^6 e} \text{m}$$

$\therefore$ $r_0 = 288 \times 10^{-16}$ m

$r_0 = 2.88 \times 10^{-14}$

7. In a diffraction pattern due to a single slit, how will the angular width of central maximum change, if

(i) orange light is used in place of green light,

(ii) the screen is moved closer to the slit,

(iii) the slit width is decreased?

Justify your answer in each case. 3

Ans. The angular width of central maxima of single slit diffraction patten is $2\theta = \frac{2\lambda}{a}$

(i) Angular width of central maxima ∝ wavelength of light used. Orange light has higher wavelength than that of green light. So, Angular width of central maxima will be more when orange light is used instead of green light.

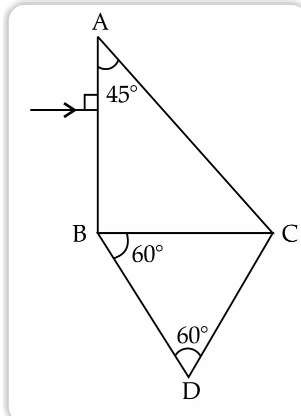
(ii) Angular width of central maxima is independent of the distance between the slit and the screen. So, if the screen is moved closer to slit there will be no change in angular width of central maxima.

(iii) Angular width of central maxima $\propto \frac{1}{\text{slit width}}$

So, if the angular width is decreased, the angular width of the central maxima will increase.

8. (a) Write two necessary conditions for total internal reflection.

(b) Two prisms ABC and DBC are arranged as shown in figure.

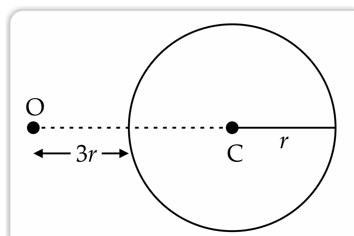


The critical angles for the two prisms with respect to air are 41.1° and 45° respectively. Trace the path of the ray through the combination. 3

OR

(a) An object is placed in front of a converging lens. Obtain the conditions under which the magnification produced by the lens is (i) negative and (ii) positive.

(b) A point object is placed at O in front of a glass sphere as shown in figure.



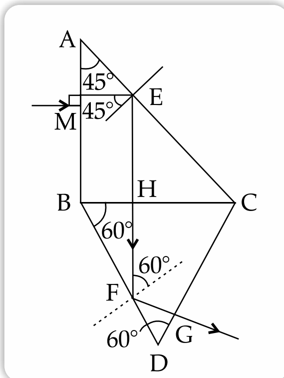
Show the formation of image by the sphere.

Ans. (a) Necessary conditions for total internal reflection:

- Light should travel from denser to rarer medium.
- Angle of incidence should be greater than the critical angle for the pair of media and the colour of light used.

(b) The ray incident normally at M enters undeviated.

At E, angle of incidence is 45°. It is greater than the critical angle. So, it is totally internally reflected.



At H, the ray is incident normally. So it enters prism BDC undeviated.

At F, the angle of incidence is 60°. It is greater than the critical angle. So, it is internally reflected.

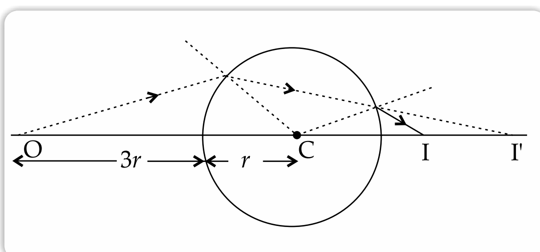
At G , the ray is incident normally. So, it comes out from the prism undeviated.

OR

(a) (i) Magnification is negative for real image formed by convex lens.

(ii) Magnification is positive for virtual image formed by convex lens.

