Unit 1: Ultrasonic waves and acoustics

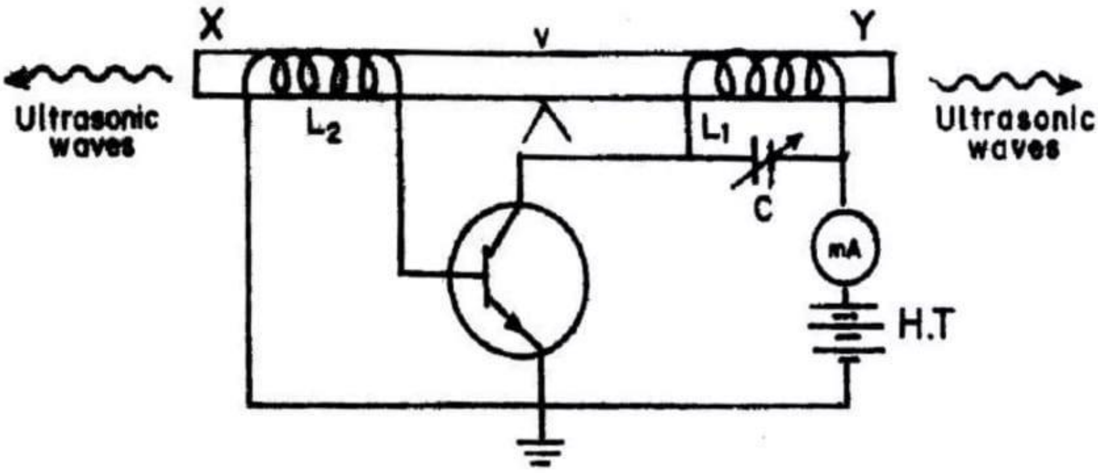
1. **Explain the working principle and construction of the magnetostriction oscillator.**

Ans:

Principle: When a rod of ferromagnetic material like nickel is magnetized. Longitudinally, it undergoes a very small change in length. This is called Magnetostriction effect.

Construction:

The circuit diagram of magnetostriction ultrasonic generator is as shown in the figure below. A short permanently magnetized nickel rod is clamped in the middle between two knife edges. A coil L_1 is wound on the right hand portion of the rod. C is a variable capacitor. L_1 and C form the resonant circuit of the collector-tuned oscillator. Coil L_2 wound on the LHS of the rod is connected in the base circuit. The coil L_2 is used as a feed back loop.



Working:

When the battery is switched on, the resonant circuit L_1 C sets up an alternating current of frequency.

$$f = \frac{1}{2\pi\sqrt{L_1 C}}$$

This current flowing through the coil L_1 produces an alternating magnetic field of frequency f along the length of the nickel rod. Due to this the rod starts vibrating due to magnetostriction effect.

The frequency of vibration of the rod is given by

$$f' = \frac{P}{2l}\sqrt{\frac{Y}{\rho}}$$

where

l = length of the rod

Y = Young's modulus of the rod material and

ρ = density of rod material

• The capacitor C is adjusted so that the frequency of the oscillatory circuit is equal to natural frequency of the rod and thus resonance takes place.

• Now the rod vibrates longitudinally with maximum amplitude and generates ultrasonic waves of high frequency from its ends

Advanatages

• The design of this oscillator is very simple and its production cost is low

• At low ultrasonic frequencies, the large power output can be produced without the risk of damage of the oscillatory circuit.

Disadvanatges

• It has low upper frequency limit and cannot generate ultrasonic frequency above 3000 kHz (ie. 3MHz).

• The frequency of oscillations depends on temperature.

• There will be losses of energy due to hysteresis and eddy current.

PIEZO ELECTRIC GENERATOR

2. **Explain the working principle and construction of the piezo-electric oscillator.**

Ans:

Principle: It works on the principle of Inverse piezo electric effect

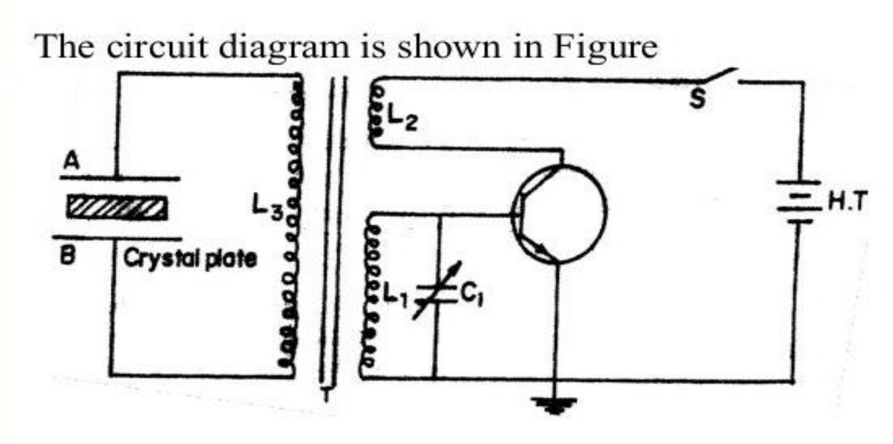
• If mechanical pressure is applied to one pair of opposite faces of certain crystals like quartz, equal and opposite electrical charges appear across its other faces. This effect is called as piezo-electric effect.

• The converse of piezo electric effect is also true.

• If an electric field is applied to one pair of faces, the corresponding changes in the dimensions of the other pair of faces of the crystal are produced. This effect is known as inverse piezo electric effect.

Construction:

The circuit diagram is shown in Figure



Piezo electric oscillator

The quartz crystal is placed between two metal plates A and B.

• The plates are connected to the primary (L_3) of a transformer which is inductively coupled to the

electronics oscillator.

• The electronic oscillator circuit is a base tuned oscillator circuit.

• The coils L_1 and L_2 of oscillator circuit are taken from the secondary of a transformer T.

• The collector coil L_2 is inductively coupled to base coil L_1.

• The coil L_1 and variable capacitor C_1 form the tank circuit of the oscillator.

Working

• When H.T. battery is switched on, the oscillator produces high frequency alternating voltages with a frequency.

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

• Due to the transformer action, an oscillatory e.m.f. is induced in the coil L_3. This high frequency alternating voltages are fed on the plates A and B.

• Inverse Piezo-electric effect takes place and the crystal contracts and expands alternatively. The crystal is set into mechanical vibrations.

• The frequency of the vibration is given by

$$f' = \frac{P}{2l}\sqrt{\frac{Y}{\rho}}$$

where P = 1,2,3,4 … etc. for fundamental, first over tone, second over tone etc., Y = Young’s modulus of the crystal and

ρ = density of the crystal.

• The variable condenser C_1 is adjusted such that the frequency of the applied AC voltage is equal to the natural frequency of the quartz crystal, and thus resonance takes place.

• The vibrating crystal produces longitudinal ultrasonic waves of large amplitude.

Advantages

• Ultrasonic frequencies as high as 5 x 108Hz or 500 MHz can be obtained with this arrangement.

• The output of this oscillator is very high.

• It is not affected by temperature and humidity.

Disadvantages

• The cost of piezo electric quartz is very high

• The cutting and shaping of quartz crystal are very complex.

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• The cutting and shaping of quartz crystal are very complex.

3. Explain advantage and disadvantage of magnetostriction and piezoelectric oscillator.

Ans:

A) Magnetostriction Oscillator

Advantages:

i) Design of this oscillator is easy and cheap

ii) At low frequency ultrasonic, the large power output can be produced without the risk of damage of circuit.

Disadvantages:

i) High frequency circuit can damage, upper limit is around 3 MHz
ii) Frequency is depends on temperature.
iii) Loss of energy due to eddy current.

B) Piezo-electric Oscillator

Advantages:
i) This can produce high frequency ultrasonic up to 500 MHz.
ii) Output of oscillator is very high.
iii) It is not affected by temperature and humidity.

Disadvantage:
i) The cost of Piezo-electric quartz is very high.

ii) Cutting and shaping quartz is complex.

Requirements of acoustically good hall

4. **What are the requirements of acoustically good hall?**

Ans:

An acoustically good hall is a space that is designed to have optimal sound quality for its intended purpose, whether it's a concert hall, a lecture hall, a recording studio, or any other kind of space where sound quality is important. To achieve this, the hall must meet certain requirements such as:

1. **Low background noise**: The hall should have low levels of ambient noise, which can be achieved by using sound-absorbing materials such as acoustic panels or curtains, or by locating the hall away from sources of noise such as busy roads or railways.
2. **Even sound distribution**: The hall should be designed to ensure that sound is evenly distributed throughout the hall, with no dead and loud spots. This can be achieved through careful placement of speakers or microphones, or by using reflective surfaces to bounce sound evenly around the room.
3. **Appropriate reverberation time:** The hall should have an appropriate reverberation time. This can be controlled by adjusting the amount and placement of sound-absorbing and reflective materials in the hall.
4. **Minimal echoes and resonances:** The hall should be designed to minimize echoes and resonances, which can cause distortion or interference with the desired sound. This can be achieved by using sound-absorbing materials on walls and ceilings, or by carefully shaping the room to eliminate standing waves.
5. **Good speech intelligibility:** If the hall is used for spoken word or lectures, it should be designed to ensure good speech intelligibility, which means that the words spoken in the hall are easily understood by listeners. This can be achieved through careful design of the acoustics and the placement of speakers and microphones.

6. **Write down properties and applications of ultrasonic sound**

OR

7. **What is an ultrasonic sound? Write applications of ultrasonic sound.**

Ans:

Ultrasonic sound refers to sound waves that have frequencies above the upper limit of human hearing, typically above 20 kHz

Properties:

a) High frequency: Ultrasonic sound waves have frequencies above 20 kHz, which is the upper limit of human hearing. They can have frequencies up to several gigahertz (GHz).
b) Short wavelength: Ultrasonic sound waves have short wavelengths, which makes them useful for detecting small objects or flaws in materials.
c) Directional: Ultrasonic sound waves can be focused in a specific direction, making them useful for imaging and measuring.

