LECTURE HANDOUTS **L 01**

Physics **I/I**

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **I Acoustics & Ultrasonics** **Date of Lecture:**

Topic of Lecture: Introduction of acoustics,Classification of sound,Weber Fechner law

Introduction:

- ❖ Acoustics is a branch of physics that deals with the study of mechanical waves in gases, liquids, and solids including topics such as vibration, sound, ultrasound and infrasound.
- ❖ A scientist who works in the field of acoustics is an acoustician while someone working in the field of acoustics technology may be called an acoustical engineer.
- ❖ The application of acoustics is present in almost all aspects of modern society with the most obvious being the audio and noise control industries.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on acoustics
- Audible range of frequency

Detailed content of the Lecture:

Introduction of acoustics

- Acoustics is the science of sound which deals with origin, propagation and properties of sound waves.
- Sound is produced by a vibrating body and it cannot travel in vacuum, this requires the medium for its propagation. Sound waves are longitudinal waves in nature.
- Acoustics is defined as the “Science of sound”, Understanding sound as a mechanical disturbance in an elastic and inertial medium.
- These disturbances or oscillations of air pressure are converted into mechanical waves which excite the auditory mechanism, resulting in a perception. Sound intensity is measured in Decibels (dB).

Classification Of Audible Sound

i). Musical sound:

- They are regular in shape
- They have periodicities
- Change in amplitude is uniform

ii). Noise sound

- They are irregular in shape
- They are not periodic
- Change in amplitude is not uniform

CHARACTERISTICS OF MUSICAL SOUND

The characteristics of the musical sound are:

- **Frequency or pitch**
- Frequency is defined as the number of vibrations produced per second. Greater the frequency of a musical note, the higher is the pitch and vice versa. Frequency is a measurable physical quantity and it can be measured accurately.
- **Intensity or loudness**
- Intensity of sound wave at a point is defined as the energy flowing per second per unit area hold normally at a point to the direction of propagation of sound wave.
- **Timbre or quality**
- The quality of a sound wave is the ability to distinguish the musical notes emitted by two or more than two musical instruments, even though they have the same pitch and loudness.

WEBER-FECHNER LAW

- This law relates the intensity of sound waves with loudness.
- This law states that the sound is proportional to the logarithm of the sound intensity.
- If L is the degree of loudness due to intensity I,
- $L = K \log I$

Where, the K is a constant. Greater the intensity of sound, the loudness is greater.

Video Content / Details of website for further learning (if any):

- https://www.khanacademy.org/science/health-and-medicine/nervous-system-and-sensory-infor/sensory-perception-topic/v/webers-law-and-thresholds
- https://www.youtube.com/watch?v=1JtuksSrdhc

Important Books/Journals for further learning including the page nos.:

- G. Sudarmozhi, Engineering Physics, Sri Kandhan publications, 2005, Page no. 2.1-2.5

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LECTURE HANDOUTS

L 02

Physics

I/I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **I Acoustics & Ultrasonics** **Date of Lecture:**

Topic of Lecture: Reverberation , Reverberation time, Factors affecting acoustics of building and its Remedy

Introduction :

- When a sound is produced in a building, it persists too long after its production. The sound generated travels towards the wall, floor, ceiling etc and are reflected back. Persistence of audible sound after the source has stopped to emit sound in the hall is called reverberation.

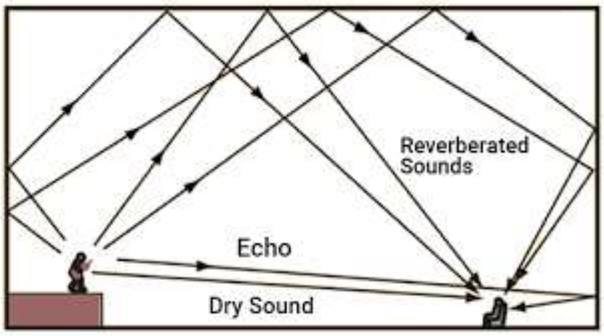
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on reverberation
- Factors controlling the reverberation time

Detailed content of the Lecture:

Reverberation

- Sound persists for some time after the original sound from the source is stopped.
- Persistence of audible sound after the source has stopped to emit sound in the hall is called reverberation.
- A listener inside the hall receives the sound till the intensity of the sound wave becomes inaudible.



Reverberation time

- The duration for which the sound persists in a hall is called reverberation time.
- The standard reverberation time is defined as the time taken by sound to fall to one millionth of its intensity just before the source is cutoff.

$$E = \frac{E_m}{10^6}$$

Where, E is the energy of the sound at any time t and E_m is the maximum sound energy produced before the source is cut off.

- The time of reverberation depends on various factors like size of the hall, loudness of the sound kind of music or the sound for which the hall is used etc.
- According to Sabine, the reverberation time is given by

$$T = \frac{0.165V}{A} \text{ seconds}$$

- Where, V is the volume of the hall and A is the total observation.
- Total absorption of any hall is given as $A = \sum as$

Factors affecting the acoustics of a building and their remedies

- **Reverberation**

  i) Providing windows and ventilators

  ii) Using curtains with full folding to increase the area

- **Loudness**

  i) Loudness can be increased by providing necessary reflecting surfaces and loud speakers wherever the loudness is insufficient.

  ii) Sound absorbing materials should be provided where the loudness is higher in the hall

- **Echoes**

  i) By providing sufficient number of doors and windows, this effect can be minimized

  ii) Providing high ceiling in a hall can reduce the effect echo

- **Echelon effect**

  i) This effect should be avoided by providing sound absorbing materials on its surface.

- **Resonance**

  i) The resonant vibrations should be avoided by maintaining the optimum level of reverberation time

  ii) This can be reduced by providing proper ventilations

- **Noises**

  i) The outside noises can be controlled by providing proper doors and windows, using double door and double walls

  ii) The noises produced inside the hall can be controlled by providing anti vibration mounts

Video Content / Details of website for further learning (if any):

- https://www.cirrusresearch.co.uk/blog/2018/04/what-is-reverberation-time-and-how-it-is-calculated/
- https://www.ques10.com/p/14361/what-is-reverberation-define-reverberation-time-ex/

Important Books/Journals for further learning including the page nos.:

- G. Sudarmozhi, Engineering Physics, Sri Kandhan publications, 2005, Page no. 2.6

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LECTURE HANDOUTS

L 03

Physics

I/I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **I Acoustics & Ultrasonics** **Date of Lecture:**

Topic of Lecture: Absorption coefficient, Measurement of Absorption coefficient

Introduction:

- The coefficient of absorption (a) of a material is defined as the ratio of sound energy absorbed by the surface to that of total sound energy incident on the surface.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on sound absorbing materials,absorption coefficient

Detailed content of the Lecture:

COEFFICIENT OF ABSORPTION (OR) ABSORPTION COEFFICIENT

- Different surfaces of an auditorium absorb sound to different extents.
- An open window transmits the entire sound energy falling on its surface where no reflection of sound is absorbed.
- In the case of material surfaces, the sound energy is partly absorbed and partly reflected.
- The coefficient of absorption (a) of a material is defined as the ratio of sound energy absorbed by the surface to that of total sound energy incident on the surface.

$$a = \frac{\text{Sound energy absorbed by the surface}}{\text{Total sound energy incident on the surface}}$$

- Since the open window is fully transmitting the sound incident on it, it is considered as an ideal sound absorber.
- Thus the unit of absorption is the open window unit (OWU) and is named as ‘sabine’ after the scientist who established the unit.

Absorption coefficient of some materials

The absorption coefficient of some of the materials is given in the table.

S. No	Materials	Absorption Coefficient/m^2
1	Open window	1.00
2	Stage curtain	0.2
3	Curtain with folds	0.4 - 0.75
4	Carpet	0.4
5	An audience	0.46
6	Perforated fiber board	0.55

Determination of absorption coefficient

- Absorption coefficient of any material can be determined by placing the material inside the room. Initially the room is kept empty and its reverberation time is assumed to be T_1.

Then $$T_1 = \frac{0.165V}{A} \quad \text{--------- (1)}$$

- Where, V is the volume of the hall and A is the total absorption inside the hall due to walls, flooring and ceiling.
- Then the sound absorbing material of area S and absorption coefficient α' is placed inside the room and again the reverberation time (T_2) is measured using the equation (2)

$$T_2 = \frac{0.165V}{A+\alpha' S} \quad \text{--------- (2)}$$

Subtracting equation (1) from Equation (2), we get

$$T_2 - T_1 = \frac{0.165V}{A+\alpha' S} - \frac{0.165V}{A}$$

$$= \frac{0.165V}{\alpha' S}$$

or $$\alpha' = \frac{0.165V}{S(T_2 - T1)} \quad \text{---- (3)}$$

Knowing the values on R.H.S of equation (3), the absorption coefficient α' of the material under test can be calculated.

Video Content / Details of website for further learning (if any):

- https://www.pveducation.org/pvcdrom/pn-junctions/absorption-coefficient
- http://www.acoustic-glossary.co.uk/sound-absorption.htm

Important Books/Journals for further learning including the page nos.:

- G. Sudarmozhi, Engineering Physics, Sri Kandhan publications, 2005, Page no. 2.9-2.12

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Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **I Acoustics & Ultrasonics** **Date of Lecture:**

Topic of Lecture: Introduction to Ultrasonics and properties

Introduction :

- Ultrasonic wave has different properties for example, ultrasonic waves produce stationary wave pattern in the liquid while passing through it.
- These waves can be detected by various methods and will be discussed

Prerequisite knowledge for Complete understanding and learning of Topic:

- Knowledge on properties of ultrasonic waves
- Methods on detection of ultrasonic waves

Detailed content of the Lecture:

Introduction to Ultrasonics

- Human ear is capable of receiving the sound waves with frequency range of 20Hz to 20,000Hz.
- The frequency ranges below 20Hz and above 20,000Hz are inaudible to human being.
- Based on the frequency, sound waves are generally classified into three types:

    i) Infrasonic waves

    ii) Audible range of frequency and

    iii) Ultrasonic waves
- The sound waves having frequency below 20Hz are called infrasonic sound.
- The sound waves having frequency 20Hz to 20000 Hz are said to be audible sound.
- The sound waves having frequency more 20000 Hz are called ultrasonic waves.

Properties of ultrasonic waves

- They are highly energetic
- They are longitudinal in nature
- Ultrasonic waves undergo reflection, refraction and diffraction like sound waves
- When ultrasonic waves passed through the liquids, stationary wave patterns are produced and it behaves as **acoustical grating element**
- When an object is exposed to ultrasonic for longer time it produces heating effect

- By increasing the frequency of ultrasonic waves, energy can be increased
- They produce cavitation effect in liquids
- They can travel over long distances without any loss of energy
- Ultrasonic waves are high frequency and high energetic sound waves.
- Ultrasonic waves produce negligible diffraction effects because of their small wavelength.
- Ultrasonic wave travels longer distance without any energy loss.
- The speed of propagation of ultrasonic waves increases with the frequency of the waves.
- At room temperature, ultrasonic welding is possible.
- Ultrasonic waves produce cavitation effects in liquids.
- Ultrasonic waves produce acoustic diffraction in liquids.
- Ultrasonic waves cannot travel through the vacuum.
- Ultrasonic waves travel with speed of sound in a given medium.
- Ultrasonic waves require one material medium for its propagation.
- Ultrasonic waves can produce vibrations in low viscosity liquids.
- Ultrasonic waves produces heat effect passes through the medium.
- Ultrasonic waves obey reflection, refraction, and absorption properties similar to sound waves.
- When the ultrasonic wave is absorbed by a medium, it generates heat. They are able to drill and cut thin metals.

Video Content / Details of website for further learning (if any):

- http://www.vidyarthiplus.in/2011/11/engineering-physics-1-ultrasonics.html
- https://www.youtube.com/watch?v=hivv2hgqDvk

Important Books/Journals for further learning including the page nos.:

- G. Sudarmozhi, Engineering Physics, Sri Kandhan publications, 2005, Page no. 2.8-2.9

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LECTURE HANDOUTS

L 05

Physics

I/I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **I Acoustics & Ultrasonics** **Date of Lecture:**

Topic of Lecture: Detection of ultrasonic waves, Magnetostriction effect - Magnetostriction generator

Introduction :

When an alternating magnetic field is applied to a bar of ferromagnetic materials, it undergoes a change in dimension there by producing ultrasonic waves at resonance is called **Magnetostriction effect (or) Magnetostriction principle.**

Prerequisite knowledge for Complete understanding and learning of Topic:

- Magnetostriction effect
- Construction working of Magnetostriction generator

Detailed content of the Lecture:

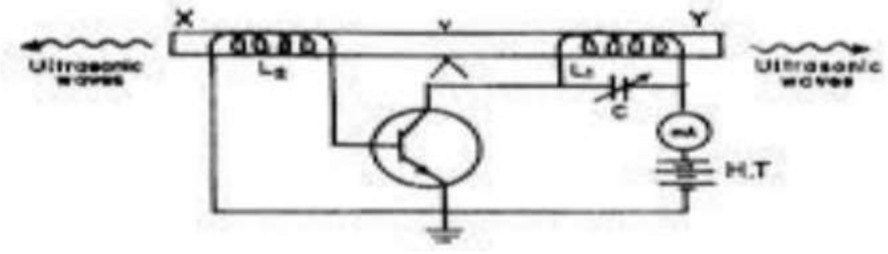
Detection of ultrasonic waves

- The presence of ultrasonic waves can be detected by the following methods.
- Piezo electric method,Kundt's tube method,Sensitive flame method,Thermal method

Magnetostriction effect

- When a bar of ferromagnetic material, like nickel, cobalt etc. is placed in an alternating magnetic field parallel to its length, it undergoes slight change in dimension.
- This change in length is independent of the field and may be decreased or increased depending on the materials.
- With high frequency alternating magnetic field, the bar contracts and expands alternatively and begins to vibrate to and fro and producing ultrasonic waves at its ends.

Magnetostriction generator



Magnetostriction oscillator

Working

- The battery is switched on and hence current is produced by the transistor. This current is passing through the coil L which in turn causes magnetic effect over the rod.
- Because of the magnetic effect, the rod starts vibrating due to magnetostriction effect. When the rod is vibrating, an e.m.f is induced in the coil L_1..
- The induced e.m.f. is fed into the base of the transistor which acts as a feed back for the circuit. In this way, the current in the transistor is built up and the vibration of the rod is maintained.
- The frequency of the oscillatory circuit is adjusted by the variable capacitor C.
- **When the frequency of the oscillatory circuit becomes equal to the natural frequency of the rod, resonance effect occurs.** At the resonance condition, the rod vibrates with larger amplitude, producing high frequency ultrasonic waves at both the ends of the rod.
- The frequency of the oscillatory circuit is given as

$$\frac{1}{2\pi\sqrt{LC}}$$

- The natural frequency of the ferromagnetic rod is given as

$$\frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

Where l is the length of the rod,E is the Young's modulus of the rod and ρ is the density of material of the rod

The ultrasonic waves are produced when,

The frequency of the oscillatory circuit = The natural frequency of the rod

$$\frac{1}{2\pi\sqrt{LC}} = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

Advantages

- The design of the oscillatory circuit is very simple and its production cost is low
- At low frequencies, large power output is possible without causing any damage to the oscillatory circuit

Disadvantages

- It can produce frequencies up to 3MHz only
- The frequency of oscillations depends on the temperature
- As the frequency is inversely proportional to the length of the rod, the length of the rod should be decreased to increase the frequency which is practically impossible.

Video Content / Details of website for further learning (if any):

- https://www.brainkart.com/article/Magnetostriction-Method--Principle,-Construction,-working,-Advantages-and-Limitations_6871/
- https://www.youtube.com/watch?v=Kb_uB3GXGwg

Important Books/Journals for further learning including the page nos.:

- G. Sudarmozhi, Engineering Physics, Sri Kandhan publications, 2005, Page no. 2.20-2.22

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LECTURE HANDOUTS

L 06

Physics

I/I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **I Acoustics & Ultrasonics** **Date of Lecture:**

Topic of Lecture: Piezoelectric effect - piezoelectric generator,

Introduction :

- The piezoelectric effect was discovered in 1880 by two French physicists, brothers Pierre and PaulJacques Curie, in crystals of quartz, tourmaline, and Rochelle salt (potassium sodium tartrate).
- This phenomenon is observable in many naturally available crystalline materials, including quartz, Rochelle salt and even human bone.

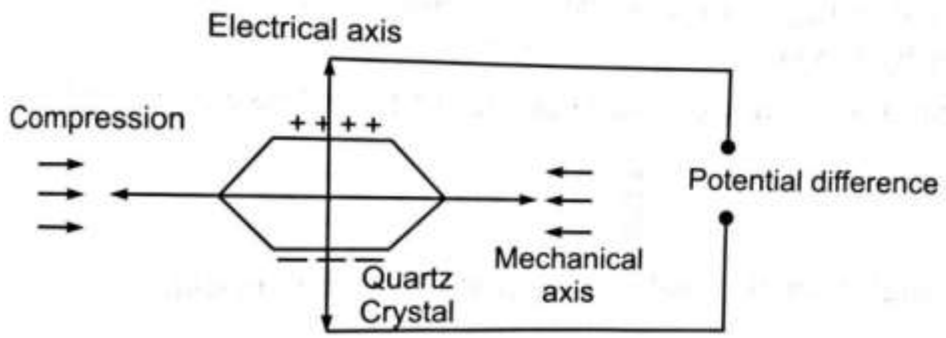
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on piezoelectric effect
- Piezoelectric generator

Detailed content of the Lecture:

Principle

- When a crystal like (calcite or quartz) under goes mechanical deformation along the mechanical axis then electric potential difference is produced along the electrical axis perpendicular to mechanical axis. This phenomenon is known as piezoelectric effect.