(b)



9. An electron is accelerated from rest through a potential difference of 100 V.
Find:
(i) the wavelength associated with
(ii) the momentum and
(iii) the velocity required by the electron. 3

Ans. (i) Wavelength $= \lambda = \dfrac{h}{\sqrt{2\,meV}}$

$$\therefore \quad \lambda = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times100}}$$

$$= 1.2\times10^{-10}\text{ m} = 1.2\text{ Å}$$

(ii) Momentum $= p = \dfrac{h}{\lambda}$

$$\therefore \quad p = \frac{6.6\times10^{-34}}{1.2\times10^{-10}}$$

$$= 5.5\times10^{-24}\text{ kg m/s}$$

(iii) Momentum $= p = mv$

$$\therefore \quad \text{Velocity } = v = \frac{p}{m}$$

$$= \frac{5.5\times10^{-24}}{9.1\times10^{-31}} = 6\times10^{6}\text{ m/s}$$

10. In a Young's double slit experiment using light of wavelength 600 nm, the slit separation is 0.8 mm and the screen is kept 1.6 m from the plane of the slits.
Calculate
(i) the fringe width
(ii) the distance of (a) third minimum and (b) fifth maximum, from the central maximum. 3

Ans. (i) Fringe width $= \beta = \dfrac{\lambda D}{d}$

$$\therefore \quad \beta = \frac{600\times10^{-9}\times1.6}{0.8\times10^{-3}} = 12\times10^{-4}\text{ m}$$

(ii) (a) Distance of 3rd minimum from central maximum $= \dfrac{5}{2}\beta = 30\times10^{-4}$ m

(b) Distance of 5th maximum from central fringe $= 5\beta = 60\times10^{-4}$ m

11. (a) **Electromagnetic waves of wavelengths λ_1, λ_2 and λ_3 are used in radar system, in water purifiers and in remote switches of TV, respectively.**
(i) Identify the electromagnetic waves, and
(ii) Write one source of each of them. 3

OR

(b) (i) State two conditions for two light sources to be coherent.
(ii) Give two points of difference between an interference pattern due to a double slit and a diffraction pattern due to a single slit.

Ans. (i) Wavelength λ_1 corresponds to Microwaves.

Wavelength λ_2 corresponds to Ultraviolet waves.

Wavelength λ_3 corresponds to Infrared waves.

(ii) Source of microwaves: Klystron / magnetron valves.

Source of ultraviolet waves: Movement of electrons in atoms from higher energy level to lower energy level.

Source of infrared waves: Vibration of atoms and molecules.

OR

(i) Condition of two light sources to be coherent:
- The two sources of light must be derived from a single source.
- The source must be monochromatic in nature.

(ii) Difference between an interference pattern due to a double-slit and a diffraction pattern due to a single slit:

Interference pattern	Diffraction pattern
Intensity is same for all maxima.	Intensity falls to successive maxima away from the normal.
Fringes are equally spaced.	Fringes are not equally spaced.

SECTION - C

CASE STUDY

12. A compound microscope consists of two converging lenses. One of them, of smaller aperture and smaller focal length is called objective and the other of slightly larger aperture and slightly larger focal length is called eye-piece. Both the lenses are fitted in a tube with an arrangement to vary the distance between them. A tiny object is placed in front of the objective at a distance slightly greater than its focal length. The objective produces the image of the object which acts as an object for the eye-piece. The eye piece, in turn produces the final magnified image. **1 × 5 = 5**

I. In a compound microscope the images formed by the objective and the eye-piece are respectively.

(A) virtual, real **(B)** real, virtual

(C) virtual, virtual **(D)** real, real

II. The magnification due to a compound microscope *does not* depend upon

(A) the aperture of the objective and the eye-piece

(B) the focal length of the objective and the eye-piece

(C) the length of the tube

(D) the colour of the light used

III. Which of the following is *not correct* in the context of a compound microscope?

(A) Both the lenses are of short focal lengths.

(B) The magnifying power increases by decreasing the focal lengths of the two lenses.

(C) The distance between the two lenses is more than $(f_o + f_e)$.

(D) The microscope can be used as a telescope by interchanging the two lenses.

IV. A compound microscope consists of an objective of 10X and an eye-piece of 20X. The magnification due to the microscope would be

(A) 2 **(B)** 10

(C) 30 **(D)** 200

V. The focal lengths of objective and eye-piece of a compound microscope are 1.2 cm and 3.0 cm respectively. The object is placed at a distance of 1.25 cm from the objective. If the final image is formed at infinity, the magnifying power of the microscope would be

(A) 100 **(B)** 150

(C) 200 **(D)** 250

Ans. I. Option (B) is correct.