Applications:

1) Medical imaging: Ultrasonic sound waves are used in medical imaging to create images of internal organs and tissues. This technique is known as ultrasound imaging or sonography.
2) Non-destructive testing: Ultrasonic sound waves can be used to detect flaws or defects in materials such as metal, plastic, and composites. This technique is known as ultrasonic testing (UT) or non-destructive testing (NDT).
3) Cleaning: Ultrasonic sound waves can be used to clean small parts or objects, such as jewelry or dental instruments.
4) Measurement: Ultrasonic sound waves can be used to measure distance, velocity, or thickness. This technique is known as ultrasonic measurement or ultrasonic sensing.
5) Pest control: Ultrasonic sound waves can be used to repel pests such as rodents and insects, as they are sensitive to high-frequency sound.

8. **Define the reverberation time and give Sabine formula for reverberation time. Find reverberation time for a hall of dimensions 40 ft x 50 ft and celling around 20 ft , having average absorption coefficient of wall 0.04 and constant K= 0.049 s.ft-1.**

Ans:

Reverberation time: Time taken by sound in a room to fall from its average intensity to inaudible level, is called reverberation time.

ii) Sabine formula for Reverberation time

Sabine proved that Reverberation time (T) of a hall of volume V is is

$T = K. (V/A)$

Where, A is effective absorption area (or area equivalent to open window)

For any surface area S,

A= αS

If there are number of surface areas S_1, S_2, S_3,………and so on having absorption coefficients α_1, α_2, α_3, …….and so on respectively then

A= $\alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \ldots\ldots\ldots$

A= $\Sigma\, \alpha_i S_i$

$$T = K \frac{V}{\alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \cdots}$$

$$T = K \frac{V}{\sum \alpha_i S_i}$$

In FPS K= 0.049 s-ft^{-1}

$$\therefore T = 0.049 \frac{V}{\sum \alpha_i S_i}$$

In MKS= 0.161 s-m^{-1}

$$\therefore T = 0.161 \frac{V}{\sum \alpha_i S_i}$$

Numerical:

Formula:

$$T = 0.049 \frac{V}{\sum \alpha_i S_i}$$

Given:

α = 0.04, K = 0.049 s-ft^{-1}

Length l = 50 ft Breadth b = 40 ft Height h = 20 ft

Therefore

V = l X b X h = 50 X 40 X 20 = 40000 cu.ft.

Area of the hall S = 2(l X b) + 2 (b X h) + 2(h X l)

= 2 (50 X 40) + 2(40 X 20) + 2(20 X 50)

= 4000 + 1600 + 2000

= 7600 sq. ft

$$T = 0.049 \frac{V}{\sum \alpha_i S_i}$$

$$T = 0.049 \frac{40000}{0.04\ X\ 7600}$$

$$T = 6.44\ sec$$

Reverberation time for the hall is T = 6.44 sec

8. **Find reverberation time for a hall of dimensions 15 m x 20 m and celling around 7 m, having average absorption coefficient of 0.15 for walls, and constant K for 0.161 s.m^{-1} How many curtain of 2 m X 1 m will be needed to get reverberation time reduced by 0.2 s, absorption coefficient of curtain 1.2?**

   Ans:
   Formula:

$$T = K\ X\ \frac{V}{\Sigma\ (\alpha i S i)}$$

$$0.161\ X\ \frac{V}{\alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \alpha_4 S_4 + \alpha_5 S_5 + \alpha_6 S_6}$$

$$0.161\ X\ \frac{V}{\alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \alpha_4 S_4 + \alpha_5 S_5 + \alpha_6 S_6}$$

Answer: **T= 2.0 s**

New required reverberation time = 2.0 - 0.2 = **1.8 s**

$$1.8\ = 0.161\ X\ \frac{V}{\alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \alpha_4 S_4 + \alpha_5 S_5 + \alpha_6 S_6 + \boldsymbol{\alpha_7 S_7}}$$

Where $\alpha_7 = 1.2\ is\ absorption\ by\ curtain$ with total area S_7

$$1.8\ = 0.161\ X\ \frac{15\ X\ 20\ X\ 7}{0.15 \text{ X } 2 \text{ X } (\ 15 \text{ X } 20 + 20 \text{ X } 7 + 15 \text{ X } 7) + \mathbf{1.2\ X}\ \boldsymbol{S_7}}$$

$$\boldsymbol{S_7 = 20.27\ m^2}$$

Given dimensions of curtain 2 m X 1 m ; Area of 1 curtain is 2 m^2

Hence number of curtains needed = Total area (S_7) / area of one curtain

= $\frac{\mathbf{20.27\ m^2}}{\mathbf{2\ m^2}} = \mathbf{10..1 \sim 10\ \boldsymbol{curtains}}$

9. **Find reverberation time for a temple of dimensions 20 m x 10 m and celling around 10 m , having average absorption coefficient of 0.11 for walls, and constant K for 0.161s-m^{-1} During the renovation of temple, engineer increased height of celling from 10 m to 12 m, what will be new reverberation time.**

Ans: ***Solve using Sabine formula as a first part of above problem.***

Reverberation time of temple: 2.9 s
Reverberation time of temple after renovation: 3.1 s

10. Find reverberation time for a hall of dimensions 10 m x 10 m and celling around 10 m , having average absorption coefficient of 0.10 for walls, and constant K for 0.161 s.m-1. During the renovation of hall, engineer increased one side from 10 m to 15 m, what will be new reverberation time.

Ans: ***Solve using Sabine formula as a first part of above problem.***

Reverberation time of hall: 2.7 s
Reverberation time of hall after renovation: 3.0 s

11. What is velocity of ultrasonic sound of frequency 5 MHz and wavelength 10 mm?

Ans

Formula:

$$V = \nu\lambda$$
$$\nu = frequency\ of\ ultrasonic\ sound$$
$$\lambda = Wavelength\ of\ ultrasonic\ sound$$

Given:
$\nu = 5\ MHz = 5\ X\ 10^6\ \ Hz$
$\lambda = 10\ mm = 10\ X\ 10^{-3}\ m$

(Always convert into SI unit; *M*→ *Mega* → 10^6*;* *m*→ *mili-* → 10^{-3} *;* *k*→ *Kilo-* $\mathbf{10^3}$
Note: Hz is equal to s^{-1}*)*

V= $5\ X\ 10^6\ \ Hz\ X\ 10\ X\ 10^{-3}\ m$; **V =** $\mathbf{50\ X\ 10^3\ m/s}$

12. What is velocity of ultrasonic sound of frequency 10 KHz and wavelength 10 cm?

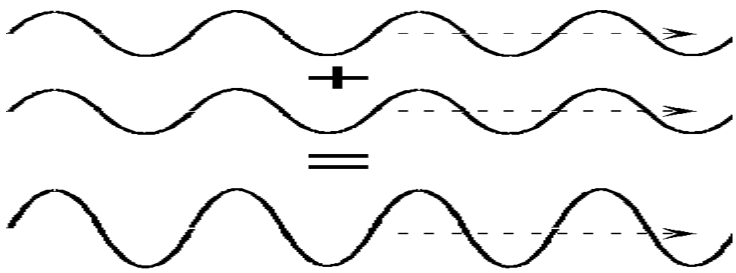
Ans: 1000 m/s

Unit 2: Electromagnetic Waves

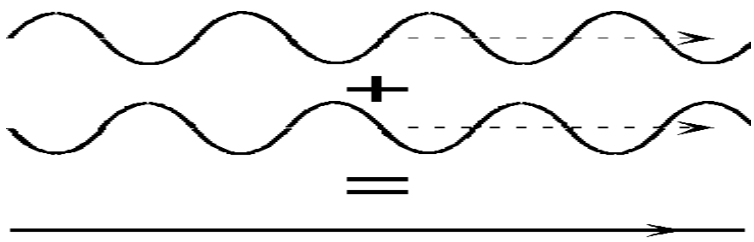
13. What is an interference? Discuss the differences between constructive and destructive interference.

Interference is the phenomenon in which two waves superimpose to form the resultant wave of the lower, higher or same amplitude. It is of following two types

(1) Constructive interference: When two waves meet at a point with same phase, constructive interference is obtained at that point (*i.e.* maximum light)



(2) **Destructive interference:** When two wave meet at a point with opposite phase, destructive interference is obtained at that point (*i.e.* minimum light)



Difference between constructive and destructive interference:

Constructive interference	**Destructive interference**
1) It produced when two waves meet in phase 2) Phase difference is 0 or 2Πn, where n=0,1,2,3,… 3) Resultant amplitude is maximum 4) Resultant intensity is maximum	1) It produced when two waves meet in phase 2) Phase difference is 180 degree or (2n-1)Π where, n = 1, 2, 3..... 3) Resultant amplitude is minimum 4) Resultant intensity is minimum

14. **What is diffraction? Discuss the differences between Fraunhofer's diffraction and Fresnel's diffraction.**

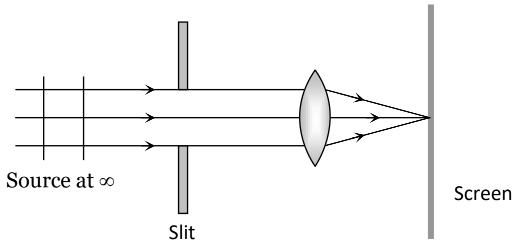
Diffraction

The phenomenon of bending of light around the corners of an obstacle/aperture of the size of the wave length of light is called diffraction.

Types of Diffraction

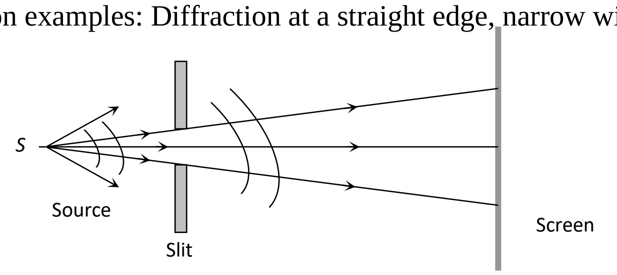
(1) **Fraunhofer diffraction:** In this case both source and screen are effectively at infinite distance from the diffracting device.

Common examples: Diffraction at single slit, double slit and diffraction grating.



(2) **Fresnel diffraction:** If either source or screen or both are at finite distance from the diffracting device (obstacle or aperture), the diffraction is called Fresnel type.

Common examples: Diffraction at a straight edge, narrow wire or small opaque disc *etc*.