- The converse of the effect is also possible.
- When an alternative potential is applied along the electrical axis, the crystal will set into electric vibrations along the mechanical axis.
- If the frequency of the crystal is equal to the natural frequency of the crystal, it vibrates with larger amplitude producing ultrasonics.

- The quartz crystal between the metal plates is connected to collector and base of transistor.
- Collector is also connected to LC circuit and high tension source shunted a by pass capacitor $C_{b.}$
- C_b is used to stop high frequency currents from passing through battery.
- The capacity of variable capacitor is adjusted so that the frequency of the oscillating circuits is
- equal to the natural frequency of the crystal. R_g provided necessary biasing for base and emitter circuit.
- When the circuit is starts functioning slowly an alternative potential difference is built across the quartz crystal which sets the crystal into vibrations.
- By varying the capacitor of capacitor C, at a particular stage the frequency of the alternating potential across the crystal coincides with the natural frequency of the quartz crystal it to produce ultrasonic waves.
- This stage is indicated by milli ammeter by showing maximum current.
- The natural frequency of quartz crystal of thickness t is given by

$$f = \frac{n}{2t}\sqrt{\frac{y}{\rho}}$$

- Where y is young's modulus and ρ is the density of crystal

Video Content / Details of website for further learning (if any):

- https://www.youtube.com/watch?v=4nbBAG-848c
- https://www.youtube.com/watch?v=fHp95e-CwWQ

Important Books/Journals for further learning including the page nos.:

- G. Sudarmozhi, Engineering Physics, Sri Kandhan publications, 2005, Page no. 2.14-2.16

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LECTURE HANDOUTS

L 07

Physics

I/I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **I Acoustics & Ultrasonics** **Date of Lecture:**

Topic of Lecture: Cavitation ,SONAR

Introduction:

- In general, cavitation is the phenomenon where small and largely empty cavities are generated in a fluid, which expand to large size and then rapidly collapse. When the cavitation bubbles collapse, they focus liquid energy to very small volumes.
- Sonar is based on the echo-sounding technique of ultrasound. When an ultrasonic wave is transmitted through water, it is reflected by the objects in the water and will produce an echo signal

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on SONAR
- Basic knowledge on Cavitation

Detailed content of the Lecture:

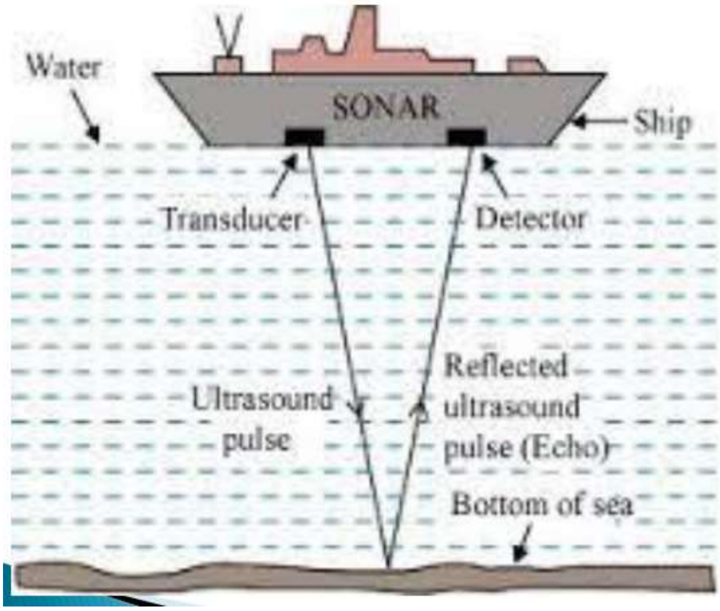
Cavitation

- In a liquid, the bubbles in the order of 10^{-9} to 10^{-8} m sizes are always present.
- The decrease in pressure above the liquid causes evaporation in the bubbles and leads to their growth.
- The growth of bubble leads to their collapse with in few milliseconds and release very large amount of pressure and temperature.
- During the collapse of the bubble, temperature of the gas within the bubble is increases abruptly at about 10, 000°C.
- Ultrasonic waves while passing through the liquid medium induce compression and rarefaction and create millions of microscopic low pressure bubble.
- A negative local pressure at the rarefaction causes local boiling of the liquid accompanied by the bubble growth and it gets collapse. This phenomenon is known as cavitation.
- Cavitation is the process of creation and collapse of bubbles due to negative local pressure created inside the bubble.

SONAR

- Sonar is based on the echo-sounding technique of ultrasound.
- When an ultrasonic wave is transmitted through water, it is reflected by the objects in the water and will produce an echo signal.
- By noting the time interval between the generation of the ultrasonic pulse and the reception of the echo signal (t), the depth of the object can be easily calculated.

- Since the ultrasonic velocity “v’ in sea water is known, the depth of sea is calculated as follows Depth of sea (distance between surface and bottom of the sea) = vt/2



- The same procedure is also used to find the distance of submarine or iceberg from the surface of the sea and the distance between two ships in the sea.

Video Content / Details of website for further learning (if any):

- https://www.youtube.com/watch?v=4nbBAG-848c
- https://www.youtube.com/watch?v=fHp95e-CwWQ

Important Books/Journals for further learning including the page nos.:

- G. Sudarmozhi, Engineering Physics, Sri Kandhan publications, 2005, Page no. 2.16-2.20

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LECTURE HANDOUTS | **L 08**

Physics | **I/I**

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **I Acoustics & Ultrasonics** **Date of Lecture:**

Topic of Lecture: Non Destructive Testing pulse echo system and through transmission

Introduction:

- Non-destructive testing defines and locates flaws within a material without destroying or defacing the product.
- Ultrasonic non-destructive testing is one of the major tests to find out the defects, cracks and discontinuities in a medium.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on NDT and its applications

Detailed content of the Lecture:

Non-Destructive Testing

- Ultrasonic energy striking at an interface of two different materials is partially reflected and partially transmitted.
- The transmitted energy in the medium is utilized for the inspection purpose.
- Depends on the information required, a number of techniques are used for the ultrasonic inspection. Some of the important testing techniques are,
  1) Pulse-echo method,2)Through transmission method and 3)Resonance method.

Pulse-echo method

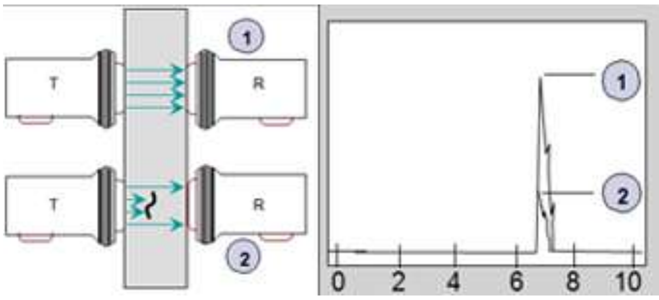
- In this method, high frequency ultrasonic waves are generated with the help of piezoelectric crystal and transmitted into the material under testing.
- The principle of reflection of ultrasonic waves at the interface of two different media is used in this method.
- The reflected sound waves are received by the transducers and converted into electrical energy.
- If the material does not have any flaws inside, the pulses produced in the CRO is as shown in the Figure.
- Two pulses, one is due to the reflection at the front surface and the other is due to the reflection at the back surface of the material are produced.

- If the material has a flaw in the path of ultrasonic waves, one additional reflection is produced as shown in the Fig. It shows that there is an acoustical impedance mismatch in the path of ultrasonic waves.
- Using the amplitude and time of travel through the material, the length of the specimen or the distance at which the flaw is located can be determined.

- In this method a single transducer can be used to transmit and receive the signals.

Through transmission method

- In this method two transducers are used in which one acts as transmitter (T) and the other acts as a receiver (R).
- The transmitter and receiver are connected in the opposite sides of the specimen which is under testing.
- The ultrasonic beam from the transmitter travel through the material to the opposite face and is received by a receiver.
- The received ultrasonic waves are converted into electrical pulses and then fed into the CRO.
- Any defect in the path of the ultrasonic beam can produce reduction of sound energy reaching the receiver.



- The material with no defect produces the pulses of same height in the CRO as shown in Figure. The existence of flaw in the material can be identified by reduction of sound energy (smaller pulse) as shown in Figure.
- Thus the defects presents inside the material can be studied using this method.
- The main disadvantage of this system is it does not give the information about exact size and location of the defect. It is useful for the inspection of large castings and where the gross defects are present.

Video Content / Details of website for further learning (if any):

- http://dx.doi.org/10.6028/NBS.TN.1199
- https://ndt-testing.org/our-services/ultrasonic-testing-pulse-echo-method/
- https://www.google.com/search?q=pulse-echo+method+pdf&sa=X&ved=2ahUKEwjSm_SUzMfoAhX0wjgGHRaUATQQ1QIoAXoECAwQAg

Important Books/Journals for further learning including the page nos.:

- G. Sudarmozhi, Engineering Physics, Sri Kandhan publications, 2005, Page no. 2.29 and 2.23

Course Faculty

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LECTURE HANDOUTS

L 09

Physics

I/I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **I Acoustics & Ultrasonics** **Date of Lecture:**

Topic of Lecture: Non Destructive Testing resonance method

Introduction:

- Non-destructive testing defines and locates flaws within a material without destroying or defacing the product. Ultrasonic non-destructive testing is one of the major tests to find out the defects, cracks and discontinuities in a medium.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on NDT and its applications

Detailed content of the Lecture:

- Non-destructive testing defines and locates flaws within a material without destroying or defacing the product.

Important testing techniques

- **Pulse-echo method**
- **Through transmission method**
- **Resonance method**

Resonance method

- The system consists of a transducer which is connected to the specimen and a CRO with transmitting and receiving signals.
- The transducer produces an ultrasonic wave (longitudinal wave) which is transmitted through the specimen. These waves get reflected between the opposite faces of a specimen. The probe is moved on the surface of the material to study the resonant frequency.
- The frequency of this longitudinal wave is varied continuously till the standing waves are setup in the material. Standing waves are created by adjusting the frequency of the ultrasonic waves.
- The frequency of the longitudinal wave is varied continuously till the standing waves are setup in the material. Standing waves are created by adjusting the frequency of the ultrasonic waves.
- Due to the formation of standing waves inside the specimen, the material vibrates at its resonance frequency with maximum amplitude.

- When the probe is moved on the surface, if a change of resonant frequency is observed, it is due to the presence of discontinuity only.
- Knowing the frequency at resonance ‘f ’ and velocity of the ultrasonic wave in the test piece ‘v’, the thickness ‘t’ can be calculated from the relation,

$$T=v/2f$$

Video Content / Details of website for further learning (if any):

- http://dx.doi.org/10.6028/NBS.TN.1199
- https://ndt-testing.org/our-services/ultrasonic-testing-pulse-echo-method/
- https://www.google.com/search?q=pulse-echo+method+pdf&sa=X&ved=2ahUKEwjSm_SUzMfoAhX0wjgGHRaUATQQ1QIoAXoECAwQAg

Important Books/Journals for further learning including the page nos.:

- G. Sudarmozhi, Engineering Physics, Sri Kandhan publications, 2005, Page no. 2.30-2.35

Course Faculty

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Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **II Lasers** **Date of Lecture:**

Topic of Lecture: Introduction, Principle of spontaneous emission and stimulated emission.

Introduction :

- Lasers are optical phenomena used in the field of science and technology now a day.
- Laser is an acronym for ***Light Amplification by Stimulated Emission of Radiation***.
- Laser is an extended Maser principle of frequency range 10^{14}Hz-10^{15}Hz in the visible region.
- Due to its remarkable properties, it is used in telecommunications, computers and nuclear reactions and plays a vital roll in medicine for surgery.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on properties and propagation of Light
- Basic knowledge in Electronic energy level.

Detailed content of the Lecture:

Characteristics of Lasers

1. Monochromatic

- The laser light is highly monochromatic (***having single frequency***) than any other light sources.
- The light from the conventional source spreads over wider range of frequencies.
- The line width Δλ emitted by a laser is nearly 5×10^{-4} Å but it is only 10^{-5} for a conventional source.

2. Coherence

- It is an important characteristic of a laser beam. The wave trains are said to be coherent when they are having ***same frequency and phase*** that gives high purity of spectral line.
- Due to this coherence property, it is possible to create high power laser in the order of 10^{13}W of 1μm diameter.

3. Intensity

- The intensity of laser light is very high.

- 1watt laser is many thousand times more intense than 10watt ordinary light.

- Since the beam spread of the laser is very smaller, a narrow beam of light with high energy is concentrated in a smaller region. This concentration of light beam is expressed in terms of intensity.

4. Directionality

- The ordinary light source emits light in all directions due to ***spontaneous emission***.
- On the other hand, laser emits light only in one direction due to ***stimulated emissions***.
- Ordinary light spreads in all directions with an angular spread of 1m/metre, whereas in laser it is highly directional with a beam spread of 1mm/metre.
- i.e., laser beam can be focused to very long distance with smaller angular spread.

Spontaneous emission

- An atom in the excited state is returns to ground state by emitting a single photon without any external inducement.
- The emitted photons move in all directions and are random.
- The radiation of light is less intense, polychromatic and incoherent
- Angular spread is more

Stimulated emission.

- An atom in the excited state is forced to go to ground state, resulting in two photons of same frequency and energy.
- The emitted photons move in a single direction and are directional.
- The radiation of light is highly intense, monochromatic and coherent
- Angular spread is less

Video Content / Details of website for further learning (if any):

https://spie.org/publications/fg12_p02_spontaneous_and_stimulated_emission?SSO=1

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.5.2-5.77

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LECTURE HANDOUTS

L 11

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **II Lasers** **Date of Lecture:**

Topic of Lecture: Population inversion and pumping methods

Introduction :

- Increasing the population of atoms in the higher energy level is essential for laser action. This can be achieved by the different types of pumping methods. Pumping method is the transfer of atoms from lower energy level to higher energy level.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on properties and propagation of Light

Detailed content of the Lecture:

Population inversion

- Consider two energy level systems E_1 and E_2. Normally the number of atoms (population) presents in the ground state N_1 is higher than the number of atoms in the excited state N_2.

  i.e., $N1 > N_2$.

- The process of making the number of atoms in the excited state higher than that of the ground state is called ***Population inversion (or) Inverted population***.

  i.e., $N_2 > N_1$

- The condition of population inversion is necessary for achieving the stimulated emission of radiation.

Condition for population inversion

- There must be at least a pair of energy levels separated by a desired radiation
- There must be a source to supply energy to the medium
- The atoms must be raised continuously to the exited state

- The process of raising the atoms from ground state to excited state by artificial means is called Pumping process.
- Optical pumping
- Electric discharge method pumping
- Inelastic collision between atoms
- Direct pumping

Video Content / Details of website for further learning (if any):

https://www.physics-and-radio-electronics.com/ physics/laser/ methodsofachievingpopulationinversion.html

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.5.7-5.10

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L 12

PHYSICS

I / I

Course Name with Code : **Engineering Physics /21BSS01**

Course Faculty :

Unit : **II Lasers** **Date of Lecture:**

Topic of Lecture: Einstein's A and B coefficients derivation

Introduction :

Laser makes use of three fundamental phenomena named,

1) Process of absorption
2) Spontaneous emission and
3) Stimulated emission

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on properties and propagation of Light

Detailed content of the Lecture:

1. Process of absorption

i) Number of atoms in the ground state (N_1)

ii) Energy density of incident radiation (Q)

$$N_{ab} = B_{12}N_1Q$$

2. Spontaneous emission

During the downward transition the atoms in the excited energy state return to the ground state spontaneously by emitting their excess energy '$h\nu$' as shown in Fig.4.3. This process is ***independent of external radiation*** and is called ***spontaneous emission***. The rate of spontaneous emission (N_{sp}) is depends on the number of atoms in excited state (N_2) only.

i.e,

$$N_{sp} = A_{21}N_2$$

Where A_{21} is the probability transition from energy level E_2 to E_1

3. Stimulated emission

The rate of stimulated emission (N_{st}) is depends on

i) The number of atoms in the excited state (N_2)and

ii) The energy density of incident radiation (Q)

$$N_{st} = B_{21}N_2Q$$

Where, B_{21} is the probability of transition of atoms moving from E_2 to E_1 by stimulation. Under equilibrium condition, the number of upward transitions must be equal to number of downward transitions.

$$B_{12}N_1Q = A_{21}N_2 + B_{21}N_2Q$$

According to Boltzman's distribution law,

$$\frac{N_1}{N_2} = e^{(E_2 - E_1)/kT} = e^{h\nu/kT}$$

$$Q = \frac{A_{21}/B_{21}}{\left(\frac{B_{12}}{B_{21}}\right)e^{h\nu/kT} - 1}$$

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}$$

Video Content / Details of website for further learning (if any):

https://sites.google.com/site/puenggphysics/home/unit-i/relation-between-einstein-s-a-and-b-coefficient

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.5.3-5.6

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LECTURE HANDOUTS

L 13

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **II Lasers** **Date of Lecture:**

Topic of Lecture: Types of lasers - He-Ne laser

Introduction :