Explanation: Objective lens produces a real image which is positioned between the focus and the optical centre of eyepiece lens. So, eyepiece lens produces a virtual image.

II. Option (A) is correct.

Explanation: Magnification when image is formed at the near point of distinct vision is $\frac{L}{f_o}\left(1+\frac{D}{f_e}\right)$.

No expression contains the aperture terms. So, magnification does not depend on aperture of the objective and the eyepiece.

III. Option (D) is correct.

Explanation: Both the lens of microscope are of short focal lengths and hence the microscope cannot be used as a telescope by interchanging the two lenses. Objective of telescope is of large focal length.

IV. Option (D) is correct.

Explanation: 10X lens and 20X lens means their magnifications are 10 and 20 respectively. So, the magnification of the microscope is 10 × 20 = 200.

V. Option (C) is correct.

Explanation: Applying lens formula for objective lens,

$$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

Or, $$\frac{1}{v_0} + \frac{1}{1.25} = \frac{1}{1.2}$$

$\therefore$ $$v_0 = 30 \text{ cm}$$

$$\text{Magnification} = \frac{v_0}{u_0}\frac{D}{f_e} = \frac{30}{1.25} \times \frac{25}{3} = 200$$

Outside Delhi Set-II, Series: A4BAB/3, 55/3/2

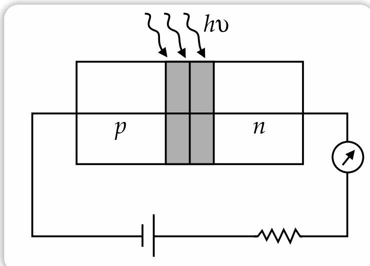
Note: Except these all other Questions are from Outside Delhi Set-I.

SECTION - A

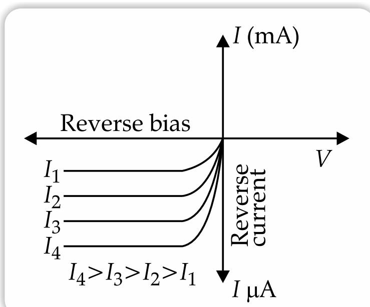
2. (a) Draw the circuit diagram of an illuminated photodiode and its I-V characteristics. 1

(b) How can a photodiode be used to measure the light intensity? 1

Ans. (a) Illuminated photo diode circuit:



I-V characteristics of photo diode:



(b) As the intensity of light increases, more number of photons are incident on the photo diode. So more number of electron-hole pairs are produced. The photo current increases. So, the photo current indicates the light intensity.

SECTION - B

4. (a) Calculate the frequency of a photon of energy 6.5×10^{-19} J.

(b) Can this photon cause emission of an electron from the surface of Cs of work function 2.14 eV? If yes, what will be maximum kinetic energy of the photoelectron? 3

Ans. (a) Frequency of photon $= \dfrac{E}{h}$

$$\therefore \quad \text{Frequency} = \nu = \frac{6.5\times10^{-19}}{6.6\times10^{-34}} \approx 10^{15} \text{ Hz}$$

(b) Work function of Cs $= \phi_0 = 2.14$ eV

Threshold frequency $= \nu_0 = \dfrac{\phi_0}{h}$

$$= \frac{2.14\times1.6\times10^{-19}}{6.6\times10^{-34}} = 0.5\times10^{15} \text{ Hz}$$

Since the energy of incident photon is more than the threshold frequency, emission of photoelectrons will be possible.

KE_{max} = Energy of incident photon – Work function

$\therefore \quad KE_{max} = 6.5 \times 10^{-19} - 2.14 \times 1.6 \times 10^{-19}$

$= 3.1 \times 10^{-19}$ J

5. Monochromatic light of wavelength 600 nm is incident from air on a water surface. The refractive index of water is 1.33. Find the (i) wavelength, (ii) frequency and (iii) speed, of reflected and refracted light. 3

Ans. Given : $\lambda = 600$ nm

$\mu = 1.33$

(i) In reflection, the ray will reflect back in the same medium as that of incident ray.