Difference between Fraunhofer's diffraction and Fresnel's diffraction:

	Fraunhofer's diffraction	**Fresnel's diffraction**
1	The source and screen are at infinite distance from the obstacle.	The source and screen are at finite distance from the obstacle.
2	The wave front is plane wave front.	The wave front is spherical or cylindrical.
3	Lens system is necessary.	Lens system is not necessary.
4	Theoretical treatment is easier.	Theoretical treatment is complicated
5	Centre of the diffraction pattern is always bright	Centre of the diffraction pattern may or may not be bright
6	Experimental observation are easy	Experimental observation are difficult

15. **What is interference and diffraction? Explain types of diffraction.**

Ans:

A) Interference:

Interference is the phenomenon in which two waves superimpose to form the resultant wave of the lower, higher or same amplitude. It is of following two types

(1) Constructive interference: When two waves meet at a point with same phase, constructive interference is obtained at that point (*i.e.* maximum light)

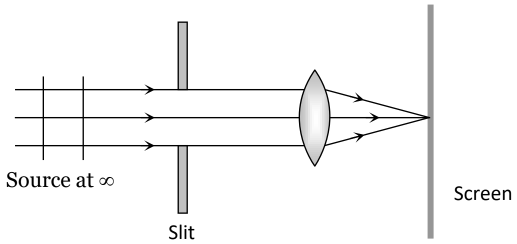
(2) **Destructive interference:** When two wave meet at a point with opposite phase, destructive interference is obtained at that point (*i.e.* minimum light)

B) Diffraction

Definition- The phenomenon of bending of light around the corners of an obstacle/aperture of the size of the wave length of light is called diffraction.

Types of Diffraction

(1) **Fraunhofer diffraction:** In this case both source and screen are effectively at infinite distance from the diffracting device.



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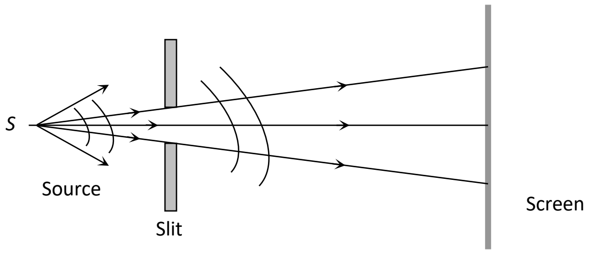
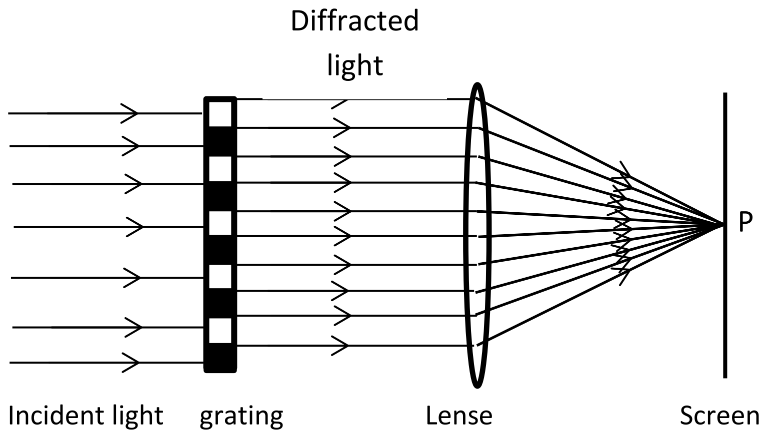
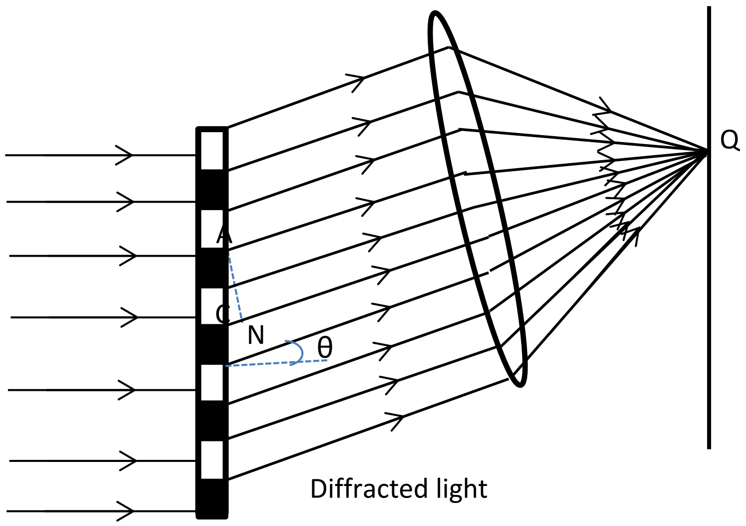


16. Derive the formula for grating element for a plane diffraction grating.

Ans:

A device consisting of large number of parallel slits of equal width and separated by equal opaque spaces is called as diffraction grating.





in ΔACN

Angle ANC = 90^0

Angle CAN=θ

Consider a plane diffraction grating having grating element d.

i. All the secondary waves traveling in the same direction of the incident light will focus at a point P on the screen forming central maxima.

ii. The secondary waves traveling in a direction inclined at an angle θ will focus at point Q on the screen.

iii. The intensity at Q is depends upon the path difference between the secondary waves.

iv. From the figure, path difference CN is

   $CN = AC\sin\theta$

   But $AC = d$

   Therefore, $CN = d\sin\theta$

v. The intensity at Q is maximum only if when

   $\boxed{d\sin\theta = n\lambda}$ where n = 0,1,2,3,………

17. **What is double refraction? Explain O-Ray and E-Ray.**

Ans:

Double refraction :

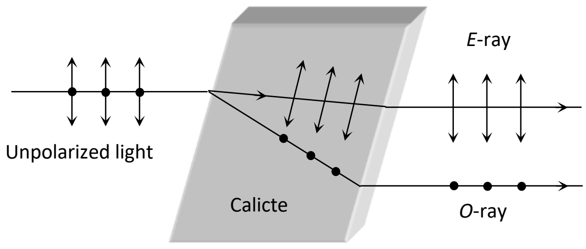


Fig. 30.40

In certain crystals, like calcite, quartz and tourmaline *etc*, incident unpolarized light splits up into two light beams of equal intensities with perpendicular to the direction of polarization this is called as double diffraction.

One of the ray is ordinary ray (*O*-ray) it obey's the Snell's law. Another ray's extra ordinary ray (*E*-ray) it doesn't obey's the Snell's law.

Difference between ordinary and extraordinary ray

Ordinary ray	**Extraordinary ray**
1) O-ray obeys the snell's law of refraction 2) The electric vector of O-ray vibrate perpendicular to principal section. 3) O ray travel with uniform velocity in all directions. 4) R.I. for O ray is constant	1) E-ray do not obey the snell's law 2) The electric vector of O-ray vibrate parallel to principal section. 3) E ray travel with different velocites in all directions. 4) R.I. varies from direction to direction.

18. **A monochromatic light of wavelength 5000 Å strikes a grating and produce third order diffraction at 45 degrees angle. Determine the grating element.**

Ans:

Formula: d sin θ=n λ

Given:

λ = 5000 Å = $5000\ X\ 10^{-10}\ m$

n=3

θ= 45 degree

d= ?

formula:

d sin θ=n λ

$$d = \frac{\text{n}\,\lambda}{\sin\theta}$$

$$d = \frac{3\text{ X }5000\,X\,10^{-10}}{\sin 45}$$

$$d = 1.76\,X\,10^{-6}\,m$$

Grating element d is $1.76\,X\,10^{-6}\,m$.

19. A monochromatic light of wavelength 4000 Å strikes a grating and produces third-order diffraction at 30 degrees angle. Determine the grating element and number of slits per cm.

Ans:

Formula: d sin θ=n λ

Given: ***(Note: Always convert into SI Unit)***

λ = 4000 Å = $4000\,X\,10^{-10}\,m$

n=3

θ= 30 degree

d=?

N=?

$$d = \frac{\text{n}\,\lambda}{\sin\theta}$$

$$d = \frac{3\text{ X }4000\,X\,10^{-10}}{\sin 30}$$

$$d = 1.21\,X\,10^{-6}\,m$$

Or

$$\boldsymbol{d = 1.21\,X\,10^{-4}\,cm}$$

Grating element d is $1.21\ X\ 10^{-4}\ cm$.

The number of slits pr centimetre are

$$N = \frac{1}{d} = \frac{1}{\mathbf{1.21\ X\ 10^{-4}\ cm}} \sim 8264\ \ /cm$$

Hence number of slits per cm is 8264 / cm

20. A monochromatic light of wavelength 3000 Å strikes a grating and produces third-order diffraction at 25º angle. Determine the grating element and number of slits per cm.

Ans: d= 2.12 X 10 $^{-6}$ m = 2.12 X 10 $^{-4}$ cm
N ~ 4717 /cm

21. Monochromatic light of wavelength 110 nm strikes a grating and produce fourth order bright line at 35o angle. Determine the no. of slits per cm.

Ans: (Hint : 110 nm = 110 X 10 $^{-9}$ m)

d= 7.67 X 10 $^{-7}$ m = 7.67 X 10 $^{-5}$ cm;
and N~ 13038 /cm

22. Monochromatic light of wavelength 10 $^{-9}$ m strikes a grating and produce fourth order bright line at $\boldsymbol{\frac{\pi}{4}\ radian}$ angle. Determine the no. of slits per cm.

Ans: (Hint: Wavelength is already in meter hence no need to convert. ; Angle given is $\boldsymbol{\frac{\pi}{4}\ radian = 45\ ^{o}}$**)**

d= 5.65 X 10^{-9} m = 5.65 X 10^{-7} cm ;
and N= 1769911 /cm

(Important notes to solve numerical:

1. Always convert given data in SI unit: meter, second, Hz, Kg are SI unit.
   1 Å = 10 $^{-10}$ m
   1 nm = 10 $^{-9}$ m
   1 mm = 10 $^{-3}$ m
   1 cm = 10 $^{-2}$ m
   1 km = 10 ^{3} m

1 MHz= 10^{6} Hz

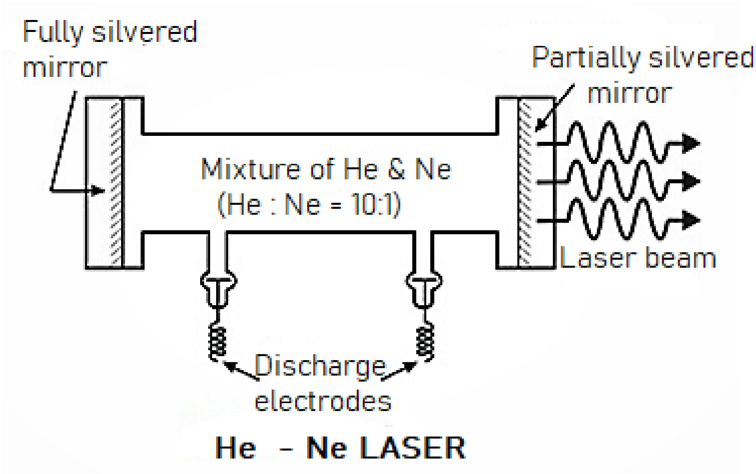
2. Always check calculator on degrees before using trigonometric function like sin, cos, tan etc.