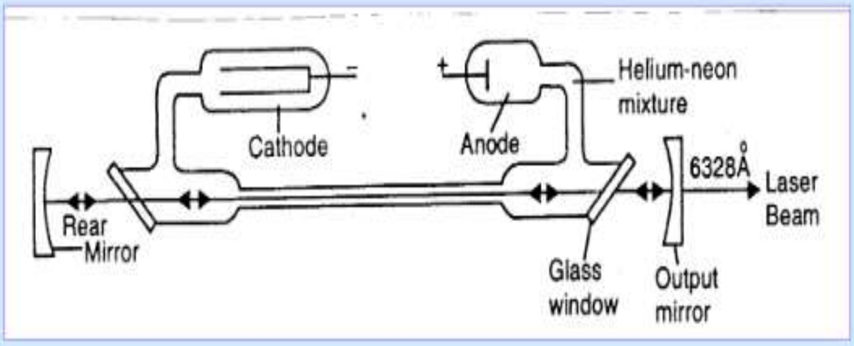
- In the mixture of helium and neon gases, He atoms are excited by electric discharge method.
- Excited He atoms collides with Ne atoms and raised it to higher energy level.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on properties and propagation of Light

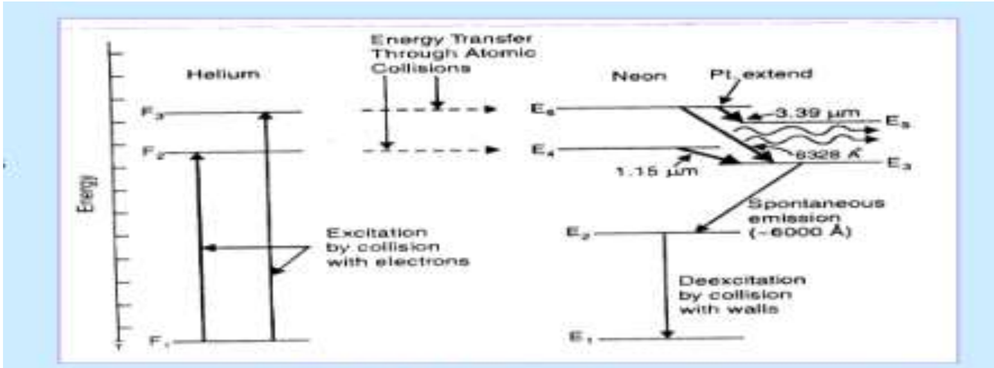
Detailed content of the Lecture:

- Consist of gas discharge tube made of quarts with 80 cm long and 1.5 cm width.
- The discharge tube is filled with themixture of neon at 0.1mm of mercury pressure and He at 1 mm of mercury pressure as active medium.
- The ratio of He-Ne mixture is 10:1
- He has the majority and Ne has the minority atoms



Schematic of a He-Ne laser with external mirrors

- The excited helium atoms transfer their energy to the neon atoms in the ground state by resonance collision method.
- Ne atoms are raised to the excited state E4 and E6
- When the population of the neon atoms in the energy level f4 and f6 becomes dominant, the stimulated emission starts.
- Release of laser of wavelength (E6 → E3) 6328
- E6 → E5: 3.29



Energy levels of He and Ne atoms and transitions between the levels.

Video Content / Details of website for further learning (if any):

[https://www.physics-and-radio-electronics.com/ physics/laser/ methodsofachievingpopulationinversion.html](https://www.physics-and-radio-electronics.com/physics/laser/methodsofachievingpopulationinversion.html)

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.5.15-5.19

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Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **II Lasers** **Date of Lecture:**

Topic of Lecture: Nd-YAG laser

Introduction :

Yittrium Aluminum Garnet crystal doped with Neodymium is used as an active medium. The neodymium ions are excited to higher energy level by optical pumping and fall back to metastable state spontaneously. During the downward transition from metastable state to ground state, laser is emitted by stimulation.

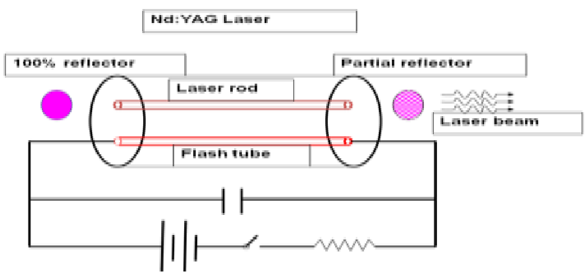
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on properties and propagation of Light

Detailed content of the Lecture:

Construction

It is a four level doped insulator laser. Nd–YAG crystal is an active medium in which few of the Yittrium ions are replaced by Neodymium ions. The length of the crystalline rod varies from 5-10cm and diameter varies from 6-9mm. Nd–YAG crystalline rod along with the source say xenon or krypton lamp is placed inside a highly elliptical reflector cavity.

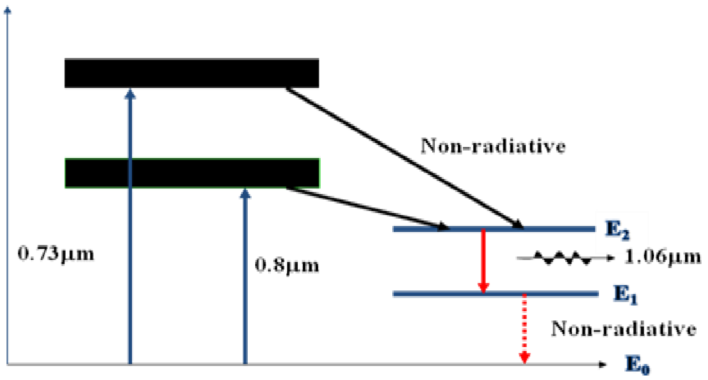


This makes the entire radiation from flash lamp to focus on Nd–YAG rod. The optical resonator is formed by using two reflecting plates highly polished and parallel in which one is fully reflecting and the other is partially reflecting.

- **Working**

The flash lamp is switched on and the light is allowed to fall on the rod. The neodymium atoms are pumped to higher energy levels E_2 and E_3 from E_1 as shown in Fig 4.7. From these higher excited energy levels, the atoms make non radiative transitions to metastable state E_4 and then the population inversion is achieved (i.e, E_4 becomes more populated) within few milliseconds. Then the stimulation starts and the stimulated emission is dominating between the energy levels E_4 and E_5.

These stimulated photons undergo multiple reflections between the parallel plates and the energy increases abruptly. After reaching sufficient energy the laser beam is emerging out of partially reflecting plate with a wave length of 1.06μm.



Video Content / Details of website for further learning (if any):

https://www.physics-and-radio-electronics.com/ physics/laser/ methodsofachievingpopulationinversion.html

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.5.13-5.15

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LECTURE HANDOUTS

L 15

PHYSICS

I / I

Course Name with Code : **Engineering Physics /21BSS01**

Course Faculty :

Unit : **II Lasers** **Date of Lecture:**

Topic of Lecture: Semiconductor lasers (homojunction & heterojunction)

Introduction :

A p-n junction made of same material with two different conducting regions say n-type and p-type is called as homojunction. The homojunction devices are lacking in carrier containment and hence, it is an insufficient light source. The devices like LED are fabricated with homojunction diode laser.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on properties and propagation of Light

Detailed content of the Lecture:

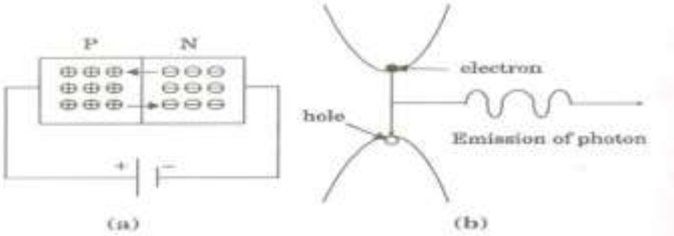
4.7.3.1 Homojunction Semiconductor laser

A p-n junction made of same material with two different conducting regions say n-type and p-type is called as homojunction. The homojunction devices are lacking in carrier containment and hence, it is an insufficient light source. The devices like LED are fabricated with homojunction diode laser.

- **Principle**

When p-n junction is forward biased, the holes are moving towards ‘n’ region and electrons are moving towards ‘p’ region. The recombination of charge carrier takes place in the junction region which results laser radiation.

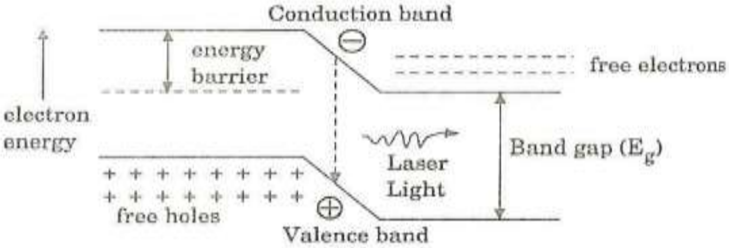
It is most compact of all lasers and also called ***injection laser***. The p-n junction diode of a single crystalline material (Eg: Gallium arsenide) is acts as an active medium. Gallium arsenide is a direct band gap semiconductor used for laser action. The indirect band gap semiconductors namely silicon and germanium are not used for laser action. The p and n regions of gallium arsenide is highly doped with holes and electrons respectively.



The thickness of junction layer is very narrow so that radiation has large divergence. The faces of p and n regions at the junction region are made parallel and well polished. This plays a roll of optical resonator. The upper and lower electrodes connected with p and n regions helps for the supply of current to the diode.

- **Working**

The population inversion is achieved by injecting the charge carriers across the junction region by forward biasing. For direct recombination process, the current in the order of 10^4 ampere/cm^2 is passed through the electrodes. The photons are emitted during recombination of electrons and holes and the rate of recombination increases. The emitted photons from recombination process are having the same phase and frequency as that of original inducing photons and will be amplified to get a beam of laser.



Video Content / Details of website for further learning (if any):

https://www.physics-and-radio-electronics.com/ physics/laser/ methodsofachievingpopulationinversion.html

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.5.19-5.24

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L 16

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **II Lasers** **Date of Lecture:**

Topic of Lecture: Industrial Applications - Lasers in welding, cutting, heat treatment

Introduction :

- laser beams are widely used in many fields of science, engineering and medicine.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on properties and propagation of Light

Detailed content of the Lecture:

- **Laser in welding**

High power lasers are generally used for laser welding and cutting. In an ordinary welding process heat is induced on the area being welded, so that the material in that area will go to molten state. The heat will spread all over the surrounding and hence it damages the material. While using the laser, due to high directionality, it is concentrated at the particular area without affecting its surrounding.

The metal plates to be welded are in contact at their edges and the laser beam is made to move along the line of contact. This high directional, concentrated laser beam heats the edges of the plate and melts, which causes the plate to fuse together.

- **Lasers in cutting and drilling**

Powerful lasers are required for cutting the materials. The power required is depending on the material being cut. The energy must be supplied in such a way that rapid evaporation of material takes place without diffusion of heat into work piece.

- **Laser heat treatment**

This kind of treatment is used for altering the compositions and microstructure of surface layers and thereby improving the surface hardness.

The powerful laser beam is made to fall on the surface of the material. The portion which is exposed to the laser beam gets heated. When the beam is moved over the surface of the material the heated spot cools down rapidly. While moving the laser over entire surface of the material the strength of the material is enhanced by the method called ***quenching***.

- **Medical applications**
- Laser is widely used in surgery in the treatment of detached retina
- It finds applications in bloodless micro surgery
- **Lasers in microelectronics**

Microelectronics is related to the study and manufacture of very small electronic components. These devices are made from semiconductors with the help of lasers using a process called ***photolithography*.** Laser is used in the fabrication process of microelectronic component due to its unique characteristics.

- **Industrial applications**
- Lasers are used in material processing
- Lasers are used in printing and jewelry industry
- **Communication and engineering applications**
- Lasers have wider applications in connection with optical fiber

Video Content / Details of website for further learning (if any):

https://www.physics-and-radio-electronics.com/ physics/laser/ methodsofachievingpopulationinversion.html

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.5.25-5.28

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LECTURE HANDOUTS

L 17

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **II Lasers** **Date of Lecture:**

Topic of Lecture: Medical applications of lasers
Introduction : • laser beams are widely used in many fields of science, engineering and medicine.
Prerequisite knowledge for Complete understanding and learning of Topic: • Basic knowledge on properties and propagation of Light
Detailed content of the Lecture: **. Medical applications** ▪ Laser is widely used in surgery in the treatment of detached retina ▪ It finds applications in bloodless micro surgery ▪ Lasers are used in cancer treatment and in the treatment of brain tumors ▪ The availability of optic fibers permitted the combination of laser technology with endoscop
Video Content / Details of website for further learning (if any): https://www.physics-and-radio-electronics.com/ physics/laser/ methodsofachievingpopulationinversion.html
Important Books/Journals for further learning including the page nos.: 5.27

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LECTURE HANDOUTS

L 18

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **II Lasers**

Date of Lecture:

Topic of Lecture: Holography (construction & reconstruction)

Introduction :

- The **hologram** acts as a diffraction grating and secondary waves from **hologram** interferes constructively in certain directions and destructively in other directions. They form a real image in front of the **hologram** and a virtual image behind the **hologram** at the original site of the object.

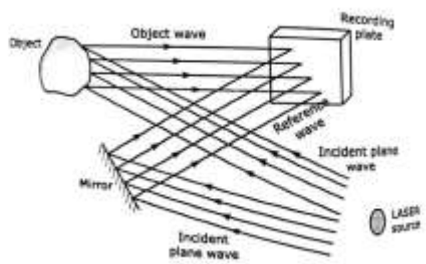
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on properties and propagation of Light

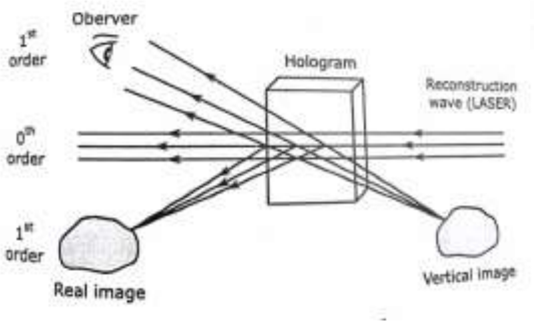
Detailed content of the Lecture:

- **construction of image(freezing)**

A weak but broad beam of laser light is splitted into wo beams by means of beam splitter. One beam directly goes to the photographic film is called as reference beam and second beam illuminates the object called as object beam. The light scattered by the object moves towards the photographic plate and interferes with the reference beam. The photographic plate carrying complex interference pattern of the object is called hologram.



- .**Reconstruction (unfreezing):** A laser beam identical to the reference beam is used for reconstruction of the object. This read out bream illuminates the hologram at the same angle as the reference beam. The hologram acts as a diffraction grating and secondary waves from hologram interferes constructively in certain directions and destructively in other directions. They form a real image in front of the hologram and a virtual image behind the hologram at the original site of the object. An observer sees light waves diverging from the virtual image. An image of the object appears where the object once stood and the image is identical to what our eyes would have perceived in all its details of the object.



Application:

- Hologram is reliable medium for data storage
- Hologram is used in concerts
- Hologram are used for authentication
- Holograms are used in exhibitions to avoid possible thefts.

Video Content / Details of website for further learning (if any):

https://www.physics-and-radio-electronics.com/ physics/laser/

methodsofachievingpopulationinversion.html

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.5.29-5.30

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LECTURE HANDOUTS

L 19

PHYSICS

I / I

Course Name with Code : **ENGINEERING PHYSICS /21BSS01**

Course Faculty :

Date of Lecture:

Unit : **III - FIBER OPTICS AND ITS APPLICATIONS**

Topic of Lecture: Introduction and Principle of Fiber optics

Introduction :

- Optical fibers are the light pipes or photon conductors made of transparent materials like glass and plastics. The development of lasers and optical fibers has brought a revolution in communication systems.

Prerequisite knowledge for Complete understanding and learning of Topic:

- To know the basic knowledge about the principle of Fiber optics.
- To know the definition of fiber optics "Fibre optics is a technology in which the electrical signals are converted into light signals, transmitted through a glass fibre and reconverted into electrical signals".

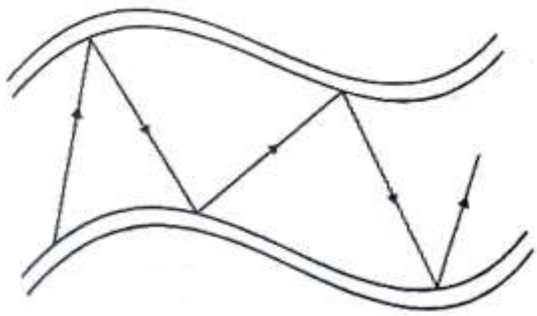
Detailed content of the Lecture:

. FIBRE OPTICS - INTRODUCTION

To have an efficient communication system, the information carried out by light waves requires a guiding medium through which it can be transmitted safely. This guiding medium is called ***optical fiber***. Apart from the use of communication, optical fibres are widely used in other areas like medical diagnosis and sensors for detecting electrical, mechanical and thermal energies.