Hence, wavelength (λ) = 600 nm

$$\text{frequency} = \upsilon = \frac{c}{\lambda} = \frac{3\times10^{8}}{600\times10^{-9}}$$

$= 0.5 \times 10^{15}$ Hz

speed $= 3 \times 10^{8}$ ms^{-1}

(ii) In refraction, the speed and wavelength change while frequency remains same.

Hence, $\quad \text{speed} = v = \dfrac{c}{\mu} = \dfrac{3\times10^{8}}{1.33}$

$= 2.26 \times 10^{8}$ ms^{-1}

$$\text{wavelength} = \lambda = \frac{v}{\upsilon} = \frac{2.26\times10^{8}}{0.5\times10^{15}}$$

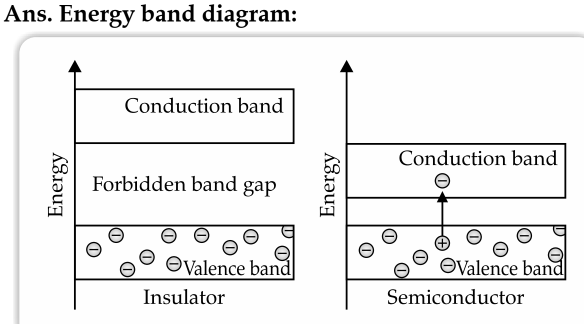
$= 4.52 \times 10^{-7}$ m

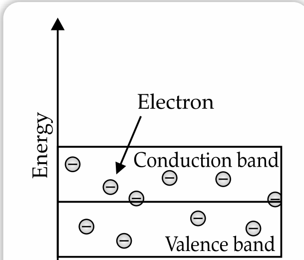
$= 452$ nm

frequency $= \upsilon = 0.5\times 10^{15}$ Hz

8. Draw the energy band diagrams for conductors, semiconductors and insulators. Which band determines the electrical conductivity of a solid? How is the electrical conductivity of a semiconductor affected with rise in its temperature? Explain. 3

Ans. Energy band diagram:





Conductor

Conduction band determines the conductivity of solids.

The gap between conduction band and valence band is small in semiconductors. Therefore, electrons, gaining energy, can jump from the valence band to the conduction band on increasing temperature. So, the conductivity of semiconductor increases with increase in temperature.

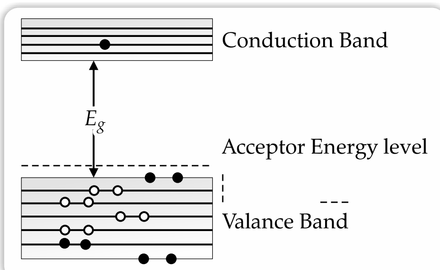
Outside Delhi Set-III, Series: A4BAB/3, 55/3/3

Note: Except these all other Questions are from Outside Delhi Set-I.

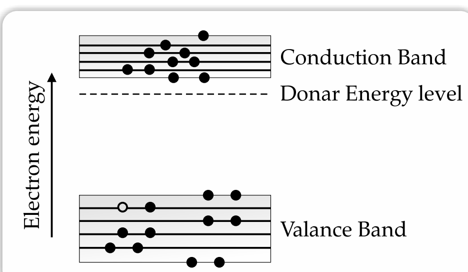
SECTION - A

3. Name the extrinsic semiconductors formed when a pure germanium is doped with (i) a trivalent and (ii) pentavalent impurity. Draw the energy band diagrams of extrinsic semiconductors so formed. 2

Ans. (i) When a pure Germanium is doped with trivalent impurity, *p*-type extrinsic semiconductor is formed.



(ii) When a pure Germanium is doped with pentavalent impurity, *n*-type extrinsic semiconductor is formed.