3. Write unit properly at given data and answer. Write units in formula and cancel from numerator and denominator and check right hand side and left side unit. If both sides unmatched your formula is wrong.)

Unit 3: LASER and Optical Fibre Cable

23. With the help of neat-labelled diagram explain construction and the working of the He-Ne laser.

Ans:

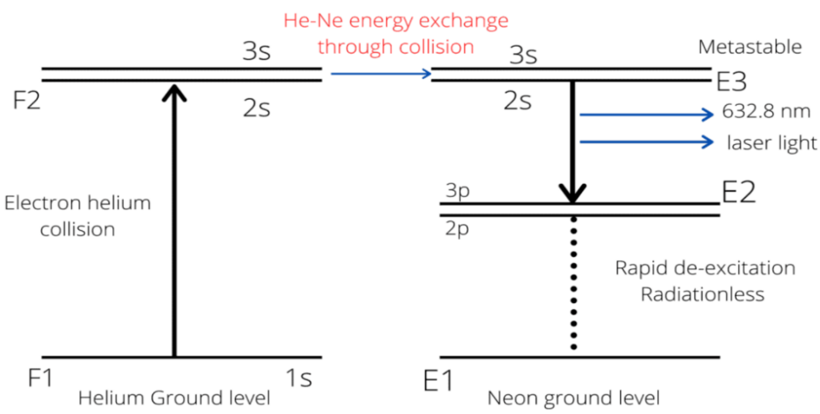


Construction:

i) It consists of a glass tube containing He and Ne gas in the proportion 10:1.
ii) Pumping is done by the discharge electrodes.
iii) Two mirrors as shown in figure are attached at the both ends forming resonator cavity.

Working:

i) When electric discharge passes through the gas tube, He atoms get excite by collision with electrons.
ii) Now the excited He atoms collide with ground state Ne atoms and exchange their energy with Ne atoms.
iii) Now the Ne atoms get excite. The de-excitation of Ne is shown in figure bellow-

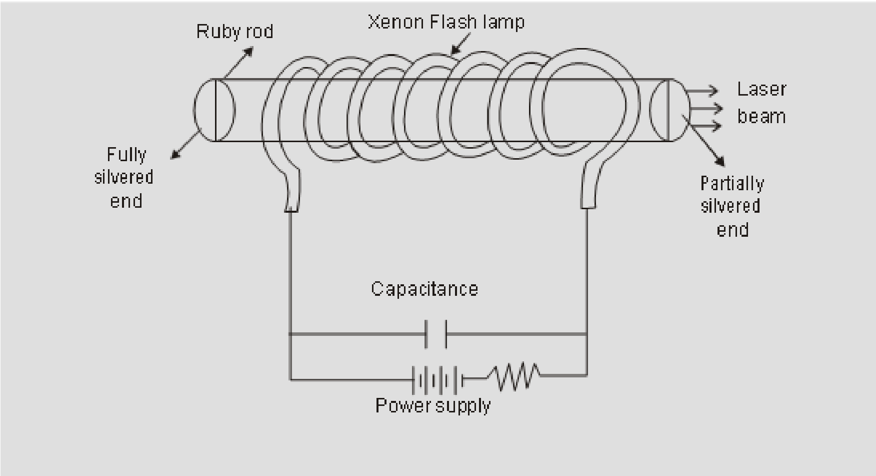


iv) Let consider E1, E2 and E3 are the ground state, first excited and second excited state which is metastable state of Ne atom.
v) The population inversion occurs in E3 state

vi) The transition from E3 to E2 gives laser light emission.

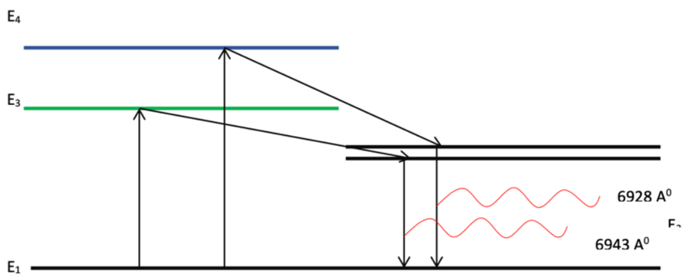
24. With the help of a neat-labelled diagram explain the construction and working of the Ruby laser.

Ans:



Construction:

i) A ruby laser most often consists of a ruby rod. Basically ruby is Al2O3 crystal in which some of the
ii) aluminium ions are replaced by chromium.
iii) The length of ruby rod is 5cm long and diameter is 0.5cm
iv) Neon flash lamp is used as optical pumping source to achieve a population inversion.
v) The rod is placed between two mirrors, forming a resonator cavity.
vi) For the cooling the assembly is kept in water chamber



Working:

i) Consider a ruby laser medium consisting of four energy levels E1, E2, E3 and E4, whereE1 is ground state, E2 is metastable state, E3 and E4 are excited states
ii) Let us assume that initially most of the electrons are in the lower energy state (E1). When light energy is supplied to the laser medium (ruby), the electrons in the ground state E1 gains enough energy and jumps into the excitation state E3 and E4.
iii) The lifetime of state E3 and E4 is very small (10-8 sec) so the electrons in the pump state do not stay for long period. After a short period, they fall into the metastable state E2 by non radiative transition.
iv) The lifetime of metastable state E2 is 10-3 sec which is much greater than the lifetime of pump state E3 and E4. Therefore, the electrons reach E2 much faster than they leave E2. This results in an increase in the number of electrons in the metastable state E2 and hence population inversion is achieved.
v) After some period, the electrons in the metastable state E2 falls into the lower energy state E1 by releasing energy in the form of photons. This is called spontaneous emission of radiation.
vi) When the emitted photon interacts with the electron in the metastable state, it stimulate to other electron to fall in the ground state E1. As a result, two photons are emitted. This is called stimulated emission of radiation.
vii) When these emitted photons again interacted with the metastable state electrons, then 4 photons are produced. Because of this continuous interaction with the electrons, millions of photons are produced.
viii) The light produced within the laser medium will bounce back and forth between the two mirrors. This stimulates other electrons to fall into the ground state by releasing light energy. This is called stimulated emission. Likewise, millions of electrons are stimulated to emit light. Thus, the light gain is achieved.
ix) The amplified light escapes through the partially reflecting mirror to produce laser light.

25. Explain construction of holograph with neat-labelled diagram.

Ans:

Principle of hologram:

It is based on the principle of interference between two coherent beams - object beam and reference beam.

<u>1) Recording of hologram:</u>

The principle of holography is illustrated in fig-

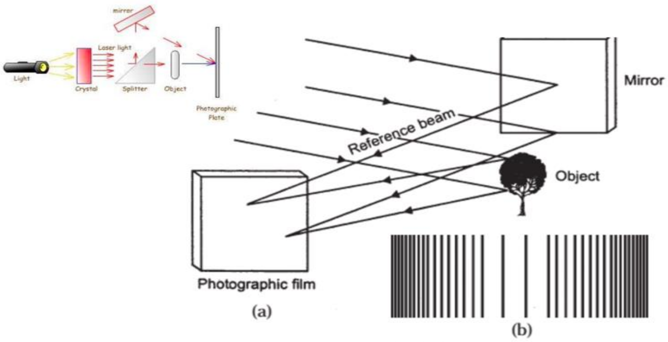


Fig 2.7

i) Using beam splitter laser beam is splitted into two beams viz a reference beam and object beam. The reference beam after reflection from the mirror is made incident on photographic plate.
ii) The object beam is incident on the object and scattered by object. The beam scattered from the object travels towards photographic plate and interferes with reference beam producing an interference pattern on photographic plate.
iii) The photographic plate carrying interference pattern is called hologram as shown in above fig, It records intensity as well as phase variation. Whenever required image is reconstructed.

<u>2) Reconstruction of image:</u>

The reconstruction of the object is schematically shown in following fig:

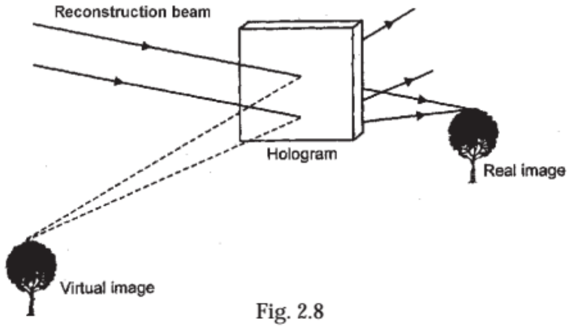


Fig. 2.8

iv) A laser beam identical to the reference beam is used which is known as reconstruction beam.
v) The hologram acts as diffraction grating. The diffracted rays form two images: a real image in front of hologram and virtual image behind the hologram at the original site of object.
vi) It has three dimensional characteristics. And it is viewed from different angles. Different perspectives of image can be observed.

26. Define with necessary diagram:

1) stimulated absorption
2) spontaneous emission
3) population inversion

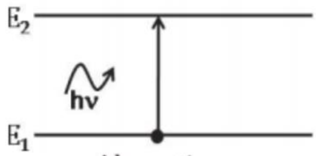
1) Stimulated absorption

Consider the system of atoms with two energy levels - ground state E1 and excited state E2. At thermal equilibrium majority of the atoms will be in ground state E1. If a photon of energy (E = E2 -E1 = hv) is incident on the atom, it absorbs the energy and jumps to excited state E2. This phenomenon is known as stimulated absorption. It can be expressed as

$$A + h\nu \rightarrow A^*$$

A – atom in energy level E_1

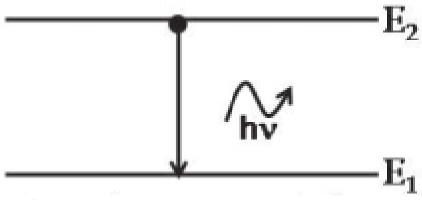
A^* – atom in energy level E_2



Absorption

2) Spontaneous emission-

Excited Energy state E2 is unstable and its lifetime (time for which atom stays in excited state) is 10^{-8} s. Hence there is transition of atom from energy state E2 to E1 with emission of photon with energy hv = E2 -E1 as shown in fig.