CONSTRUCTION OF THE OPTICAL FIBRE

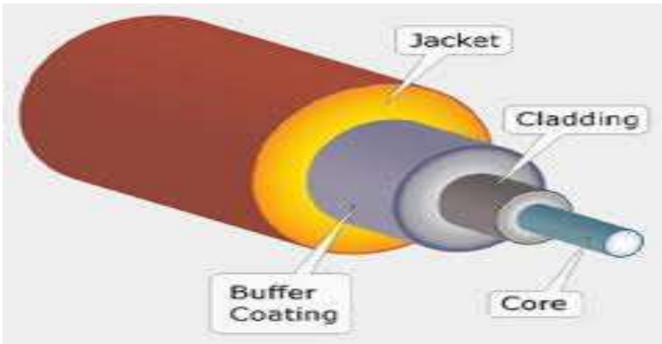
An optical fibre is a transparent media as thin as human hair, made of glass or plastic used to guide the light waves along its length. An optical fibre works on the principle of ***total internal reflection***. When the light enters at one end of the fibre it undergoes total internal reflection from the side walls and travel the length of the fibre.



Light transmission through fiber

Optical fibre is constructed with three coaxial regions .The inner cylinder made of glass or plastic called ***core*** is used to guide the light. It is surrounded by a middle region of glass or plastic called ***cladding*** which is used to confine the light to the core.

The cladding is covered by the outermost region called ***buffer***, which protects the inner region from the moisture. The refractive index of core region is always higher than the cladding.

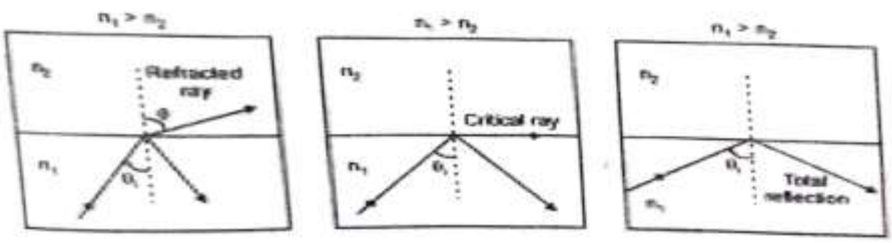


Structure of fiber

Light entering the core and striking the core-cladding interface at an angle greater than critical angle will be reflected back into the core. The light beams undergo total internal reflection and passes along the length of the cable. Since the angle of incidence and reflection are equal, the light will continue to propagate through the fibre.

PRINCIPLE OF FIBER TRANSMISSION

The principle of transmission of light through optical fiber is ***total internal reflection***. For total internal reflection, the angle of incidence (θ_i) should be greater than the critical angle (θ_c) of the medium.



a) when $\theta_i < \theta_c$ b) when $\theta_i = \theta_c$ c) when $\theta_i > \theta_c$

Principle of total internal reflection

Case 1: When $\theta_i < \theta_c$, the light ray is refracted into the rarer medium (cladding) i.e., no light is transmitted through the core region, as shown in Fig.a.

Case 2: When $\theta_i = \theta_c$, the angle of incidence is increased to a certain value called ***critical angle*** so that angle of refraction is 90°. The refracted ray just emerges along the core-cladding interface as shown in Fig.b.

Case 3: When $\theta_i > \theta_c$, the light is reflected back into the denser medium (core). In order to arrive at the condition of total internal reflection, the angle of incidence must be higher than the critical angle. The reflection of light in the core region is shown in Fig.c.

Video Content / Details of website for further learning (if any):

https://en.wikipedia.org/wiki/Optical_fiber

http://www.jb.man.ac.uk/research/fibre/intro2fibre.htm

Important Books/Journals for further learning including the page nos.:

Engineering Physics, Dr.G.SudarMozhi, Sri kandhan Publication,2016. Page No.4.1-4.4

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L 20

PHYSICS

I / I

Course Name with Code : **ENGINEERING PHYSICS /21BSS01**

Course Faculty :

Date of Lecture:

Unit : **III - FIBER OPTICS AND ITS APPLICATIONS**

Topic of Lecture: Propagation of light in optical fibers Numerical aperture and Acceptance angle

Introduction :

- Numerical aperture -In optics, the **numerical aperture** (NA) of an optical system is a dimensionless number that characterizes the range of angles over which the system can accept or emit light.
- Acceptance angle-The **acceptance angle** of an optical fiber is defined based on a purely geometrical consideration (ray optics): it is the maximum **angle** of a ray (against the fiber axis) hitting the fiber core which allows the incident light to be guided by the core.

Prerequisite knowledge for Complete understanding and learning of Topic:

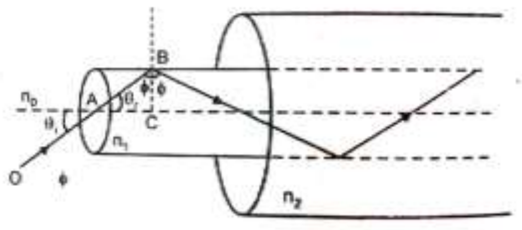
- Basic knowledge about the refractive index of core and cladding

Detailed content of the Lecture:

PROPAGATION OF LIGHT IN OPTICAL FIBERS

Let us consider the optical fibre into which light is entered at one end . Let n_1 is the refractive index of core and n_2 is the refractive index of cladding. The refractive index of the core is always greater than the refractive index of cladding i.e., $n_1 > n_2$.

Let n_0 is the refractive index of the medium (air) where the light is entering into the fibre. The light is allowed to travel along the path OA and enters into the core at an angle of θi to the axis of fibre. The light is refracted at an angle of θr and strikes the core-cladding interface at an angle of φ at B. If ϕ is greater than the critical angle θ_c, the ray undergoes total internal reflection and propagates through the fiber.



Light propagation in optical fiber

According to Snell's law,

$$n_0 \sin\theta_i = n_1 \sin\theta_r \qquad \text{----------} \quad (1)$$

At B, on the interface of core-cladding,

$$\phi = 90 - \theta_r$$

Applying Snell's law again,

$$n_1 \sin(90 - \theta_r) = n_2 \sin 90$$

$$n_1 \cos\theta_r = n_2$$

$\because \sin(90-\theta_r) = \cos\theta_r$ and $\sin 90 = 1$

$$\cos\theta_r = \frac{n_2}{n_1} \qquad \text{-------} \quad (2)$$

Rewriting equation (1),

$$\sin\theta_i = \frac{n_1}{n_0}\sin\theta_r$$

$$= \frac{n_1}{n_0}\sqrt{1-\cos^2\theta_r} \qquad \text{----------} \ (3)$$

$\sin^2\theta + \cos^2\theta = 1$

Substituting the value of $\cos\theta_r$ in equation (3) from equation (2),

$\sin^2\theta = 1 - \cos^2\theta$

$\sin\theta = \sqrt{1-\cos^2\theta}$

$$\sin\theta_i = \frac{n_1}{n_0}\sqrt{1-\frac{n_2^2}{n_1^2}}$$

$$= \frac{n_1}{n_0}\sqrt{\frac{n_1^2-n_2^2}{n_1^2}}$$

$$= \frac{\sqrt{n_1^2-n_2^2}}{n_0}$$

$$\theta_i = \sin^{-1}\frac{\sqrt{n_1^2-n_2^2}}{n_0} \qquad \text{----------} \ (4)$$

Equation (4) is called ***Acceptance angle*** (θi), the maximum angle at which a ray of light can enter through the fibre so that the light will be totally internally reflected.

Numerical aperture

It is the measure of amount of light rays that can be accepted by the fibre. The sine of the acceptance angle of the fibre is called ***numerical aperture***.

i.e, $$NA = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

When the medium surrounding the fibre is air, $n_0 = 1$

$$\boxed{NA = \sqrt{n_1^2 - n_2^2}}$$

Fractional index change (Δ)

It is the ratio of difference in refractive index of core and cladding to the refractive index of core.

i.e., $$\Delta = \frac{n_1 - n_2}{n_1} \qquad \text{-------- (5)}$$

Relation between Numerical aperture (NA) and Fractional index change (Δ)

From equation (5), we can write

$$n_1 \Delta = n_1 - n_2. \qquad \text{--------- (6)}$$

We know, $$NA = \sqrt{n_1^2 - n_2^2}$$

$$= \sqrt{(n_1 + n_2)(n_1 - n_2)} \qquad \text{---------- (7)}$$

Substituting the equation (6) in (7),

$$NA = \sqrt{(n_1 + n_2)(n_1 \Delta)}$$

If $n_1 \approx n_2$,

$$NA = \sqrt{2n_1^2 \Delta} - \qquad \text{----- (8)}$$

$$\boxed{NA = n_1 \sqrt{2\Delta}}$$

Video Content / Details of website for further learning (if any):

https://circuitglobe.com/numerical-aperture-of-optical-fiber.html

https://vlab.amrita.edu/?sub=1&brch=189&sim=343&cnt=1

Important Books/Journals for further learning including the page nos.:

Engineering Physics, Dr.G.SudarMozhi, Sri kandhan Publication, 2016. Page No.4.4 - 4.7

Course Faculty

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MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS

L 21

PHYSICS

I / I

Course Name with Code : **ENGINEERING PHYSICS /21BSS01**

Course Faculty :

Date of Lecture:

Unit : **III - FIBER OPTICS AND ITS APPLICATIONS**

Topic of Lecture: Classification based on materials and refractive index profile

Introduction :

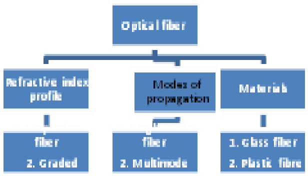
- Fiber **Classifications**. Optical fiber falls into three basic **classifications**: step-**index** multimode, graded-**index** multimode, and single mode. A mode is essentially a path that light can follow down the fiber. Step-**index** fiber has a core with one **index of refraction**, and a cladding with a second **index**

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic definition of refractive index
- Core and Cladding

Detailed content of the Lecture:

Optical fibers are generally classified based on refractive index profile, modes of propagation



Optical fiber based on refractive index profile

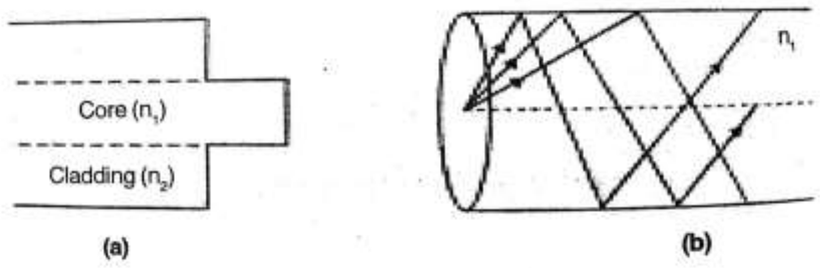
Based on the refractive index of core and cladding materials, fibres are classified into

i) Step index fibre and

ii) Graded index fibre

i) Step index fibre

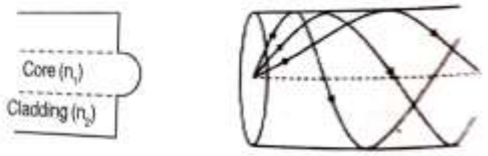
If the refractive index of the core is uniform throughout and undergoes a change only at cladding boundary is called *step index fibre*. As the refractive index of core (n_1) and cladding (n_2) is changed step by step, it is called step index fibre. The light ray is propagated in the form of meridinal rays and it passes through the axis of the fibre.



Step index fiber

ii) Graded index fibre

If the refractive index of the core is varying with the radial distance from the axis of the fibre it is called graded index fibre. The refractive index is maximum at the axis of the core and goes on decreasing while moving towards core-cladding interface i.e., the refractive index of core and cladding are equal, at the core-cladding interface. The light ray is propagated in the form of skew rays and it will not cross the axis of the fiber.



Graded index fiber

Difference between step index fibre and graded index fiber:

S.No	Step index fibre	Graded index fibre
1	The refractive index of core (n_1) and cladding (n_2) is changed step by step, it is called step index fibre	The refractive index of the core is varying with the radial distance from the axis of the fibre it is called graded index fibre
2	The light ray is propagated in the form of meridinal rays and it passes through the axis of the fibre.	The light ray is propagated in the form of skew rays and it will not cross the axis of the fibre
3	It has lower bandwidth	It has higher bandwidth
4	Distortion is more	Distortion is lesser

Video Content / Details of website for further learning (if any):

https://en.wikipedia.org/wiki/Refractive_index_profile

http://msheiksirajuddeen.blogspot.com/2011/12/optical-fibres-are-generally-classified.html

Important Books/Journals for further learning including the page nos.:

Engineering Physics, Dr.G.SudarMozhi, Sri kandhan Publication,2016. Page No.4.7-4.9

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LECTURE HANDOUTS

L 22

PHYSICS

I / I

Course Name with Code : **ENGINEERING PHYSICS /21BSS01**

Course Faculty :

Date of Lecture:

Unit : **III - FIBER OPTICS AND ITS APPLICATIONS**

Topic of Lecture: Classification based on materials, refractive index profile

Introduction :

- Single mode fiber
- Multimode fiber
- Glass fibre
- Plastic fibre

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge about the optical fibre

Detailed content of the Lecture:

Optical fiber based on modes of propagation

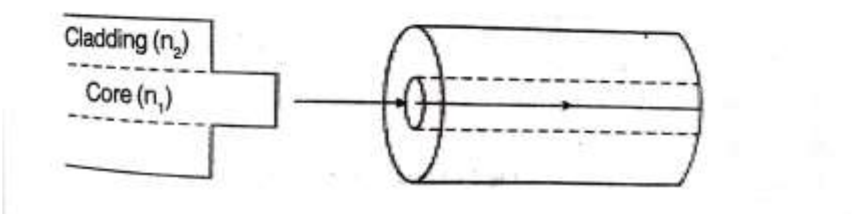
Based on the modes of propagation, optical fibres can be further classified into

i) Single mode fibre and

ii) Multimode fibre.

i) Single mode fibre

Single mode fibre is the fiber in which light travels along a single path that is along the axis. This type of fibre may have a core diameter of 2–10μm and cladding diameter of 50–125μm. Due to its small core diameter, a single mode of light transmission is only possible. This is used for long distance communication. Laser beam can be easily launched into this single mode fibre.



Single mode step index fibre

The advantages of single mode step index fibre are stated below.

- ➢ It has very small core diameter

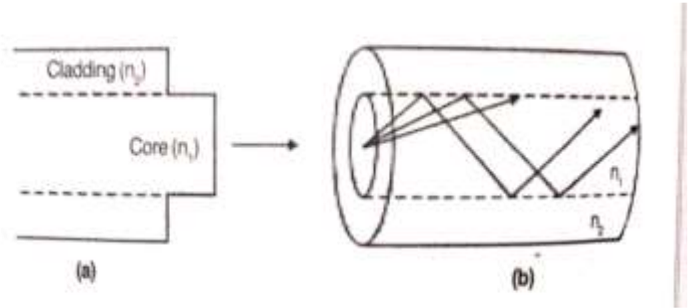
- Since it allows only one mode, the entire light energy is concentrated along the axis
- They provide superior transmission quality
- Transmission loss is very small
- It is compatible with integrated optic technology
- Life time of more than 20years is anticipated

ii) Multi mode fibre

A multimode optic fibre is one in which more than one path is possible for light rays to travel through the core. A typical multimode optical fibre has a core diameter in the range of 50-200µm. The light can be launched into multimode fibre using LED.

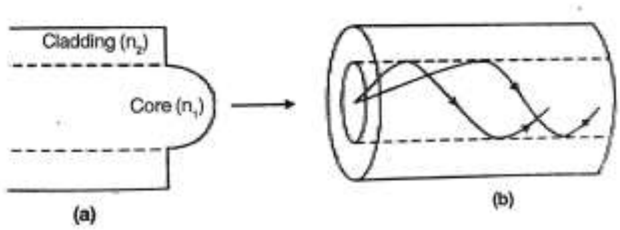
The disadvantage of multimode fibre is that they suffer from ***intermodel dispersion***. Multimode propagation can be achieved in both step index and the graded index fibres and is explained below.

A *multimode step index fibre* is similar to the single mode step index fiber with large core diameter. The light travels in zigzag path inside the fibre and many such paths of propagation are permitted. Each path of light is travel with slightly different velocities.



Multimode step index fibre

A *multimode graded index fibre* has a core diameter of 50-200µm and cladding diameter of 100-250µm. The refractive index of the core is maximum at the axis of the fibre. If the diameter of the core is high, the intermodal dispersion loss must be high. But because of gradual decrease in the refractive index of the core, the intermodal dispersion loss is minimized. The propagation of light in this type of fibre.



Multimode graded index fibre

Optical fibers based on materials

. Based on the materials used for the manufacturing of optical fibre, they are classified into

i) Glass fibre and

ii) Plastic fibre

i) Glass fibre

The glass fibres are prepared by fusing the mixture of metal oxides and silica glasses. Silica (SiO_2) having refractive index of 1.458 is commonly used for glass fibres. To produce the materials having slightly different refractive indices for core and cladding, some of the dopants will be added to silica. Refractive index of silica increases with the addition of GeO_2 or P_2O_5 and decreases with the addition of B_2O_3. The resulting material is randomly connected by molecular network rather than well defined ordered structures as found in crystalline materials.

Some of the fibre compositions are;

1. GeO_2–SiO_2 as a core and SiO_2 as a cladding
2. P_2O_5–SiO_2 as a core and SiO_2 as a cladding
3. SiO_2 as a core and B_2O_3–SiO_2 as a cladding

ii) Plastic fibre

Plastic fibres are made of plastics. It is of low cost. It has higher signal attenuation than glass fibres. It can be handled without any special care due to its toughness and durability. Since refractive index differences between core and cladding is higher, numerical aperture and angle of acceptance of this type of fibre is also higher.