SECTION - B

5. The work function of a metal is 2.31 eV. Photoelectric emission occurs when light of frequency 6.4 $\times 10^{14}$ Hz is incident on the metal surface. Calculate (i) the energy of the incident radiation, (ii) the maximum kinetic energy of the emitted electron and (iii) the stopping potential of the surface. 3

Ans. (i) Frequency of incident radiation = $\nu = 6.4 \times 10^{14}$ Hz

Energy of incident radiation = $E = h\nu = 6.6 \times 10^{-34} \times 6.4 \times 10^{14} = 42.24 \times 10^{-20}$ J

(ii) $KE_{max} = h\nu - \phi_0$

$\therefore \quad KE_{max} = 42.24 \times 10^{-20} - 2.31 \times 1.6 \times 10^{-19}$

$= 5.28 \times 10^{-20}$ J

(iii) If stopping potential = V_S, then

$eV_S = KE_{max}$

$$\therefore \quad V_S = \frac{KE_{max}}{e}$$

$$= \frac{5.28 \times 10^{-20}}{1.6 \times 10^{-19}}$$

$= 3.3 \times 10^{-1} = 0.33$ V

6. A beam of light consisting of two wavelengths 600 nm and 500 nm is used in Young's double slit experiment. The silt separation is 1.0 mm and the screen is kept 0.60 m away from the plane of the slits. Calculate:

(i) the distance of the second bright fringe from the central maximum for wavelength 500 nm, and

(ii) the least distance from the central maximum where the bright fringes due to both the wavelengths coincide. 3

Ans. (i) Distance of 2[nd] bright fringe from central maximum = $\frac{2\lambda D}{d}$

$$= \frac{2 \times 500 \times 10^{-9} \times 0.6}{1 \times 10^{-3}}$$

$= 6 \times 10^{-4}$ m

(ii)
$$\frac{n\lambda_1 D}{d} = \frac{(n+1)\lambda_2 D}{d}$$

Or, $n\lambda_1 = (n+1)\lambda_2$

Or, $$\frac{n}{(n+1)} = \frac{\lambda_2}{\lambda_1}$$

Or, $$\frac{n}{(n+1)} = \frac{500}{600}$$

$\therefore \quad n = 5$

So, least distance from central maximum

$$= \frac{5\times 600\times 10^{-9}\times 0.6}{1\times 10^{-3}} = 18\times 10^{-4} \text{ m}$$

10. (a) James Chadwick, in 1932 studied the emission of neutral radiations when Beryllium nuclei were bombarded with alpha particles. He concluded that emitted radiations were neutrons and not photons. Explain.

(b) Two nuclei may have the same radius, even though they contain different number of protons and neutrons. Explain. 3

Ans. (a) In 1932 James Chadwick observed emission of neutral radiation when beryllium nuclei were bombarded with alpha-particles . It was found that this neutral radiation could knock out protons from light nuclei such as those of helium, carbon and nitrogen. The only neutral radiation known at that time was photons. Application of the principles of conservation of energy and momentum showed that if the neutral radiation consisted of photons, the energy of photons would have to be much higher than is available from the bombardment of beryllium nuclei with α-particles. So, Chadwick assumed that the neutral radiation consists of a new type of neutral particles called neutrons.

(b) Radius of nucleus depends on the total number of neutrons and protons.

Let assume one nucleus has n_1 neutrons and p_1 protons. The second nucleus has n_2 neutrons and p_2 protons. If

$$n_1 + p_1 = n_2 + p_2$$

then the radius of the two nuclei will be equal even though they are having different number of neutrons and different number of protons.

11. (a) The energy of hydrogen atom in an orbit is –1.51 eV. What are kinetic and potential energies of the electron in this orbit?

(b) The electron in a hydrogen atom is typically found at a distance of about 5.3×10^{-11} m from the nucleus which has a diameter of about 1.0×10^{-15} m. Assuming the hydrogen atom to be a sphere of radius 5.3×10^{-11} m, what fraction of its volume is occupied by the nucleus?

Ans. (a) Total energy = – 1.51 eV

So, Potential energy = 2 × Total energy

= – 3.02 eV

Kinetic energy = – Total energy

= 1.51 eV

(b)

$$\text{Volume of nucleus} = \frac{4}{3}\pi R^3$$

$$\text{Volume of atom} = \frac{4}{3}\pi R^3$$

Fraction of volume occupied by the nucleus =

$$\frac{\frac{4}{3}\pi r^3}{\frac{4}{3}\pi R^3} = \frac{(0.5\times 10^{-15})^3}{(5.3\times 10^{-11})^3} = 8.39 = 8.4\times 10^{-16}.$$

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