Spontaneous emission

"Emission of photon by an excited atom without any external energy is known as spontaneous emission." It can be expressed as-

$$A^* \rightarrow A + h\nu$$

3) Population inversion

Population inversion

Let N_1 and N_2 be the number of atoms in the ground state E_1 and excited state E_2.

In thermal equilibrium, $N_1 > N_2$. "If number of atoms in higher energy state is greater than number of atoms in lower energy state (N2 > N1), it is known as population inversion.

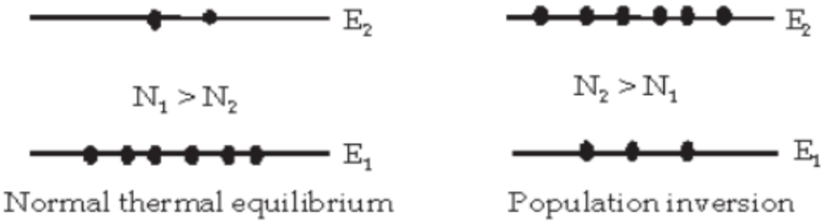


Fig. 2.3

27. Explain the advantages of optical fibre over conducting wire.

8. Advantages of optical fibers over conducting wires

Optical fibers have many advantages over conducting wires:

1. **Optical fibers are cheaper:** Optical fibers are made from *silica (SiO_2), which* is one of the most abundant material on the earth.
2. **Smaller in size, lighter in weight, flexible yet strong:** The cross section of an optical fiber is about a few hundred micron. Hence, the fibers are less bulky. Typically, RG-19/U coaxial cable weighs about 1100 kg/km whereas a PCS fiber cable weighs 6 kg/km only. Optical fibers are quite flexible and strong.
3. **Not hazardous:** In wire communication, short circuit and the sparking occurs accidently. Such accidents can't occur with fiber links because of their insulating nature
4. **Immune to EMI and RFI :** In optical fibers, information is carried by photons. Photons are electrically neutral and cannot be disturbed by high voltage fields. Therefore, fibers are immune to externally caused background noise generated through electromagnetic interference (EMI) and radio frequency interference (RFI).
5. **No cross talk:** The light waves propagating along the optical fiber are completely trapped within the fiber and can't leak out. Further, light cannot couple into the fiber from sides. Hence, possibility of cross talk is minimized when optical fiber is used. Also, transmission is more secure and private.
6. **Wider bandwidth:** Optical fibers have ability to carry large amount of information while a telephone cable composed of 900 pairs of wire can handle 10,000 calls, a 1 mm optical fiber can transmits 50,000 calls.
7. **Low loss per unit length:** The transmission loss per unit length of an optical fiber is about 4 dB/km. Therefore, longer cable-runs between repeaters are feasible. If copper cables are used, the repeaters are to be spaced at intervals of about 2 km. In case of optical fibers, the interval can be as large as 100 km and above.
8. Can be operated over high temperature range.

28. Explain the structure of optical fibre cable. Explain any two types of optical fibre cable.

Optical Fibers

1. Structure of Optical Fiber

Optical fibers are glass or plastic conduits as thin as a human hair, designed to guide light waves along their length.

An optical fiber works on the principle of total internal reflection. When light enters one end of the fiber, it undergoes successive total internal reflections from sidewalls and travels down the length of the fiber along a zigzag path,

[see Fig. 1]

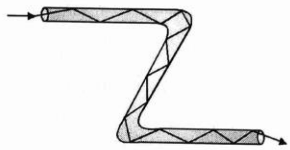


Fig. 1

A practical optical fiber has in general three coaxial regions. (See Fig. 2)

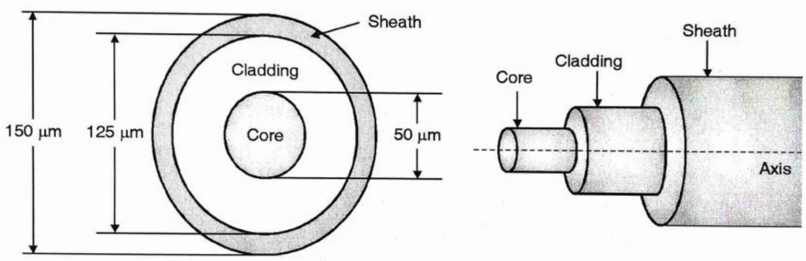


Fig. 2 : Cross-sectional view of an optical fiber

The inner most region is the light guiding region known as the **core**. It is surrounded by a coaxial middle region known as the **cladding**. The outermost region is called the **sheath.**

The refractive index of cladding always lower than that of the core. The purpose of the cladding is to make the light to be confined to the core. Light launched into the core and striking the core-to-cladding interface at an angle greater than critical angle will be reflected back into the core. Since the angles of incidence and reflection are equal, the light will continue to rebound and propagate through the fiber. The sheath protects the cladding and the core from abrasions, contamination and the harmful influence of moisture. In addition, it increases the mechanical strength of the fiber. Optical fibers are constructed, either as a single fiber or a flexible bundle or a cable. A fiber bundle is a number of fibers in a single jacket. Each fiber carries light independently.

Types of optical fibres:-

There are three types of optical fibres,

i) Single mode step index fibre
ii) Multimode step index fibre
iii) Graded index fibre

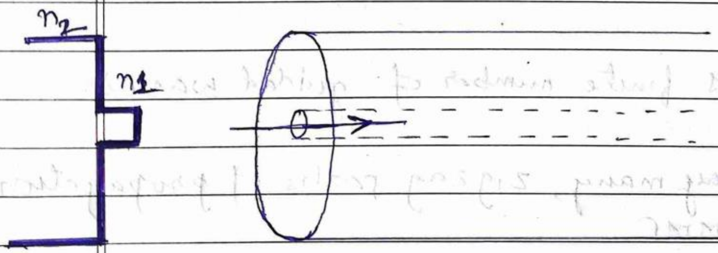
i) Single mode step index fibre:- (SMF)

Structure:- i) It has very fine thin core of diameter of 8 μm to 12 μm.

ii) The external diameter of the cladding is of the order of 125 μm.

iii) The refractive index of the fibre changes abruptly at the core-cladding boundary.

iv) The refractive index of core is greater than cladding.



index profile

Single (Monomode) mode step index fibre (SMF)

Propagation:-

i) Light travels in SMF along the axis of the fibre
ii) Both Δ & NA are very small for SMF.
iii) Due to low NA, light coupling into the fibre becomes difficult.

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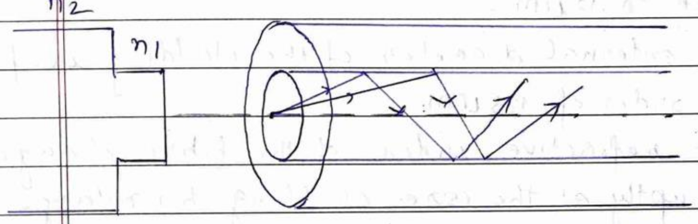
ii) Multimode step index fibre (MMF):-

Structure:- i) A MMF is very much similar to the SMF except that its core is of larger diameter.

ii) The core diameter is of the order of 50 to 100 μm.

iii) The external diameter of cladding is about 150 to 250 μm.



index profile MMF ray paths.

Propagation:-

i) The MMF allows finite number of guided waves.

ii) In other words ~~may~~ many, zigzag paths of propagation are permitted in MMF

iii) The path length of some rays are shorter & others are longer.

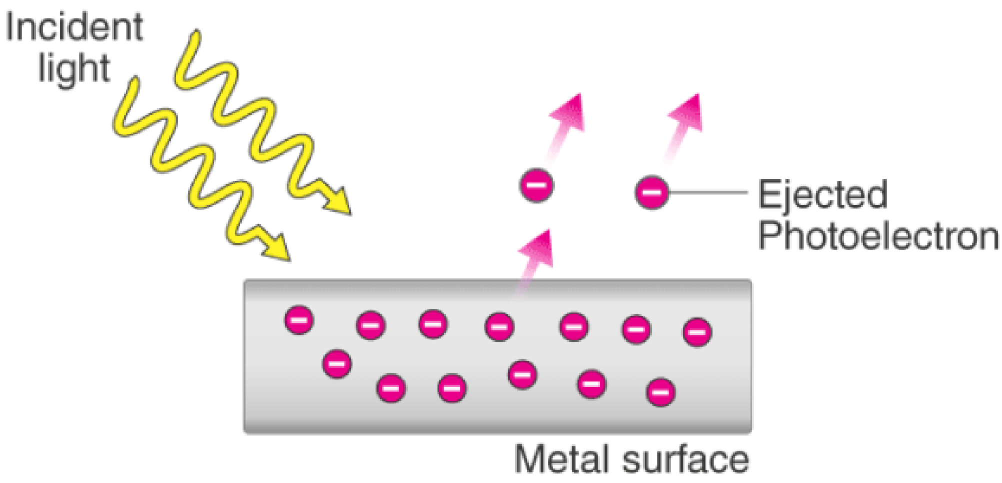
iv) Because of this difference there is time delay between high & low order modes.

Unit 4: Quantum Mechanics

29. What is the photoelectric effect? Describe Einstein's theory of the photoelectric effect.

Photoelectric effect

The photoelectric effect is a phenomenon in which electrons are ejected from the surface of a metal when light is incident on it. These ejected electrons are called **photoelectrons**



Einstein theory for photoelectric effect:

When a beam of light of energy hv incident on metal. Its energy is utilised in two ways.

i) Einstein consider light as particle and is called as photon.
ii) Consider an incident photon of energy hv where h is planks constant and v is the frequency of the photon then
iii) A part of energy of the photon is used to free the electron from the metal surface. The minimum energy required to free the electron from the metal is called the work function of that metal (W).

iv) The remaining part of the energy is used to give the KE to ejected photoelectrons.

a. $hv = W + \frac{1}{2} mv^2$
b. This is a Einstein's photoelectric equation.

v) If energy of photon is just sufficient to liberate the electron from the metal, then

$$Wo = \frac{1}{2} mv^2$$

$$hv = hvo + \frac{1}{2}\, mv^2$$

$$\frac{1}{2}\, mv^2 = h(v - vo)$$

i) If $v < vo$, no electron can be ejected from the metal surface. When $(v = vo)$, Photo-ejects just starts. When $v > vo$, the electrons are ejected acquired KE from the incident radiation.