Some of its compositions are,

1. Polystyrene as core and methylmetha crylate as cladding
2. Methylmetha crylate as core and its co-polymer as cladding

FIBER MATERIALS

The materials used for fabricating optical fibres must satisfy the following conditions:

1. It must be possible to make long, thin and flexible fibres from the materials
2. It must be transparent to guide the light efficiently
3. Materials having slightly different refractive indices for the core and cladding must be available
4. The material must be available at low cost with higher efficiency

Video Content / Details of website for further learning (if any):

http://msheiksirajuddeen.blogspot.com/2011/12/optical-fibres-are-generally-classified.html

Important Books/Journals for further learning including the page nos.:

Engineering Physics, Dr.G.SudarMozhi, Sri kandhan Publication,2016. Page No.4.9-4.12

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LECTURE HANDOUTS

L 23

PHYSICS

I / I

Course Name with Code : **ENGINEERING PHYSICS /21BSS01**

Course Faculty :

Date of Lecture:

Unit : **III - FIBER OPTICS AND ITS APPLICATIONS**

Topic of Lecture: Double crucible technique of fibre and Splicing

Introduction :

In Double Crucible technique

- Fabrication cost is low
- Fibres can be fabricated continuously

In Splicing

- Splicing is a method used to connect the fibres permanently to carry the information for a longer distance

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge about the fiber.
- Principle of Fiber Optics

Detailed content of the Lecture:

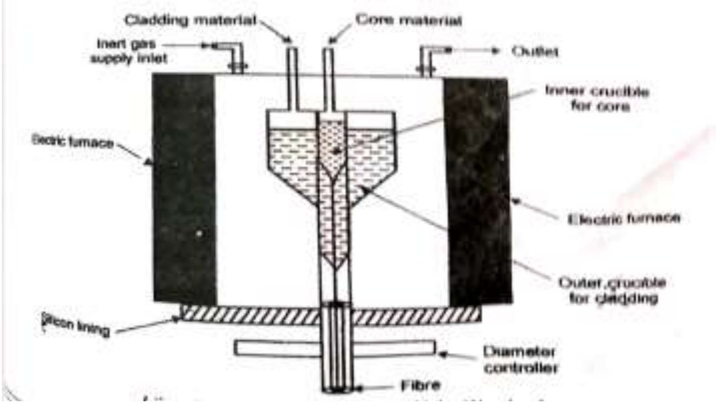
. FABRICATION OF GLASS FIBRE - Double Crucible Technique

Principle

The raw materials of core and cladding are separately placed in the crucibles (a pot in which substances are heated to higher temperatures) kept one inside the other and is heated to very high temperature using a furnace. The molten materials are drawn out together to form the fibre.

Description

The experiment consists of two crucibles namely inner and outer crucibles made of platinum or silica. The inner crucible is kept inside the outer crucible. The inner crucible contains core glass and the outer crucible contains the cladding glass materials. Both the crucibles are placed inside a vertical furnace, which is capable of heating up to 1200ºC. Using this technique, various refractive indices of core and cladding is obtained by adding the dopant materials.



Double Crucible Technique

Working

Highly purified molten materials of different refractive indices are taken into inner and outer crucibles. The core glass powder is taken in inner crucible and cladding glass powder is taken in outer crucible. The electric furnace is switched on and materials inside the crucibles are heated to the higher temperature and melted. Then the molten material is allowed to emerge out through the nozzle of the crucible. Now the core material will start diffusing into the cladding material to form an optical fibre and fibre is drawn out through the bottom of the outer crucible. Finally the fibre is coated by the polymer and protective layers.

Advantages

- Fabrication cost is low
- Fibres can be fabricated continuously

Disadvantages

- Materials used for core and cladding should be pure, otherwise contamination will occur
- Silica crucibles should not be used more than once, in such cases crucibles made of platinum should be used, which is costlier

SPLICING OF FIBRE

Splicing is a method used to connect the fibres permanently to carry the information for a longer distance. In this technique two fibres can be connected with the help of an elastomer (rubber) and adhesive gel.

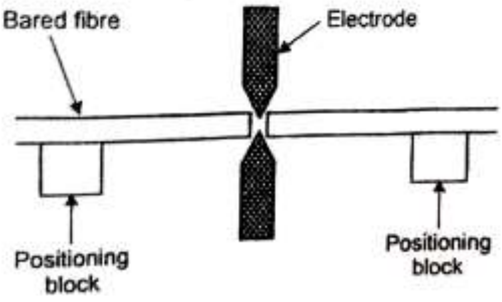
There are two types of splicing technique namely,

1) Fusion splicing

2) Mechanical splicing

Fusion splicing

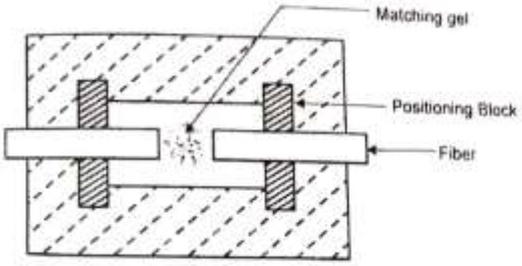
In this splicing, the two fibre ends are viewed through a microscope and then aligned. An electric arc consists of tungsten electrodes are used as heating source for fusion. After the alignment, the electric arc emits a spark between electrodes at the gap to burn off dust and moisture. The spark raises temperature above the melting point of the glass and fusing the ends together permanently.



Fusion splicing

Mechanical splicing

Mechanical splicing is preferred for the short and medium routes. It provides greater flexibility. The mechanical mounts are used to hold the fibres in position. Any kind of irregularities like scratches while cleaning the fibre ends will lead a loss of optic power.



Mechanical splicing

The matching gel is injected in the region where the ends of two fibres are kept. The matching gel is a highly transparent semi fluid with an index matching the refractive index of the core. The light energy which emerges out of one end of fibre is flowing freely through the matching gel and reaching another fibre. Thus the optical energy is transferred from one fibre to another.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=-MqnnTk2LB0

https://www.brainkart.com/article/Double-Crucible-Method_6892/

https://en.wikipedia.org/wiki/Fusion_splicing

Important Books/Journals for further learning including the page nos.:

Engineering Physics, Dr.G.SudarMozhi, Sri kandhan Publication,2016. Page No.4.13-4.16

Course Faculty

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LECTURE HANDOUTS

L 24

PHYSICS

I / I

Course Name with Code : **ENGINEERING PHYSICS /21BSS01**

Course Faculty :

Date of Lecture:

Unit : **III - FIBER OPTICS AND ITS APPLICATIONS**

Topic of Lecture: Loss in optical fiber – attenuation, dispersion, bending

Introduction :

The loss of transmission causes in the fibre is due to

- Attenuation
- Dispersion

Prerequisite knowledge for Complete understanding and learning of Topic:

- To know the basics knowledge about transmission, dispersion and absorption

Detailed content of the Lecture:

. LOSS IN OPTICAL FIBRE

When the light is transmitted through the optical fibre it suffers transmission losses. The loss of transmission causes in the fibre is due to

1) Attenuation 2) Dispersion

Attenuation

Loss of optical power by the optical signal in the fibre is called attenuation. Attenuation is also defined as the ratio of the output power (P_{out}) of a fibre of length L, to the input power (P_{in}).

$$\text{Attenuation} = \frac{10}{L} \log\left(\frac{P_{out}}{P_{in}}\right) \quad \text{in dB/km}$$

The attenuation may be explained with respect the following factors:

i) Absorption due to impurity ions

ii) Rayleigh scattering due to inhomogeneties and

iii) Radiative loss by wave guide imperfection and micro bending.

i) Absorption

Absorption is related to the materials used for fibre and is caused by,

a) atomic defects

b) extrinsic absorption

c) intrinsic absorption

a) Atomic defects: Atomic defects are the imperfections of the atomic structure of fibre material such as missing molecules and high density clusters of atoms. The losses arises from these defects are negligible compared to intrinsic and extrinsic effect.

b) Extrinsic absorption: The presence of impurity plays a vital role in the absorption process. When the light waves are transmitted through fibre materials, some of the photons are absorbed by these impurities and some of the photons interact with these impurities. The electrons of the impurity atoms absorb the photons and get excited to higher energy level. Later these electrons give up their absorbed energy in the form of heat energy or light energy. This leads some loss of energy.

c) Intrinsic absorption: The property of absorbing light energy by the fibre material even it is free from impurities and defects is called intrinsic absorption.

ii) Scattering loss

We know the glass materials are used for the fabrication of fibres. By nature glass has a disordered structure in which the material density fluctuations are absorbed in the composition. This leads the variation of refractive index of the glass. The variation of refractive index of the material causes the light scattered called ***Reyleigh scattering***.

Due to scattering, the photon moves in random direction and having the probability of leaving the fibre thus leads a loss of energy.

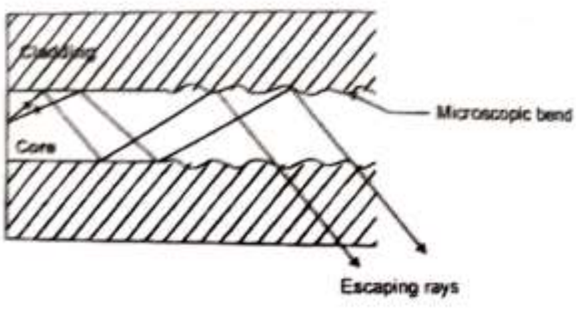
iii) Radiative loss

Radiative loss occurs in fibre due to bending of radius of curvature. The bending of fibre may be classified into

a) Microscopic bending and b) Macroscopic bending.

a) Microscopic bending

These kinds of losses are due to non-uniformity or micro bends inside the fibre material.



Microscopic bending loss

These micro bending are also caused due to non-uniform pressure created during the cabling of fibre or during manufacturing. The lights which get reflected from these surfaces are escaped from the fibre material and leads loss of energy.

Micro bending losses can be reduced by providing a compressible jacket over the fibre which protects the core region.

b) Macroscopic bending

In which the radius of the core is large compared to fibre diameter. This kind of bending is occurred when a fibre cable turns at a corner. At these corners the light will not satisfy the condition for total internal reflection and hence it escapes from the fiber. It causes large curvature radiation losses.

Dispersion

The degradation of the optical signal when the light travels along a fibre is called ***dispersion***. The most significant types of dispersion in fibre optic cable are,

i) Chromatic dispersion ii) Modal dispersion iii) Waveguide dispersion

i) Chromatic dispersion This type of dispersion is occurred due to different wavelength of light traveling at different speed inside the fibre. The effect of chromatic dispersion can seen when a white light passes through a glass prism and is spread out into the colours.

Chromatic dispersion can be reduced by improving the quality of the light source and by increasing the purity of the glass material.

ii) Modal dispersion When more than one mode is propagating through a fibre the modal dispersion occurs. Some modes of light travel slow and some other modes of light travel faster. The light pulses arrive at the fibre end at slightly different time will cause the pulse to spread out in time as it travels along the fibre. This effect is known as *intermodal dispersion.*

Modal dispersion can be reduced by improving the quality of light source.

iii) Waveguide dispersion

This dispersion is caused by the shape of the fibre core and by its chemical composition. The light dispersed while traveling through the fibre cable can be controlled by modifying the composition of glass.

Video Content / Details of website for further learning (if any):

https://www.fiberoptics4sale.com/blogs/archive-posts/95048006-optical-fiber-loss-and-attenuation

https://www.juniper.net/documentation/en_US/release-independent/junos/topics/concept/fiber-optic-cable-signal-loss-attenuation-dispersion-understanding.html

Important Books/Journals for further learning including the page nos.:

Engineering Physics, Dr.G.SudarMozhi, Sri kandhan Publication,2016. Page No.4.16-4.20

Course Faculty

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LECTURE HANDOUTS

L 25

PHYSICS

I / I

Course Name with Code : **ENGINEERING PHYSICS /21BSS01**

Course Faculty :

Date of Lecture:

Unit : **III - FIBER OPTICS AND ITS APPLICATIONS**

Topic of Lecture: Fibre optical communication system

Introduction : The basic concept of optical fiber communication is similar to other types of communication system. In the fiber optic communication system, initially the input electrical signals are converted into optical signals by a transmitter.

•

Prerequisite knowledge for Complete understanding and learning of Topic:

i) Transmitter

ii) Optical fibre

• iii) Receiver

Detailed content of the Lecture:

. FIBER OPTIC COMMUNICATION SYSTEM

The basic concept of optical fiber communication is similar to other types of communication system. In the fiber optic communication system, initially the input electrical signals are converted into optical signals by a transmitter. Then the signals are allowed to transmit through optical fibre without any loss of energy. The light signals are received at the end of the fiber then converted into electrical signals by a receiver.

The basic components of fibre optic communication systems are,

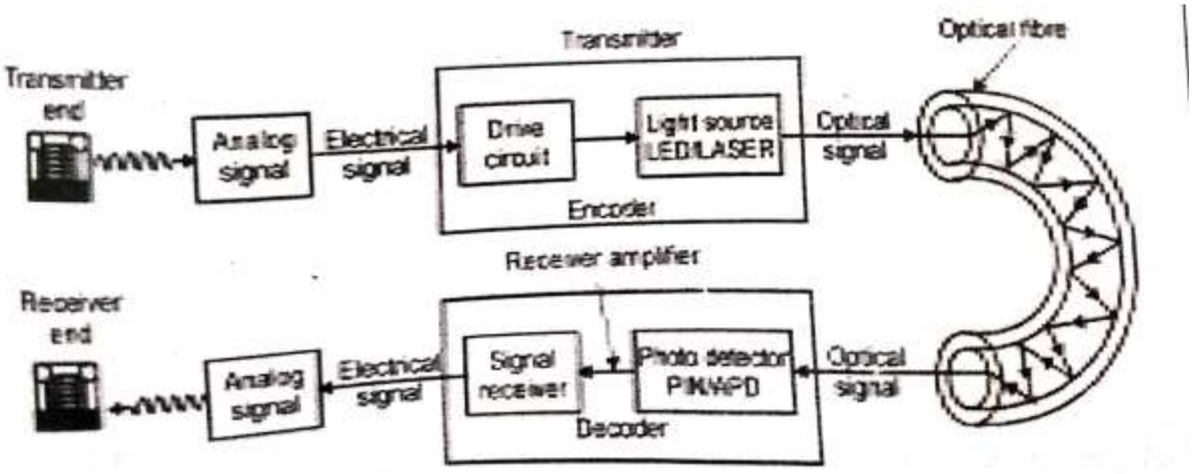
i) Transmitter

ii) Optical fibre

iii) Receiver

Transmitter

The transmitter consists of a light source supported by necessary drive circuits. The source is the active component in optical communication system. The information signal source which is in the analog form to be transmitted is converted from analog signal to electrical signal. This results in successful launching of light into the optical fiber. The drive circuit transfers the electric input signal into digital pulses and it is converted into optical pulses by the light source. The light source is generally a LED. The optical pulses are focused onto the optical fibre.



Fibre optic communication system

Optical Fibre

It acts as a wave guide and transmits the optical pulses towards the receiver by the principle of total internal reflection. The transmission medium may be either wires or coaxial cables.

Receiver

Similar to the source, detector is an important component in fiber optic communication system. The photo detector receives the optical pulses and converts the optical pulses into electrical pulses. The electrical signals are amplified by an amplifier. These electrical signals are converted from digital to analog signals and reach the receiver end.

Video Content / Details of website for further learning (if any):

https://en.wikipedia.org/wiki/Fiber-optic_communication

https://www.elprocus.com/basic-elements-of-fiber-optic-communication-system-and-its-working/

Important Books/Journals for further learning including the page nos.:

Engineering Physics, Dr.G.SudarMozhi, Sri kandhan Publication,2016. Page No.4.20-4.22

Course Faculty

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LECTURE HANDOUTS

L 26

PHYSICS

I / I

Course Name with Code : **ENGINEERING PHYSICS /21BSS01**

Course Faculty :

Date of Lecture:

Unit : **III - FIBER OPTICS AND ITS APPLICATIONS**

Topic of Lecture: Fiber optic Light sources

Introduction :

- Light Emitting Diode
- Semiconductor laser diode

Prerequisite knowledge for Complete understanding and learning of Topic:

- To Know the basic knowledge about the Light Emitting Diode and Semiconductor laser diode

Detailed content of the Lecture:

LIGHT SOURCES FOR FIBRE OPTICS

Light Emitting Diode (LED)

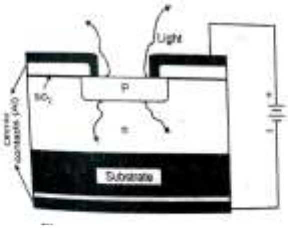
LED is a semiconductor p-n junction diode which converts electrical energy into light energy under forward bias condition. It emits light in both visible and infrared region.

Principle

The principle used in the LED is ***injection luminescence***. When LED is forward biased, the majority of positive charge carriers moves from ‘p’ to ‘n’ region and negative charge carriers moves from ‘n’ to ‘p’ region and becomes excess minority carriers. This excess minority charge carriers diffuses through the junction and recombines with the majority charge carriers in n and p region respectively.

Construction

The p-n junction is made by doping Silicon with GaAs crystal using diffusion or epitaxial techniques. A shallow p-n junction is formed on GaAs substrate such that ‘p’ layer is formed by diffusion on ‘n’ layer. The thickness of ‘n’ layer is taken higher than that of ‘p’ layer, to increase the probability of charge carriers to recombine.