Characteristics of Photoelectric Effect-

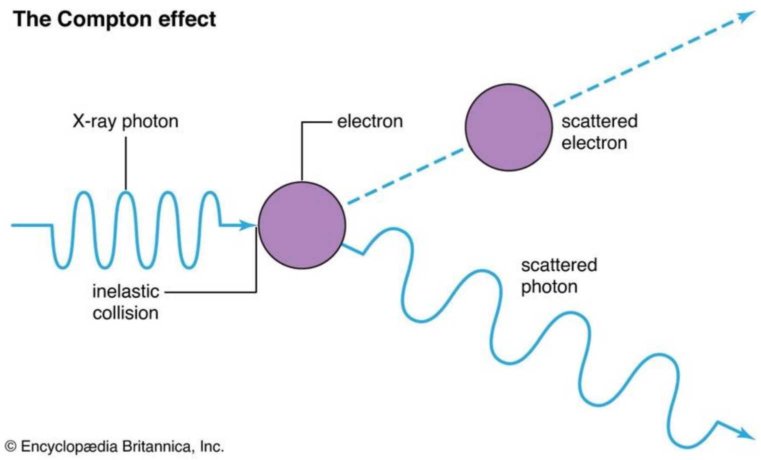
i) Photoelectric current is proportional to the intensity of incident light.
ii) For a given material, certain minimum frequency of incident light is required. This minimum value of frequency is known as a threshold frequency vo and corresponding wavelength as threshold wavelength.
iii) The KE of the photo-electron depend upon frequency of incident light radiation and not on intensity.
iv) KE of electron is proportional to frequency of the incident radiation.
v) Photoelectric effect is different from thermionic emission because the ejection on photo-electron is independent of temperature of cathode.
vi) Photoelectric effect is an instantaneous process.

30. What is the Compton effect? Write characteristics of Compton effect.

Ans:

i) Compton effect gives direct and conclusive evidence in support if particle nature of electromagnetic radiation. Compton explained this by treating x-rays as a stream of photons.

ii) Statement: When a monochromatic beam of x-ray of wavelength λ is allowed to incident on a scattering material , the scattered beam contains radiations of longer wavelength λ' in addition to the radiation of incident wavelength λ. The difference between λ' and λ i.e. $(\lambda' - \lambda)$ is known as Compton shift and effect is known as Compton effect.



The Compton shift $\Delta\lambda$ is given by-

$$\Delta\lambda = \lambda' - \lambda = \frac{h}{moc}(1 - \cos\theta)$$

From the expression of Compton shift following points are concluded,

iii) It is clear that, increase in wavelength or Crompton shift is independent of wavelength of incident radiation as well as nature of scattering material.

iv) Compton shift depends upon scattering angle angle θ only.

v) The Compton shift increase with increase in scattering angle θ.

31. What is a matter wave? Give the properties of matter waves.

Ans:

i) In 1923, de-Broglie suggested that wave-particle duality is not restricted to radiation but must be universal. All material particles should also display a dual wave-particle behaviours.

ii) The wavelength associated with matters is called matter wave, and given by

i. $\lambda = \frac{h}{mv}$ or $\lambda = \frac{h}{p}$

Properties of matter wave:

iii) Matter's waves are produced by the motion of particles.

iv) Matter waves are independent of charge of particle

v) These waves are not electromagnetic or acoustic waves but are new kind of waves.

vi) The do not required medium to travel.

vii) The smaller the velocity of particle, longer is wavelength associated with it.

viii) The lighter the particle, the longer is the wavelength of the matter wave.

ix) The velocity of matter wave is not constant, it depends upon velocity of material particle

32. Write note on de-Broglie hypothesis and Heisenberg's uncertainty principal.

Ans:

i) de-Brogalie hypothesis: In 1923, de-Broglie suggested that wave-particle duality is not restricted to radiation but must be universal.

All material particles should also display a dual wave-particle behaviours.

The wavelength associated with matters is called matter wave, and given by

$$\lambda = \frac{h}{mv} \quad \text{or } \lambda = \frac{h}{p}$$

Where,

h is plank's constant given by h=6.63 X 10^{-34}

m is mass of the matter

v is velocity of the matter

mv=p momentum of matter

ii) Heisenberg's Uncertainty principle: According to classical physics, if the initial coordinates are known then, position and velocity of the particle can be determined exactly.

But due to dual nature of material particle, it is very difficult to locate exact position and momentum of particle simultaneously.

Heisenberg's Uncertainty principle states that, " It is not possible to know simultaneously and with exactness both position and momentum of particle."

i.e. $\Delta x.\Delta p \geq \frac{\hbar}{2} \ where\ \hbar = \frac{h}{2\pi}$

Thus uncertainty principle indicates that, the more precisely we know the position of the particle the less precise is our information about it's momentum.

consider an example in which we need to locate position of electron. To measure the position of electron, to measure a position of an electron in an atom, one must use radiation which is high enough to observe, that radiation (photon) will interact with electron and change its velocity and hence change its momentum.

To measure momentum more precisely we need to use less and less energy radiation, so electron will not deflect much, but we will not able to observe it's position.

33. If an electron placed in electric potential V, derive the de-Broglie wavelength of the electron.

Ans:

In 1923, de-Broglie suggested that wave-particle duality is not restricted to radiation but must be universal.

All material particles should also display a dual wave-particle behaviours.

The wavelength associated with matters is called matter wave, and given by

$$\lambda = \frac{h}{mv} \quad \text{or } \lambda = \frac{h}{p}$$

Let us consider the case of an electron at rest mass m_o and charge e, which is accelerated by a potential V from rest to velocity v

$$\frac{1}{2}m\mathrm{v}^2 = \mathrm{eV}$$

$$\lambda = \frac{\mathrm{h}}{\mathrm{m}}\sqrt{\frac{\mathrm{m}o}{2\mathrm{eV}}}$$

$$\lambda = \frac{\mathrm{h}}{\sqrt{2\mathrm{m}eV}}$$

$$\lambda = \frac{6.625\ \mathrm{X}10^{-34}}{\sqrt{2X\ 1.6X10^{-19}X9.1X10^{-31}X\ V}}$$

$$\lambda = \frac{12.26\ \mathrm{X}10^{-10}}{\sqrt{V}}$$

$$\lambda = \frac{12.26}{\sqrt{V}}\text{Å}$$

34. Derive the equation of de-Broglie wavelength (λ=h/p). Calculate the wavelength associated with the moving electron with the velocity 2 X 10 ^{6} ms-1.
(Given, Mass of electron m =9.1×10-31 Kg; Planck's Constant, h = 6.62607015×10^{-34} J-s)

Ans:

In 1923, de-Broglie suggested that wave-particle duality is not restricted to radiation but must be universal.

All material particles should also display a dual wave-particle behaviours.

According to Einstein's mass-energy relation,

$E = mc^2 \Rightarrow E = mc.c$

$E = p.c$

(where, c= velocity of light/Photon; p= mass X velocity=momentum)

According to plank's hypothesis, Energy E of radiation is related to packets (quanta) of energy,

$E = h\nu$

From both equations

$p.c = h\nu$

$$\frac{c}{v} = \frac{h}{p}$$

But $\frac{c}{v} = \lambda$

Therefore

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

Numerical:

Given : Velocity of electron $2 \text{ X } 10^{6}\ ms^{-1}$.

$$\lambda = \frac{h}{mv}$$

$$\lambda = \frac{6.62607015 \times 10^{-34}}{9\, X\, 10^{-31}\, X\, 2\, X\, 10^{6}}$$

$$\boldsymbol{\lambda = 3.68\, X\, 10^{-10}}\ \mathbf{m}$$

35. If an electron placed in electric potential V, derive the de-Broglie wavelength of the electron. If the voltage of 220 V is applied to the conductor, what will be the de-Broglie wavelength of the electron moving in the conducting wire?

(Given, Mass of electron m =9.1×10-31 Kg; Planck's Constant, h = 6.62607015×10−34 J-s)

Ans:

All material particles should also display a dual wave-particle behaviours.

The wavelength associated with matters is called matter wave, and given by

$$\lambda = \frac{h}{mv} \quad \text{or } \lambda = \frac{h}{p}$$

Let us consider the case of an electron at rest mass m_o and charge e, which is accelerated by a potential V from rest to velocity v

$$\frac{1}{2}m\mathrm{v}^2 = \mathrm{eV}$$

$$\lambda = \frac{\mathrm{h}}{\mathrm{m}}\sqrt{\frac{\mathrm{m}o}{2\mathrm{eV}}}$$

$$\lambda = \frac{\mathrm{h}}{\sqrt{2\mathrm{m}eV}}$$

$$\lambda = \frac{6.625\ \mathrm{X}10^{-34}}{\sqrt{2X\ 1.6X10^{-19}X9.1X10^{-31}X\ V}}$$

$$\lambda = \frac{12.26\ \mathrm{X}10^{-10}}{\sqrt{V}}$$

$$\lambda = \frac{12.26}{\sqrt{V}}\text{Å}$$

Given:

Voltage applied on electron: 220 V

$$\lambda = \frac{12.26}{\sqrt{V}}\text{Å}$$

$$\lambda = \frac{12.26}{\sqrt{220}}\text{Å}$$

$$\lambda = 0.82\ \text{Å}$$

36. If electron accelerated from 419 V to 500 V, what will be change in the de-Broglie wavelength of electron. (Given, Mass of electron m =9.1×10-31 Kg; Planck's Constant, h = 6.62607015×10−34 J-s)

Given:

Voltage applied on electron: 419 V

$$\lambda = \frac{12.26}{\sqrt{V}}\,\text{Å}$$

$$\lambda = \frac{12.26}{\sqrt{419}}\,\text{Å}$$

$$\lambda = 0.5989\ \text{Å}$$

Voltage applied on electron: 500 V

$$\lambda = \frac{12.26}{\sqrt{500}}\,\text{Å}$$

$$\lambda = 0.5482\ \text{Å}$$

$$Change\ in\ the\ wavelength\ is\ (0.5482 - 0.5989)\ \text{Å} = -\ 0.0507\ \text{Å}$$

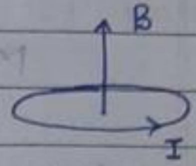
de-Broglie wavelength of electron will decrease by 0.0507 Å

Unit 5: Magnetic Materials for engineering Applications

37. What is dipole moment? Explain the sources of origin of dipole moment in materials.

Ans:

Magnetic dipole moment of a current carrying loop.



Consider a current carrying loop of cross section area A. let I be the current passing through the loop. then magnetic dipole moment of the loop is $M = I \times A$.

Origin of magnetic dipole moment or origin of magnetism.

Orbital motion of electrons:

We know that electrons in an atom revolves around the nucleus. This motion of electrons set orbital current which produce / equivalent to a current carrying loop. This current carrying loop produce magnetic dipole moment. This dipole moment is arises due to orbital motion of electron hence it is known as orbital dipole moment. The total magnetic moment of an atom is the vector sum of magnetic orbital moments of indiviual e^-s. Total magnetic moment of an atom is denoted by M_0.

Spin magnetic dipole moment: (Spin motion of electron). Every electron spin about its axis

This spin motion possesses dipole moment. This is known as spin magnetic dipole moment M_S.

Resulting net magnetic dipole moment of the atom is vector sum of M_0 and M_S.

$$M = M_0 + M_S$$

where M is net magnetic dipole moment of the atom.

Note: The origin of magnetism is spin and orbital motion of electrons. These magnetic dipole moments are responsible for magnetic properties of the materials.

38. Define the terms magnetic induction and magnetization. Obtain the expression for total magnetic induction in the material placed in external magnetic field.

Ans:

Magnetic induction: The process by which a magnetic substance acquires magnetic properties temporarily due to the presence of a magnet close to it, is known as magnetic induction.

The magnetization of a material may be defined as the net magnetic moment per unit volume of the material.

Total Magnetic Induction can derive as follow-

B= $B_o + B_m$ (1)
But
B_o= $\mu_o H$
B_m= $\mu_o \ M_z$

Where,

B= Total magnetic induction
B_m=Magnetic induction due to magnetisation
B_o= Magnetic induction in vacuum
H= Magnetic intensity
Therefore eq. 1 becomes
B=$\mu_o H$ + $\mu_o \ M_z$
B= $\mu_o(H + M_z)$
$But \ M_z$= χH
B= $\mu_o(H + \chi H)$
B= $\mu_o H(1 + \chi)$
Let, $\mu_r = 1 + \chi$
B= $\mu_r \ \mu_o H$
B= $\boldsymbol{\mu H}$

Where,
μ_o= Magnetic permeability in vacuum
μ_r= Relative permeability
χ= Magnetic susceptibility

Which is expression for Magnetic Induction.

39. Define paramagnetic substances. Give their properties.

1. Dimagnetic :

The substances which are weekly repaired by magnetic field are called as dimagnetic substances for ex: Antimony, bismatch, copper, diamond, silver, gold, etc.

Properties :

1. Diamagnetic substances are weekly repaired by magnet.
2. The magnetization is week and in the opposite direction of external magnetic field.
3. Diamagnetic arises due to orbital motion of electrons in an atom 4. In the absence of external magnetic field, the resultant magnetic moment of each atom of diamagnetic substance is zero.
5. The intensity of magnetisation is very small and negative.
6. Magnetic susceptibility is small and negative.
7. The relative permeability is slightly less than one.
8. Diamagnetic substances loss their magnetism on removal of external magnetic field

40. Define paramagnetic substances. Give their properties.

Ans.

Q. What are Paramagnetic Substances? State the properties of paramagnetic substances - 9 mk.

→ The substances which are weekly attracted by magnet are called as paramagnetic substances. for example: maganeses, chromium, platinum, aluminum, sodium etc.

Properties:

i) Paramagnetic Substances are weekly attracted by magnet.

2) These substances are weekly magnetised in the same direction of the external magnetic field.

3) Paramagnetism arises due to spin motion of electrons.

4) In the absence of external magnetic field magnetic moment of paramagnetic substances is zero.

5) The intensity of magnetisation is very small and positive.

6) The magnetic susceptibility is small and positive.

7) Relative permeability for paramagnetic substances is slightly greater than one.

8) These substances loss their magnetism on removal of external magnetic field.

9) The magnetic field lines can pass through these substances.

41. Define ferromagnetic substances. Give their properties.

Ans:

ferromagnetic substances.

Q. what are ferromagnetic substances ? state the properties of ferromagnetic substances.

→ The substance which are strongly attracted by a magnet are called as ferromagnetic substances. for example: steel, Iron, nickel, cobalt etc

Properties:

1) ferromagnetic substances are strongly attracted by magnets

2) These substances are strongly magnetised in the same direction of applied magnetic field.

3) ferromagnetism arrises due to spin - orbit interactions of ~~atoms~~ .electrons.

4) The dipole moments of ferromagnetic substances are arranged in the form of domain.

5) The intensity of magnetisation is very large and positive.

6) The magnetic susceptibility is very large and positive.

7) Relative permeability is much greater than one.

8) The magnetic field lines can pass through such substances.

9) These substances are used to build permanent magnets.

42. Define:
i) Magnetic susceptibility
ii) Permeability of free space
iii) Magnetic intensity.
Ans:

i) Magnetic susceptibility

Magnetic susceptibility is a measure of how easily a material can be magnetized in the presence of an external magnetic field. It is defined as the ratio of the magnetization of a substance to the strength of the applied magnetic field. Materials with a high magnetic susceptibility are easily magnetized and have a strong response to an applied magnetic field, while materials with a low magnetic susceptibility are less responsive.

ii)) Permeability of free space

Permeability of free space, denoted by μ0, is a fundamental constant in physics that characterizes the behavior of magnetic fields in vacuum. It is defined as the ratio of the magnetic flux density to the magnetic field strength in a vacuum. Its value is approximately 4π × 10^−7 H/m.

iii) Magnetic intensity

Magnetic intensity, also known as magnetic field strength, is a measure of the strength of a magnetic field at a given point in space. It is defined as the force exerted by a magnetic field on a unit magnetic pole placed at that point, and is measured in units of amperes per meter (A/m). Magnetic intensity is related to the permeability of the medium in which the magnetic field is present and the current flowing through a conductor that produces the magnetic field

43. **What is a magnet? Explain spin and orbital origin of magnetic moment of an electron.**

Ans:

A magnet is defined as. An object which is capable of producing magnetic field and attracting unlike poles and repelling like poles.

(For spin and orbital origin refer answer of Q. 37)

Unit 6: Crystal Structure

44. Summarize the differences between crystalline solids and amorphous solids.

Ans.

Sr. No.	**Crystalline solids**	**Amorphous Solids**
1	They have a definite characteristic geometrical shape.	They are of irregular shape.
2	They have a long range order. .	They have a short range order.
3	They have a sharp melting point	Gradually soften over a range of temperature
4	They are anisotropic in nature i.e. their physical properties show different values when measured along different directions in the same crystal.	Isotropic in nature. Isotropic means that in all the directions their physical properties will remain same.
5	When cut with a sharp edged tool, they split into two pieces and the newly generated surfaces are plain and smooth.	When cut with a sharp edged tool, they cut into two pieces with irregular surfaces.
6	They have a definite and characteristic heat of fusion.	They do not have definite heat of fusion.
7	They are called true solids.	Like liquids, amorphous solids have a tendency to flow, though very slowly. Therefore, sometimes these are called pseudo solids or super cooled liquids.
8	e.g NaCl,	Talcum powder,

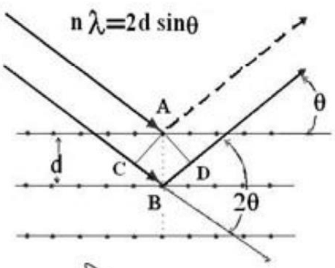
45. Show nλ=2dsinθ for X-Ray diffraction. ***OR*** **Derive Bragg's law for X-Ray diffraction.**
50. Derive Bragg's law for X-Ray diffraction.

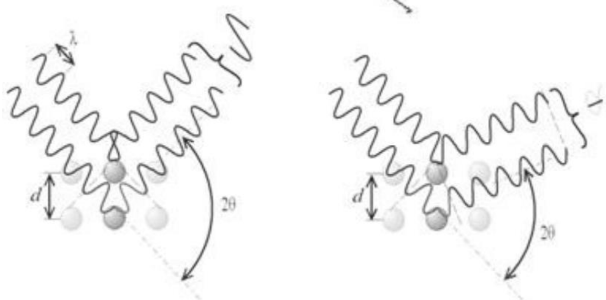
Ans.

Bragg's Law:

i) Consider a set of parallel planes called Bragg's planes. Each atom is acting as a scattering centre.

ii) The intensity of the reflected beam at certain angles will be maximum when the path difference between two reflected waves from two adjacent planes is an integral multiple of λ.





iii) Let'd' be the distance between two adjacent planes, 'λ' be the wavelength of the incident x-ray, 'θ' be the glancing angle.

iv) The path difference between the rays reflected at A & B is given by-

$$PD = CB + BD$$

$$PD = d\,sin\theta + d\,sin\theta$$

$$PD = 2dsin\theta$$

For the reflected light intensity to be maximum, the path difference is nλ where 'n' is the order of scattering.

$$2d\sin\theta = n\lambda,$$

This is called Bragg's law.

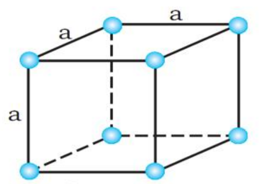
46. Draw the diagrams and write the co-ordination number of each of the following.

i. **Simple cubic structure:**

It has eight lattice point or atoms at the eight corners of the cube or unit cell. Since each corner atom is common to eight unit cells. Hence its contribution to each unit cell is 1/8.