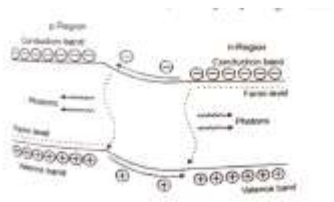


Light Emitting Diode

Ohmic contacts are made with the help of aluminium in such a way that top layer of the ‘p’ material is left uncovered for the emission of light. Biasing is done using ohmic contacts. The whole p-n junction is insulated to minimize the losses due to reflection.

Working

When the diode is forward biased, the majority charge carriers from ‘n’ and ‘p’ region cross the junction and become minority charge carriers in the other region. i.e., the majority of electrons in ‘n’ region cross the junction and reach the ‘p’ region and become minority charge carriers in ‘p’ region. Like wise the majority of holes in ‘p’ region cross the junction and reach the ‘n’ region and become the minority charge carriers in the ‘n’ region. The excess of minority carriers are injected in both ‘p’ and ‘n’ region.



Recombination of charge carriers

Similarly the excess minority carriers of holes in n region recombine with the electrons which are the majority carriers in n region and then laser radiates.

Thus the electron hole recombination process occurs more and more and the light energy is emitted through the top layer of ‘p’ material as shown.

Advantages

- They are smaller in size.
- The cost of diode is very low.
- .

Disadvantages

- Power output is very low.
- Intensity is lesser.
- .

Semiconductor Laser Diode

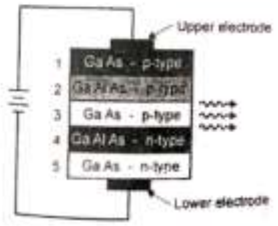
Principle

The electrons in conduction band combines with a holes in the valence band and hence the recombination of electron and hole produces energy in the form of light.

Construction

This kind of diode is a combination of different layers. It consists of five layers. A layer of p type semiconductor (Layer-3) made of GaAs will acts as an active region. This semiconductor layer has a narrow band gap. This layer is placed between two layers (Layer-2 and 4) having wider band gap. The p type layer of GaAs

(Layer-1) is used for making necessary biasing with the lower electrode. All the four layers are grown over the substrate (Layer-5) which is made of n type of GaAs. The junction between the 3rd and 4th layer is well polished and hence it acts as an optical resonator.



Semiconductor Laser Diode

Working

The Diode is forward biased with the help of electrodes. Due to forward biasing the charge carriers are produced in the layers 2 and 4. The charge carriers produced are injected into the active region (Layer-3) till the population inversion is achieved. Some of the spontaneously emitted photons released during recombination process start stimulate the injected charge carriers to emit photons. After the condition of population inversion is reached more number of photons are produced. The photons are reflected back and forth and hence the intense coherent beam of laser emerges out from the p- n junction region between the layers 3 and 4.

Video Content / Details of website for further learning (if any):

https://circuitglobe.com/light-emitting-diode-led.html

https://en.wikipedia.org/wiki/Light-emitting_diode

https://www.pantechsolutions.net/fiber-optics-laser-diode-module

Important Books/Journals for further learning including the page nos.:

Engineering Physics, Dr.G.SudarMozhi, Sri kandhan Publication,2016. Page No.4.22-4.26

Course Faculty

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LECTURE HANDOUTS

L 27

PHYSICS

I / I

Course Name with Code : **ENGINEERING PHYSICS /21BSS01**

Course Faculty :

Date of Lecture:

Unit : **III - FIBER OPTICS AND ITS APPLICATIONS**

Topic of Lecture: Detectors , Endoscope

Introduction :

The commonly used detectors are;

- p-i-n photo diode and
- Avalanche photodiode.

Endoscope

Fibre endoscope is used to study the interior parts of the human body that cannot be viewed directly.

Prerequisite knowledge for Complete understanding and learning of Topic:

- To know the basic knowledge about the Principle of photodiode.

Detailed content of the Lecture:

. Detectors perform the reverse function of fibre optic sources. They convert light energy into electrical energy at the receiving end of the fibre optic communication. The commonly used detectors are;

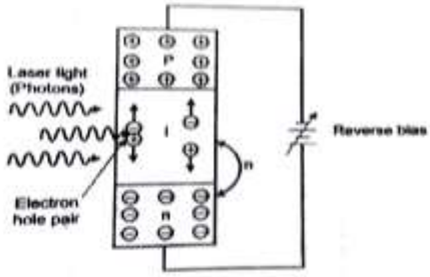
1) p-i-n photo diode and
2) Avalanche photodiode.

p-i-n photodiode

p-i-n photodiode detector works on the principle of reverse bias. When a photon is made to incident on the intrinsic region of the diode, the electrons in the valence band is move towards the conduction band and thus creating electron-hole pair. These electrons and holes are accelerated by the external electric field which results in photocurrent. Thus light is converted into electrical signal.

Construction

It consists of three regions viz, p, i and n. The p-region is highly doped with the positive charge carriers and n-region is highly doped with negative charge carriers. The central i-region is a neutral region lightly doped with n-material.



p-i-n photodiode.

Working

The pin photodiode is applied with high reverse bias voltage. When a photon (of energy greater than or equal to the band gap energy of the photodiode) is incident on the depletion region (i), the electron-hole pair is created due to the absorption of photon. These charges are accelerated by the applied voltage which gives rise to photo current. The photo current produced is directly proportional to the incident light energy.

Avalanche photodiode

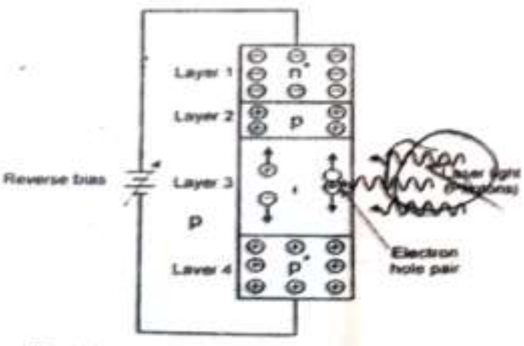
In this diode enormous electron-hole pairs are created from a single electron-hole pair by collision process.

Principle

This diode works on the principle of reverse bias. When light is made to incident on the intrinsic region, electron-hole pairs are generated. By avalanche effect more number of electron-hole pairs is created which results large photocurrent is produced than p-i-n photodiode

Construction

It consist of four different regions viz, p+, i, p and n+. The layer-1 is made of heavily doped n-region (n+).The layer-2 is made of p-region. The layer-3 is lightly doped with p material called intrinsic region (i) and the layer-4 is heavily doped with p-material (p+).



Avalanche photodiode

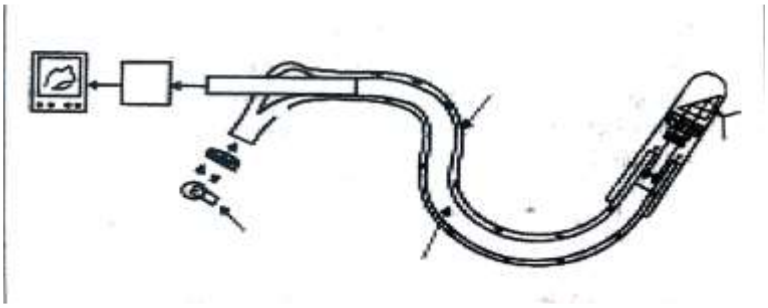
Working

When the light is incident on the intrinsic region under reverse bias condition, the light is absorbed and thus electron-hole pair creates. When the biasing voltage is increased, the generated electron moves into p-region (layer-2) and n+ region (layer-1). These electrons collide with free electrons in n+ region and release more number of free electrons and thus avalanche is produced. In this way a single photo generated electron releases thousands of free electrons and produce enormous output current. Since large current is produced with a single photon on the diode, the detectors are termed as ***sensitive detector.***

ENDOSCOPE

The fibre endoscope consists of bundle of flexible fibres containing up to 140000 thin optical fibres of few mm thicknesses. Fibre endoscope is used to study the interior parts of the human body that cannot be viewed directly.

The endoscope consists of two fibres called inner and outer fibers.



Fiber endoscope

Video Content / Details of website for further learning (if any):

https://en.wikipedia.org/wiki/Endoscope

https://www.cancer.net/navigating-cancer-care/diagnosing-cancer/tests-and-procedures/types-endoscopy

Important Books/Journals for further learning including the page nos.:

Engineering Physics, Dr.G.SudarMozhi, Sri kandhan Publication,2016. Page No.4.26-4.28,4.31-4.32

Course Faculty

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Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **IV Crystal Physics** **Date of Lecture:**

Topic of Lecture: Crystals, Lattice, Unit cell, Bravais lattice

Introduction :

- Matter is divided into three states namely solids, liquids and gases.
- solids are classified into two categories based on the arrangement of atoms or molecules.
- The classifications of solids are, Crystalline solids and Non crystalline solids or amorphous solids

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on atomic structure of the materials

Detailed content of the Lecture:

Crystals

- The materials possessing such a regular arrangement of atoms are called crystals.
- Each atom is at regular interval along with the other atoms in all direction
- Crystalline solids have directional properties, they are called as ***anisotropic substances***.
- Example: Copper, Silver, Nickel, Iron, etc.

Non-crystalline solids or Amorphous Solids

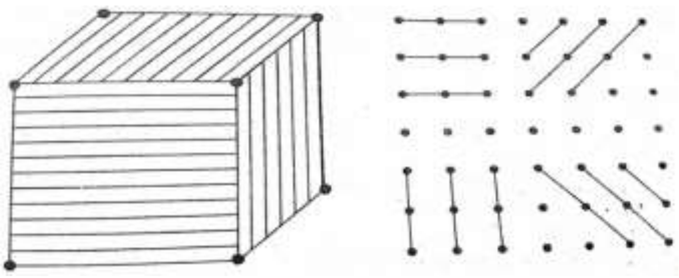
- The solid substance in which the atoms or molecules are arranged randomly (not regular) is called non-crystallize solid or Amorphous solid.
- These types of substances are called ***isotropic substances***.
- Example: Glass, Plastic and Rubber.

Lattice:

- The crystals are having regular and periodic arrangement of atoms.
- A lattice or space lattice is defined as an array of points in three dimensions and have identical surroundings to that of every other point.

Unit Cell:

- The unit cell is defined as the smallest geometrical unit which when repeated in space over three dimensions gives the actual crystal structure
- A unit cell is the smallest volume that carries full description of the entire lattice.



BRAVAIS LATTICES

- There are fourteen different ways of arranging points in space lattice from the 7 crystal systems.

S. No.	Name of the System	Type of unit cell
1	Cubic	i) Simple ii) Body centered iii) Face centered
2	Tetragonal	i) Simple ii) Body centered
3	Orthorhombic	i) Simple ii) Body centered iii) Face centered iv) Base centered
4	Monoclinic	i) Simple ii) Base centered
5	Triclinic	i) Simple triclinic
6	Trigonal	i) Simple trigonal
7	Hexagonal	i) Simple hexagonal

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=BjVTdZ_htu8

https://www.youtube.com/watch?v=VPCDSmoomGk

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015,Page no. 1.1-1.7

Course Faculty

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LECTURE HANDOUTS

L 29

PHYSICS

I / I

Course Name with Code : Engineering Physics / 21BSS01

Course Faculty :

Unit : IV Crystal Physics **Date of Lecture:**

Topic of Lecture: Lattice planes and Miller indices

Introduction :

- A lattice or space lattice is defined as an array of points in three dimensions and have identical surroundings to that of every other point.
- Lattice points representing the locations of atoms in an imaginary geometry. The actual array of atoms is called the structure.
- A Set of equally spaced planes containing lattice points are called lattice planes or atomic planes.
- A set of three numbers are introduced with in the parentheses by Miller and is called Miller indices.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on atomic structure of the materials

Detailed content of the Lecture:

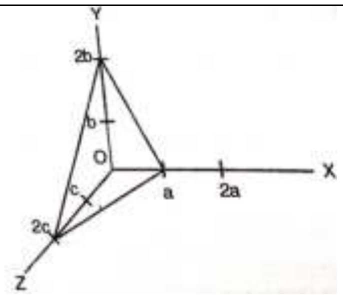
Miller indices.

- Miller indices are defined as the reciprocal of the intercepts made by the plane on the crystallographic axes in the smallest numbers.
- The integers should be enclosed with in the bracket i.e. (1 1 1)
- Comma or dot between any two numbers in the bracket may be avoided
- The Miller indices for any plane say (1 3 2) should be read as one three two only

Salient features of Miller indices

- A plane parallel to any coordinate axis will meet at infinity only. The intercept of this plane is considered as infinity. Hence the Miller indices for that particular axis are zero
- A plane passing through the origin has non zero intercept
- All equally spaced parallel planes have same Miller indices

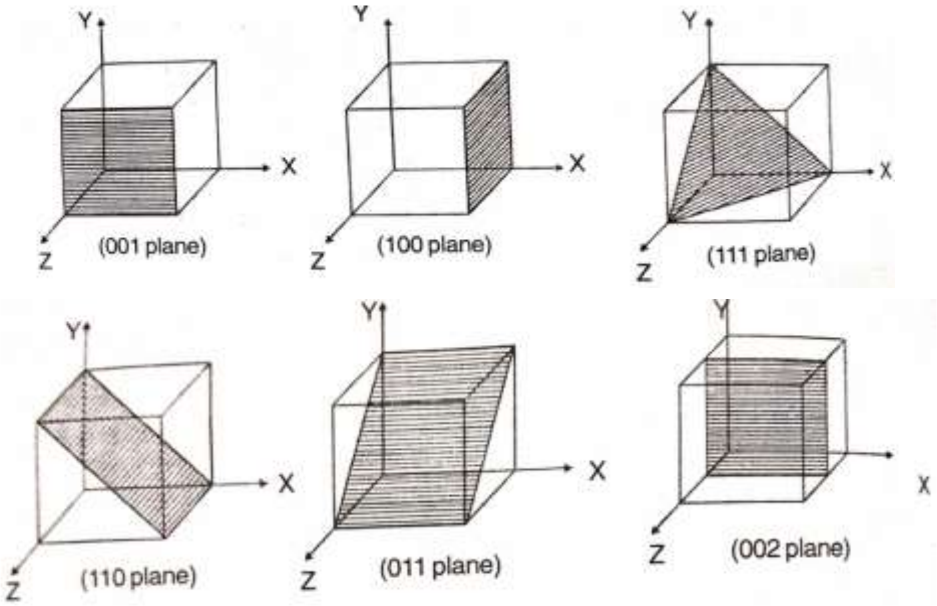
Steps to find out



Miller indices

- Find the intercepts made by the plane (ABC) along the three axes and expressed in terms of axial lengths.   OA: OB : OC = 1a : 2b :2c
- Find the co-efficient of the intercepts i.e, 1, 2, 2
- Find the reciprocals of intercepts
- Convert these reciprocals into whole numbers by multiplying each reciprocal with the LCM. In this case 2 is the LCM. The numerator values are: 2 1 1
- Enclose all these numbers within the parenthesis (bracket) (2 1 1)

Some examples of Miller indices of cubic crystal planes



Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=9-us_oENGoM

https://www.youtube.com/watch?v=n84gzYlB0BQ

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015,Page no.1.8-1.9

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LECTURE HANDOUTS

L 30

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **IV Crystal Physics** **Date of Lecture:**

Topic of Lecture: d - spacing in a cubic lattice

Introduction :

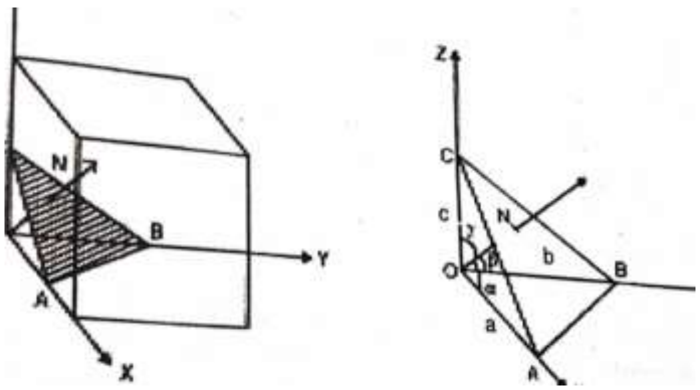
- d-spacing or the inter planar distance is the distance between any two successive lattice planes.
- Relation between the inter planar distance(d),lattice constant (a) and miller indices (hkl)

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on atomic structure of the materials

Detailed content of the Lecture:

d - spacing in a cubic lattice



- OX, OY and OZ represents the axes and OA, OB, OC are the intercepts by the plane.
- α, β and γ represents the angle between ON and along with other axis OA, OB and OC respectively.
- The intercepts of the plane on the three axes are $OA = \frac{a}{h}, \quad OB = \frac{a}{k}, \quad OC = \frac{a}{l}$
- $\therefore \quad OA : OB : OC = \frac{a}{h} : \frac{a}{k} : \frac{a}{l}$

From $\Delta\ ONA$, *From* $\Delta\ ONB$,

$$\cos\alpha = \frac{ON}{OA} = \frac{d}{a/h} = \frac{dh}{a} \qquad \cos\beta = \frac{ON}{OB} = \frac{d}{a/k} = \frac{dk}{a}$$

From Δ *ONC*,

$$\cos\gamma = \frac{ON}{OC} = \frac{d}{a/l} = \frac{dl}{a} \qquad \therefore \quad \cos\alpha : \cos\beta : \cos\gamma = \frac{dh}{a} : \frac{dk}{a} : \frac{dl}{a}$$

$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1, \left(\frac{dh}{a}\right)^2 + \left(\frac{dk}{a}\right)^2 + \left(\frac{dl}{a}\right)^2 = 1$$

or $$\frac{d^2}{a^2}\left(h^2 + k^2 + l^2\right) = 1$$

$$d^2 = \frac{a^2}{h^2 + k^2 + l^2}$$

or $$\boxed{d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}}$$

- The above equation gives the relation between inter atomic distance 'a' and the inter planer distance'd' and is called d-spacing.
- The interplanar distance between (100) plane is,

$$d_{100} = \frac{a}{\sqrt{1^2 + 0^2 + 0^2}} = a$$

- The interplanar distance between (110) plane is

$$d_{110} = \frac{a}{\sqrt{1^2 + 1^2 + 0^2}} = \frac{a}{\sqrt{2}}$$

- The interplanar distance between (111) plane is

$$d_{111} = \frac{a}{\sqrt{1^2 + 1^2 + 1^2}} = \frac{a}{\sqrt{3}}$$

- $d_{100} : d_{110} : d_{111} = 1 : \frac{1}{\sqrt{2}} : \frac{1}{\sqrt{3}}$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=zyAu4JQmHdc

https://www.youtube.com/watch?v=7VutiZCgKAk

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015,Page no.1.11-1.13

Course Faculty

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LECTURE HANDOUTS | **L 31**

PHYSICS | **I / I**

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **IV Crystal Physics** **Date of Lecture:**

Topic of Lecture: Calculation of number of atoms, atomic radius, Packing factors for simple cubic structure (SC)

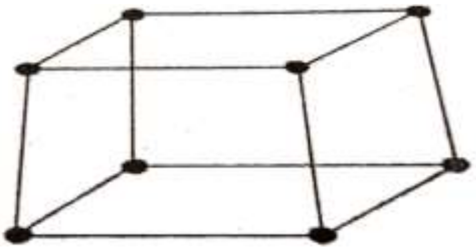
Introduction :

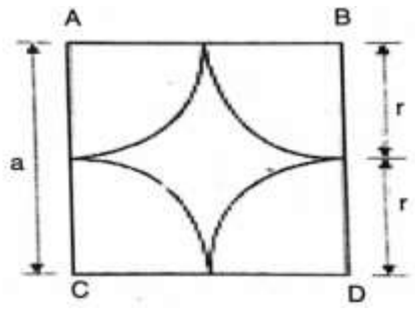
- The total number of atoms present in a unit cell is called number of atoms per unit cell.
- Atomic radius is defined as half of the distance between any two nearest neighbouring atoms in the crystal structure.
- Co-ordination number is defined as the number of nearest neighbouring atoms to any particular atom in the crystal structure.
- Packing factor is the ratio of the total volume occupied by the atoms in a unit cell (v) to the total volume of a unit cell (V).

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on atomic structure of the materials.

Detailed content of the Lecture:





- Number of atoms per unit cell $\frac{1}{8} \times 8 = 1$
- The lattice constant, a = 2r, *or* *Atomic radius* $r = \frac{a}{2}$
- The coordination number for simple cubic is 6.
- $\text{Atomic Packing Factor} = \frac{\text{Volume occupied by the total number of atoms per unit cell}}{\text{Total volume of the unit cell}}$

- Volume occupied by the total number of atoms per unit cell (v) $= 1 \times \frac{4}{3}\pi r^3, = 1 \times \frac{4}{3}\pi\left(\frac{a}{2}\right)^3 = \frac{4\pi a^3}{24}$

Volume of the unit cell $(V) = a \times a \times a = a^3$

$$\therefore \text{APF} = \frac{v}{V} = \frac{\pi a^3/6}{a^3} = \frac{\pi}{6} \quad or \quad \boxed{APF = 0.52}$$

- Atomic Packing Factor for simple cubic structure = 0.52
- It is understood that only 52 % of volume of the unit cell is only occupied by the atoms and the remaining area is kept vacant.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=ziFnzWBTazk

https://www.youtube.com/watch?v=rroulXtAxXk

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015,Page no.1.15-1.31

Course Faculty

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Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **IV Crystal Physics** **Date of Lecture:**

Topic of Lecture: Calculation of numberf of atoms, atomic radius, Packing factors for body centered cubic structure (BCC)

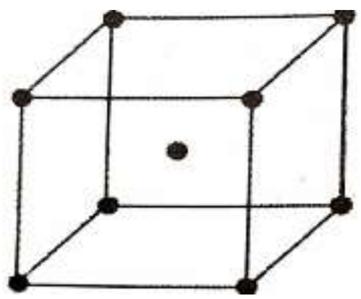
Introduction :

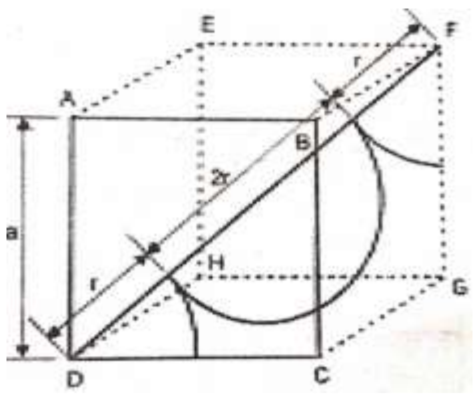
- The total number of atoms present in a unit cell is called number of atoms per unit cell.
- Atomic radius is defined as half of the distance between any two nearest neighbouring atoms in the crystal structure.
- Co-ordination number is defined as the number of nearest neighbouring atoms to any particular atom in the crystal structure.
- Packing factor is the ratio of the total volume occupied by the atoms in a unit cell (v) to the total volume of a unit cell (V).

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on atomic structure of the materials.

Detailed content of the Lecture:





- Number of atoms due to corner atom per unit cell $\frac{1}{8} \times 8 = 1$
- Number of atoms due to body centered atom / unit cell = 1
- **Total number of atoms per unit cell in BCC = 1 + 1 = 2**
- <u>Atomic Radius- BCC structure</u>

$$DF^2 = FG^2 + GD^2$$
$$= FG^2 + GC^2 + CD^2$$

$$= a^2 + a^2 + a^2$$

$$= 3a^2$$

$$or \quad DF = a\sqrt{3}$$

From the diagram, $DF = 4r$

Hence $4r = a\sqrt{3}$, $r = \frac{a\sqrt{3}}{4}$

Atomic radius of a BCC structure $r = \frac{a\sqrt{3}}{4}$

- Coordination number of BCC structure is 8
- Atomic Packing Factor $= \frac{v}{V}$

Volume of two spherical atoms $(v) = 2 \times \frac{4}{3}\pi r^3$ $\quad \because \quad r = \frac{a\sqrt{3}}{4}$

$$= \frac{8}{3}\pi r^3$$

$$= \frac{8}{3}\pi\left[\frac{a\sqrt{3}}{4}\right]^3, = \frac{8\pi}{3}\left[\frac{a^3 3\sqrt{3}}{64}\right], = \pi a^3\frac{\sqrt{3}}{8}$$

- Volume of the unit cell of a cubic system (V) = a^3

Atomic Packing Factor $= \frac{v}{V}$, $= \frac{\pi a^3 \sqrt{3}/8}{a^3}$, $= \frac{\pi\sqrt{3}}{8} = 0.68$

- **Atomic packing factor for BCC structure = 0.68**
- It is understood that 68 % of volume of the unit cell is occupied by the atoms and the remaining is kept vacant

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=8gJDNvOYiEA

https://www.youtube.com/watch?v=SZLAwTCMYzY

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015,Page no.1.11-1.35

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LECTURE HANDOUTS

L 33

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **IV Crystal Physics** **Date of Lecture:**

Topic of Lecture: Calculation of number of atoms, atomic radius, Packing factors for face centered cubic structure (FCC)

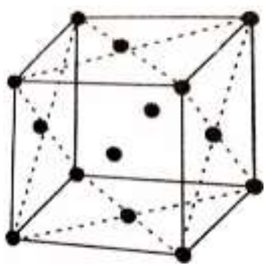
Introduction :

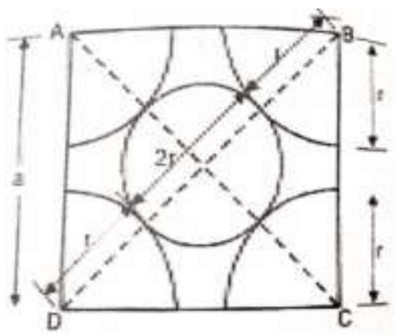
- The total number of atoms present in a unit cell is called number of atoms per unit cell.
- Atomic radius is defined as half of the distance between any two nearest neighbouring atoms in the crystal structure.
- Co-ordination number is defined as the number of nearest neighboring atoms to any particular atom in the crystal structure.
- Packing factor is the ratio of the total volume occupied by the atoms in a unit cell (v) to the total volume of a unit cell (V).

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on atomic structure of the materials.

Detailed content of the Lecture:





- Total number of atoms per unit cell in FCC structure is 4
- **Atomic radius of FCC structure**

$$AC^2 = AB^2 + BC^2$$
$$= a^2 + a^2$$
$$= 2a^2$$

or $AC = a\sqrt{2}$, From the diagram AC = 4r,Hence, $4r = a\sqrt{2}$, $r = \frac{a\sqrt{2}}{4}$

Atomic radius of FCC structure is = $\frac{a\sqrt{2}}{4}$

- total number of nearest neighbours in FCC structure = 12
- **Atomic packing factor**
- Total number of atoms per unit cell of a FCC structure = 4
- Volume of 4 spherical atoms (v) = $4 \times \frac{4}{3}\pi r^3$

$$= \frac{16}{3}\pi r^3$$

Since $r = \frac{a\sqrt{2}}{4}$ for FCC structure,

$$v = \frac{16}{3}\pi\left[\frac{a\sqrt{2}}{4}\right]^3 = \frac{16\pi}{3}\left[\frac{a^3\,2\sqrt{2}}{64}\right] = \frac{\pi a^3\sqrt{2}}{6}$$

- Volume of the unit cell for a cubic structure (V) = a^3
- Atomic packing factor =

$$\frac{\frac{\pi a^3\sqrt{2}}{6}}{a^3} = \frac{\pi\sqrt{2}}{6} = 0.74$$

- Atomic packing factor for FCC structure = 0.74
- In which 74% of volume of a unit cell is occupied by the atoms and remaining volume is vacant.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=-wqGxHQksSQ

https://www.youtube.com/watch?v=_h-Xv9nsJLc

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015,Page no.1.11-1.35

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LECTURE HANDOUTS

L 34

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **IV Crystal Physics** **Date of Lecture:**

Topic of Lecture: Calculation of number of atoms, atomic radius, Packing factors for Hexagonal closed packing structure (HCP)

Introduction :

- The total number of atoms present in a unit cell is called number of atoms per unit cell.
- Atomic radius is defined as half of the distance between any two nearest neighbouring atoms in the crystal structure.
- Co-ordination number is defined as the number of nearest neighboring atoms to any particular atom in the crystal structure.
- Packing factor is the ratio of the total volume occupied by the atoms in a unit cell (v) to the total volume of a unit cell (V).

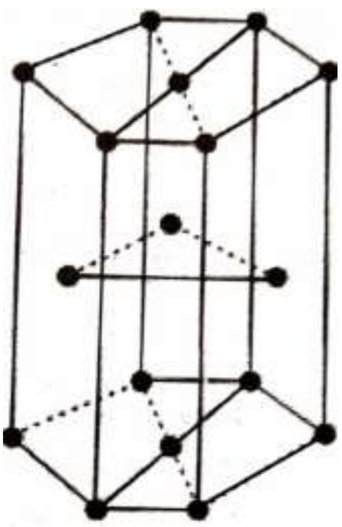
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on atomic structure of the materials.

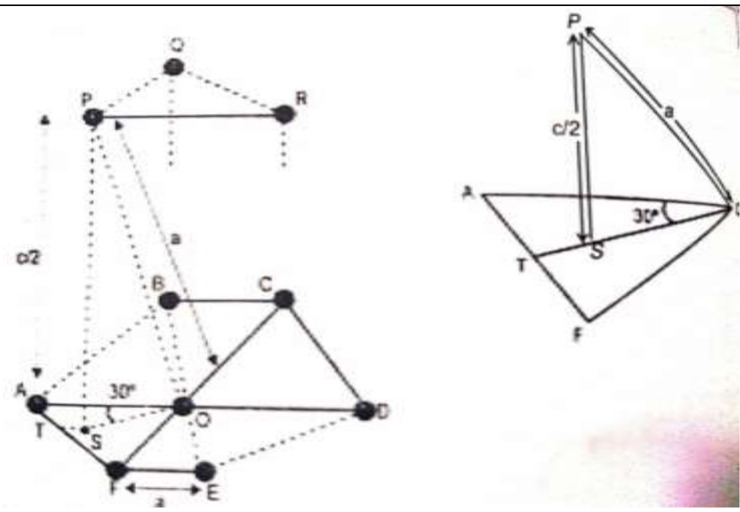
Detailed content of the Lecture:

Hexagonal Close Packed Structure (Hcp)

- Total no. of atom per unit cell in HCP structure is 6
- Co-ordination number is 12
- $\therefore$ Atomic radius $r = \frac{a}{2}$



Atomic packing factor:



- Volume of the atoms in a unit cell, v = $6\times\frac{4}{3}\pi r^3$,

  Since atomic radius

  $r = \frac{a}{2}$

  $v = \frac{24\pi}{3}\left(\frac{a}{2}\right)^3$,v

$= \pi a^3$

- Total volume of the HCP unit cell, V = Area of the base $\times$ height
- Area of the base = Area of 6 triangles

  = 6 $\times$ area of one triangle (OFA)

- area of the triangle OFA = $\frac{1}{2}\times$ AF$\times$ OT

  Substituting the value of OT from equation (1) and AF = a,

- Area of the triangle OFA = $\frac{1}{2}a^2\frac{\sqrt{3}}{2}$ = $\frac{a^2\sqrt{3}}{4}$, Area of the base = $6\times\frac{a^2\sqrt{3}}{4}$,= $\frac{3\sqrt{3}}{2}a^2$
- Total volume of the unit cell (V) = $\frac{3\sqrt{3}}{2}a^2\times c$
- Atomic packing factor = $\frac{\pi a^3}{\frac{3\sqrt{3}}{2}a^2 c}$ = $\frac{2\pi}{3\sqrt{3}}\left(\frac{a}{c}\right)$

  $= \frac{2\pi}{3\sqrt{3}}\sqrt{\frac{3}{8}} = \frac{\pi}{3\sqrt{2}} = 0.74$

Atomic packing factor for HCP = 0.74

- 74% of volume of the unit cell of HCP structure is occupied by the atoms and remaining is kept vacant.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=k4vUoT0LI6o

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015,Page no.1.11-1.35

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LECTURE HANDOUTS

L 35

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **IV Crystal Physics** **Date of Lecture:**

Topic of Lecture: Crystal defects-point defect and line defect

Introduction :

- Crystal defect is generally used to describe the deviation from the perfect periodic array of atoms in the crystalline materials.
- In an ideal crystal the atoms are arranged continuously in a perfect manner. But in real crystals, irregularities, imperfections, defeats and lattice distortions are generally present.
- The electrical and magnetic properties of the crystalline materials are affected by the imperfections in the crystals.

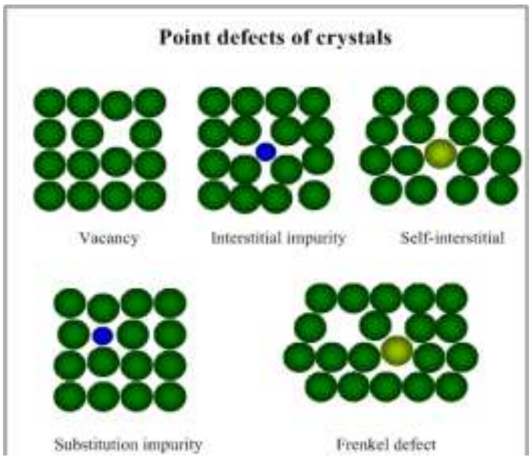
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on atomic structure of the materials.
- Basic knowledge on lattice, lattice plane, lattice vibration.

Detailed content of the Lecture:

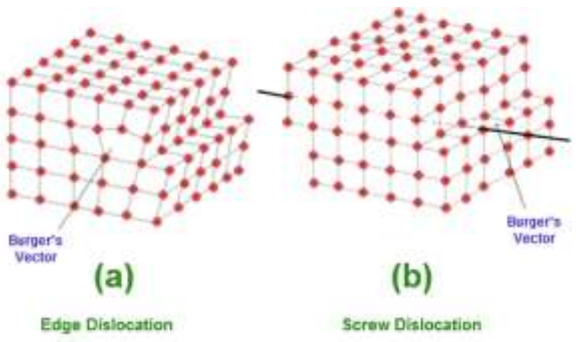
- The crystalline defects are broadly classified based on their geometry.
- Point defects, Line defects, Surface defects and Volume defects.