Total contribution from all the 8 atoms at its corner to the cell is 1

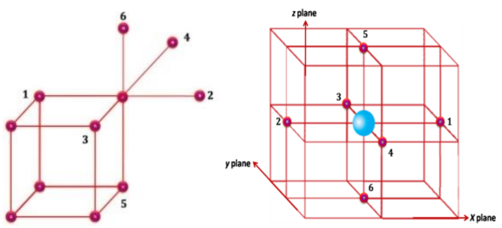
∴Total Number of atoms per unit cell=1



Primitive
(or simple)

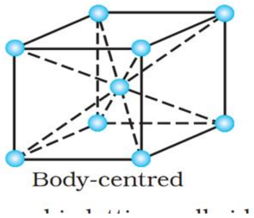
a=b=c, α=β=γ=90°

Simple cubic unit cell consists of eight corner atoms. Let us consider any of the corner atoms. The atom at the corner of the cell is surrounded by six nearest equidistant neighbours out of which four in its own plane (horizontal plane) and two are from vertical plane (above and below it). Hence the co-ordination number for an atom in simple cubic is 6.



∴ **Co-ordination Number=6**

ii. **Body cantered cubic structure**



a=b=c, α=β=γ=90º

In addition to the corner atoms, it has one atom at the body centre wholly belongs to the unit cell in which it is present. Thus in a body-cantered cubic (bcc) unit cell:

8 corners atoms per corner atom = 1 atom

1 body centre atom = 1 × 1= 1 atom

∴Total number of atoms per unit cell = 2 atoms.

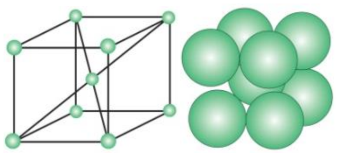
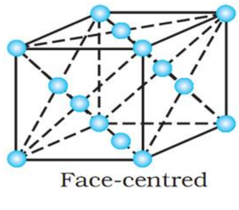


Fig.10 Co-ordination number of BCC

In BCC structure, there will be one atom at the body-centre and eight

atoms at the eight corners of the unit cell. Thus for an atom at the body centre obviously there are eight neighbours (corner atoms). Hence, the co-ordination number of an atom in body cantered cubic structure is 8.

iii. **Face cantered cubic structure**



a=b=c, α=β=γ=90º

In addition to corner atoms, it has one atom at the centre of each face which is shared by two adjoining unit cells. There are six such faces. It can be seen in Fig. that each atom located at the face-centre is shared between two adjacent unit cells and only 1/2 of each atom belongs to a unit cell.

$8 \times \frac{1}{8} = 1$ atom

6 face centred atoms × $\frac{1}{2}$ atom per unit cell= $6 \times \frac{1}{2}$ = 3 atom

∴ Total number of atoms per unit cell=4 atoms.

In FCC structure, each corner atom is in contact with face cantered atom. There are 4 such face cantered atoms in xy plane, 4 in yz plane and 4 in xz plane and total number is 12.

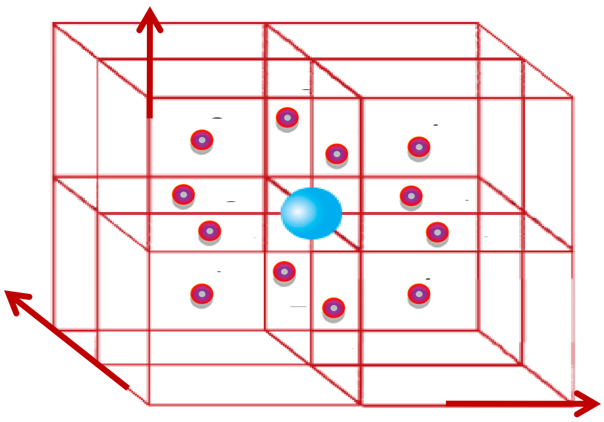


Fig.11 Co-ordination number of FCC cell

∴ **Co-ordination Number=12**

47. Summarize the important features of Miller indices with example.

Ans.

Miller indices are defined as the set of three smallest possible integers (numbers) which indicate the orientation of a plane or group of parallel planes in a crystal lattice.

Miller Indices

i) The crystal lattice may be regarded as made up of an infinite set of parallel equidistant planes passing through the lattice points which are known as lattice planes.

ii) Miller indices are defined as the reciprocals of the intercepts made by the plane on the three crystallographic axes. In simple terms, the planes passing through lattice points are called 'lattice planes'.

iii) For a given lattice, the lattice planes can be chosen in a different number of ways.

iv) The orientation of planes or faces in a crystal can be described in terms of their intercepts on the three axes. Miller introduced a system to designate a plane in a crystal.

v) Miller introduced a set of three numbers to specify a plane in a crystal.

vi) This set of three numbers is known as 'Miller Indices' of the concerned plane.

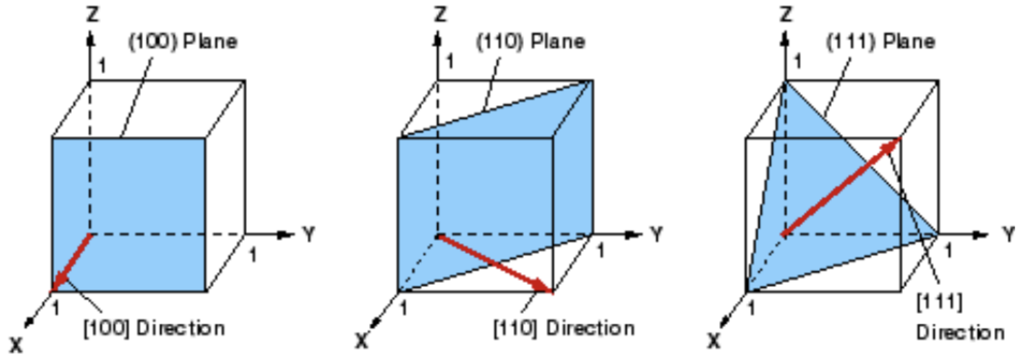
vii) Miller indices are set of three possible integers represented as (h, k, l) which is used to designate plane in the crystal, is the reciprocal of the intercept made by the planes on the crystallographic axes.

viii) For the cubic crystal especially, the important features of Miller indices are, A plane which is parallel to any one of the co-ordinate axes has an intercept of infinity (∞).

ix) Therefore the Miller index for that axis is zero; i.e. for an intercept at infinity, the corresponding index is zero.

x) Example (1 0 0) plane (plane parallel to Y and Z axes)
In the above plane, the intercept along X axis is 1 unit. The plane is parallel to Y and Z axes. So, the intercepts along Y and Z axes are '∞'. Now the intercepts are 1, ∞ and ∞. The reciprocals of the intercepts are = 1/1, 1/ ∞ and 1/ ∞. Therefore, the Miller indices for the above plane is (1 0 0).

xi) Miller Indices Of Some Important Planes:



48. What is a space lattice? Explain BCC and FCC with diagram.

Ans.

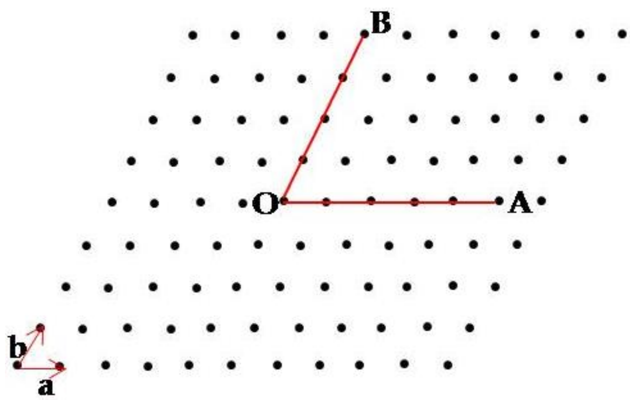
To study crystal structure, it is convenient to imagine points in space at which atoms are located.

<u>Lattice:</u>

A Lattice is an array of imaginary points that indicates the possible position of atom in the unit cell or in a crystal where the probability of finding an atom or an ion is the highest.

<u>Space Lattice:</u>

The regular three-dimensional periodic arrangement of points in a space such that environment around each point is identical is called “space lattice”.



(i) Body Cantered Cubic Structure

In addition to the corner atoms, it has one atom at the body centre wholly belongs to the unit cell in which it is present. Thus in a body-centered cubic (bcc) unit cell:

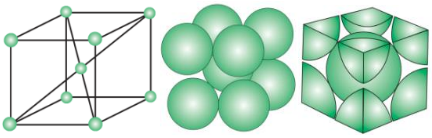


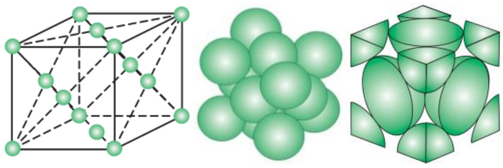
Fig.7 A body-centred cubic unit cell

8 corners atoms $\times \frac{1}{8}$ per corner atom= $8 \times \frac{1}{8}$ = 1 atom

1 body centre atom = 1 × 1= 1 atom

∴Total number of atoms per unit cell=2 atoms.

i. Face cantered cubic structure



In addition to corner atoms, it has one atom at the centre of each face which is shared by two adjoining unit cells. There are six such faces. It can be seen in Fig. that each atom located at the face-centre is shared between two adjacent unit cells and only 1/2 of each atom belongs to a unit cell.

$8 \times \frac{1}{8} = 1$ atom

6 face centred atoms × $\frac{1}{2}$ atom per unit cell= $6 \times \frac{1}{2}$ = 3 atom

∴ Total number of atoms per unit cell=4 atoms.

49. What is crystalline and non-crystalline material, give two examples each.

Ans.

i) The matter is usually regarded to exist in solid state or fluid state (liquid, gas or plasma.)

ii) All the materials are composed of atoms and molecules. A solid is an essentially an ordered array of atoms, bound together by electric forces to form a very large molecule.

iii) There are three different types of solids. Crystalline, poly crystalline and amorphous or non-crystalline solid.

iv) In a crystal, atoms are arranged into a regular periodically repeated structure that extends throughout the whole sample. The atoms are said to have long range order.

v) Poly crystalline material is composed of many small crystals or grains of somewhat irregular size.

vi) In an amorphous solid a long range order is absent. (i.e.,) they have short range order. There is no periodicity in which atoms are arranged in space. They are also regarded as super cooled liquids.

vii) Metallic crystals : copper, silver, aluminium etc.
Non metallic crystals: Germanium, silicon
Amorphous or non crystalline materials: glass, rubber, plastic