Point defects



- Point defects are called *zero dimensional defects*.
- The defect due to imperfect packing of atoms during crystallization is called *point defects.*
- The point defect increases the internal energy of the crystal and hence the value of mechanical strength at that point is reduced.
- Different types of point imperfections are Vacancies,Interstitials,Impurities,Electronic defeats

Line Defect



Line defects

- They are one dimensional imperfection and also called dislocations. A dislocation may be defined as a disturbed region between two perfect parts of a crystal.
- The dislocation is responsible for the phenomenon of slip by which the metals are deformed plastically.
- It is connected with the mechanical phenomena such as creep, fatigue and brittle fracture and helpful in explaining the crystal growth.
- The dislocations are arises due to i) Growth accidents ii) Thermal stresses iii) External stresses and iv) Phase transformations.
- The voids and vacant sites in the crystals favours the generation of dislocations.
- The dislocations are of two types namely,Edge dislocation and Screw dislocation.
- Creation of extra half plane or a plane that does not extend up to the base of the crystal is called edge dislocation.
- The displacement of the atoms in one part of the crystal related to the rest of the crystal is called screw dislocation.
- The magnitude and direction of this dislocation can be determined with the help of Burger vectors.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=ie-KfQionjY

Important Books/Journals for further learning including the page nos.:

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LECTURE HANDOUTS

L 36

PHYSICS

I / II

Course Name with Code : Engineering Physics / 21BSS01

Course Faculty :

Unit : IV Crystal Physics Date of Lecture:

Topic of Lecture: Crystal defects-surface defect, Burger vector

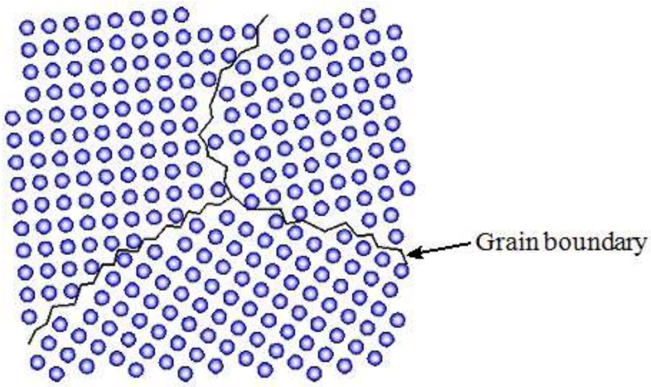
Introduction :

- They are *two dimensional* and also called plane defects. The surface defect is classified into i) External Surface Imperfections and ii) Internal Surface imperfections.
- The external surface of a crystal is an imperfection in itself, as the atomic bonds do not extend beyond the surface.
- Internal surface imperfection is due to change in stacking of atomic planes across the boundary

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on atomic structure of the materials.
- Basic knowledge on lattice, lattice plane, lattice vibration..

Detailed content of the Lecture:



External surface imperfections

- The atoms on the surface may be visualized and it cannot be compared with the atoms within the crystal.
- The atoms on the surface have neighbours on only one side, where as the atoms inside the crystal have neighbours on both side.
- The surface atom possesses energy higher than that of the internal atoms.

Internal surface imperfection

Grain Boundaries

- The grain boundaries are the surface imperfections which separate crystals of different orientations in a poly crystalline aggregate.

Tilt or twist boundaries

- When the neighbouring crystalline regions tilted with respect to each other by a small angle are called tilt or twist boundary.

Twin boundaries

- Surface imperfection which separate two orientations that are mirror images of one another are called twin boundaries.
- Twin boundaries occur in pairs, that the orientation change introduced by one boundary is restored by the other.

Stacking fault

- These imperfections caused due to fault in the stacking sequence of atomic planes. The FCC crystals having stacking layers

Ferro magnetic domain walls

- When two ferromagnetic regions differ from one another due to the direction of magnetization, the boundary between them is an imperfection and is called a ferromagnetic domain wall.
- The domain walls determine the magnetic properties of ferromagnetic materials.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=ecn8bPDV6Sc

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015,Page no.1.11-1.35

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Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **V Properties of matter and thermal physics** **Date of Lecture:**

Topic of Lecture: Elasticity, Hooke's law, Relationship between three modulii of Elasticity

Introduction :

- Elasticity is the property by virtue of which material bodies regain their original shape and size after the external deforming forces are removed.
- When the external force acts on a body, there is a change in its length, shape and volume. If a body recovers its original shape, size or volume completely on the removal of external forces, it is called *perfectly elastic body*.
- The bodies which do not regain their original shape and size are called *plastic bodies*.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on elastic properties of the materials

Detailed content of the Lecture:

Stress

- The restoring force per unit area over the elastic material is called ***stress***.
- Restoring force per unit area perpendicular to the surface is called *normal stress* and the restoring force parallel to the surface per unit area is called *tangential stress*.

Strain

- ***Strain*** is defined as the ratio of the change in shape to the original shape. Strain being ratio has no units. Longitudinal Strain, Shearing strain and Volume strain

HOOKE'S LAW

- The relationship between strain and stress is called Hooke's Law. According to this law stress is directly proportional to strain within the elastic limit. $\frac{\text{stress}}{\text{strain}} = E$
- E is a constant called coefficient of elasticity or modulus of elasticity.
- **Elastic Limit:** The maximum stress up to which a body exhibits the property of elasticity is called elastic limit.

Relationship between three modulus of Elasticity

- Young's Modulus (Y), Bulk modulus (K), Rigidity modulus (η)

the relation between Y, η and σ as

$$\eta = \frac{Y}{2(1+\sigma)} \quad and ------(1)$$

The relation between Y, K and σ as

$$K = \frac{Y}{3(1-2\sigma)} \quad ------(2)$$

Re arranging equation (1), we have

$$2+2\sigma = \frac{Y}{\eta} \quad ------(3)$$

Re arranging equation (2), we have

$$1-2\sigma = \frac{Y}{3K} \quad ------(4)$$

Adding equation (3) and (4), we have

$$3 = \frac{Y}{3K} + \frac{Y}{\eta}$$

$$= Y\left(\frac{1}{3K} + \frac{1}{\eta}\right)$$

$$\frac{3}{Y} = \frac{\eta+3K}{3K\eta}$$

$$or \quad \frac{1}{Y} = \frac{\eta+3K}{9K\eta}$$

$$or \quad Y = \frac{9K\eta}{\eta+3K}$$ is Relationship between three modulus of Elasticity

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=HALbtyDUjp0

https://www.youtube.com/watch?v=D5vnqohxEOI

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LECTURE HANDOUTS | **L 38**

PHYSICS | **I / I**

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **V Properties of matter and thermal physics** **Date of Lecture:**

Topic of Lecture: Stress- strain diagram, Poisson's ratio, Factors affecting elasticity

Introduction :

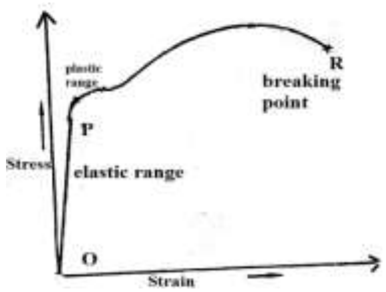
- The elastic properties of the metals can be studied under uniform stress using stress-strain diagram.
- Poisson's ratio is the relation between lateral strain and longitudinal strain
- Various factors such as temperature, stress and impurity affect the elastic property of the materials,depends on the factors elasticity may increase or decrease

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on elastic properties of the materials

Detailed content of the Lecture:

Stress- strain diagram



- The elastic properties of the metals can be studied under uniform stress using stress-strain diagram.
- When a material of uniform bar or wire is given stress continuously, the strain will be exhibit linearly up to the point P and it obeys Hook's law.
- Hook's law holds good only for the straight line portion of the curve (OP) called *elastic range*.
- When the applied stress is withdrawn, the material regains its original condition between the points O and P.
- The limit up to which the body regains its original condition when the stress is withdrawn is called *elastic limit*.
- If the stress applied increases gradually beyond P, the strain increases more rapidly. When the stress is removed in this range, the material does not regain its original condition. Hence this region is called as *plastic range*.
- If the stress-strain relation is studied beyond the plastic range, it is observed that the wire loses its

shape and become thinner in diameter and is breaks at the point R, called *breaking point*.

POISSON'S RATIO (γ)

- The ratio of lateral strain to longitudinal strain is called ***Poisson's ratio***.

Let the original length of the wire = L

Original Diameter of the wire = D

Increases in length = l

Decrease in diameter = d

$$\text{Poisson's ratio, } \gamma = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \frac{d/D}{l/L} = \frac{\beta}{\alpha}$$

Where β is lateral strain and α is longitudinal strain.

Factors Affecting Elasticity

- Effect of temperature: a rise in temperature reduces the elastic property of a material.
- The material like carbon filament is highly elastic at room temperature.
- In certain cases like invar steel, elasticity is unaffected by the change in temperature.
- Effect of impurities: The addition of impurity atoms to any material reduces its elastic property.
- The impurity atoms generally having different atomic radii and hence it acts as the centre of distortion and decreases the elastic property.
- Effect of hammering and rolling: While hammering or rolling, crystal grains break into smaller sizes which results the increase of elastic property.
- Effect of annealing:When the material is heated and then cooled (annealing), large crystal grains are formed in the crystalline structure. The larger crystal structure results in the reduction of the elastic property.
- Effect of stress:When the material is stressed, the elastic property decreases gradually

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=foE4IMFPAUE

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.2.3,2.8

Course Faculty

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Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **V Properties of matter and thermal physics** **Date of Lecture:**

Topic of Lecture: Bending moment, depression of a Cantilever

Introduction :

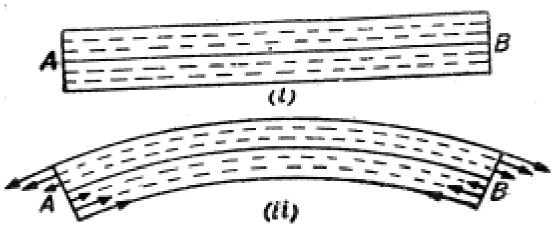
- A ***beam*** is defined as the rod of uniform cross-section (circular or rectangular) whose length is large in comparison to its breadth and thickness.
- Beams are used in the construction of bridges or for the purpose of supporting loads.
- A cantilever is a thin uniform beam fixed horizontally at one end and loaded with a weight at the other end.
-

Prerequisite knowledge for Complete understanding and learning of Topic:

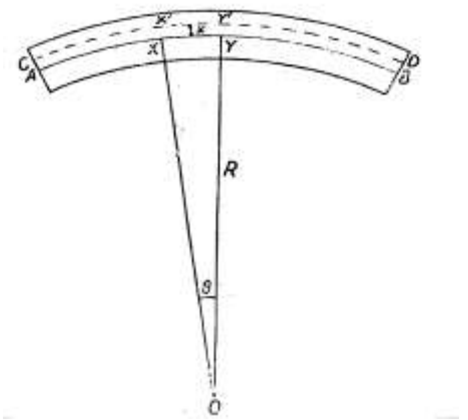
- Basic knowledge on elastic properties of the materials
- Knowledge on bending of beam and cantilever

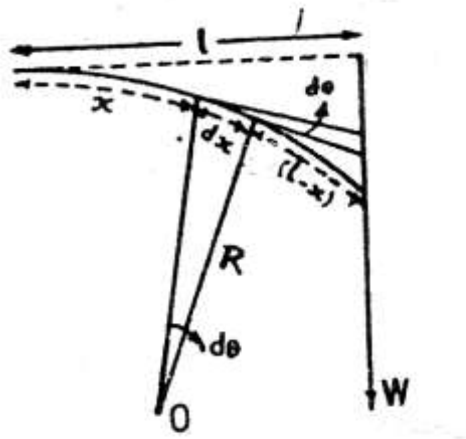
Detailed content of the Lecture:

Bending moment of a beam



- Let a beam fixed at one end is loaded at the other end as shown in the Figure.
- The load acts vertically downwards at its free end and the reaction at the support acts vertically upwards which constitute the ***external bending couple***.
- Due to elasticity, a restoring couple is developed inside the beam. The moment of this elastic couple is called the ***internal bending moment.***
- When the beam is in equilibrium, External bending moment = Internal bending moment





Expression for the bending moment

- XY = Rϑ and X'Y' = (R+ x)ϑ
- Increase in length = X'Y' – XY = (R+ x) ϑ – Rϑ = x ϑ

$$\text{Linear strain} = \frac{\text{increase in length}}{\text{original length}} = \frac{x\theta}{R\theta} = \frac{x}{R}$$

- $\text{Young's modulus Y} = \frac{\text{Stress}}{\text{Strain}}$ or $\text{Stress} = \text{Y} \times \text{strain} = \text{Y}\frac{\text{x}}{\text{R}}$
- Force acting on the element of area of cross-section δA is F = Stress × Area

$$= Y\frac{x}{R}\,\delta A$$

- The forces producing elongation on the upper region and producing contraction on the lower region of AB constitute a couple. Moment of the force about the neutral axis AB

$$= \left[\frac{Yx}{R}\delta A\right]x$$

$$= \frac{Yx^2\delta A}{R}$$

- The sum of moments of forces acting on all the filaments

$$= \sum\frac{Yx^2}{R}\delta A$$

$$= \frac{Y}{R}\sum x^2\delta A$$

Here $\sum x^2\delta A = Ak^2 = I_g$

- Where A is the area of cross-section and k is the radius of gyration. I_g is called the geometrical moment of inertia of the beam. Hence bending moment $= \frac{YI_g}{R}$

Depression of a cantilever

- Let AB represents the neutral axis of a cantilever of length *l,* fixed at the end A and loaded at B with a weight W. The end B is depressed to the position B'. The neutral axis AB shifts to the position AB'
- Consider an element PQ at a distance *x* from the fixed end A. the moment of the external couple or the deflecting couple = W (*l* - *x*)
- The moment of restoring couple or bending moment = $\frac{YI_g}{R}$

- Under equilibrium conditions both the moments are equal. $W(l-x) = \frac{YI_g}{R}$ ------(1)
- Where R is the radius of curvature of the neutral axis at P. let us consider the point Q at a smaller distance *dx* from P.

$$Let \quad \angle POQ = d\theta$$

$$or \quad PQ = R\,d\theta = dx$$

$$\therefore \quad R = \frac{dx}{d\theta} \quad -----(2)$$

Substituting equation (2) in equation (1), we get

$$W(l-x) = YI_g \left(\frac{d\theta}{dx}\right)$$

$$or \quad d\theta = \frac{W(l-x)\,dx}{YI_g} \quad -----(3)$$

- Draw tangents at P and Q and they meet at C and D. The angle between the tangents at P and Q is also equal to dθ. The depression CD = *dy*, Then dy = (*l* - *x*) dθ ----- (4)

Substituting the value of dθ from equation (3) $dy = \frac{W(l-x)^2 dx}{YI_g}$

Total depression caused by the load is

$$y = \int_0^l \frac{W(l-x)^2}{YI_g} dx$$

$$= \frac{W}{YI_g} \int_0^l l^2 - 2lx + x^2)\,dx$$

$$= \frac{W}{YI_g} \left[l^2 x - \frac{2lx^2}{2} + \frac{x^3}{3} \right]_0^l$$

$$y = \frac{Wl^3}{3YI_g} \quad ------(5)$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=7IeJgDSQkaw

https://www.youtube.com/watch?v=C-FEVzI8oe8

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.2.8-2.14

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LECTURE HANDOUTS

L 40

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **V Properties of matter and thermal physics** **Date of Lecture:**

Topic of Lecture: Young's modulus by uniform bending, I-shaped girders

Introduction :

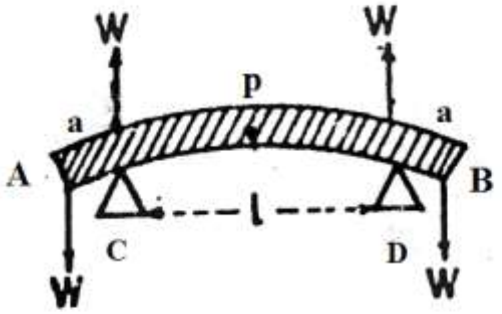
- The ratio of the longitudinal stress to the longitudinal strain within the elastic limit is called Young's modulus of elasticity. The unit of Young's modulus is N/m^2.
- If load is applied on both end of the beam and elevation is take place at the centre portion is called as uniform bending.
- The girders in the form of I-shape are called as I-shape grider.They are used in building construction.

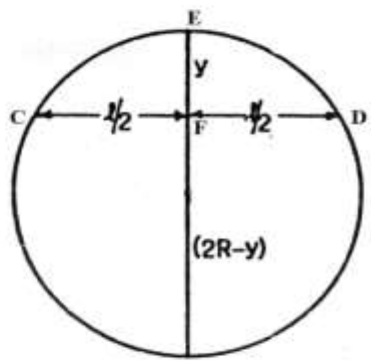
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on elastic properties of the materials
- Knowledge on uniform bending and non uniform bending

Detailed content of the Lecture:

Young's modulus by uniform bending





- Let AB is a beam supported on two knife edges C and D. Let CD = *l*. Equal weights are suspended at its ends A and B.Let AC = BD = *a*.
- The reactions at each knife edge act upwards. The beam bends into an arc of a circle of radius R. The elevation of the midpoint of the beam is *y*.
- The external bending moment with respect to P

$$= W\,(AP) – W\,(CP) = W\,(AP– CP) = W\,(AC) = Wa$$

- This external bending moment must be balanced by the internal bending moment $\frac{YI_g}{R}$

- $$\therefore \quad \frac{YI_g}{R} = Wa$$
$$\frac{1}{R} = \frac{Wa}{YI_g} \qquad ------(1)$$

$$EF\ (2R - EF) = CF^2 = y\,(2R - y) = (l/2)^2$$

$$y\,2R = \frac{l^2}{4} \qquad (y^2\ neglected)$$

$$y = \frac{l^2}{8R} \qquad ------(2)$$

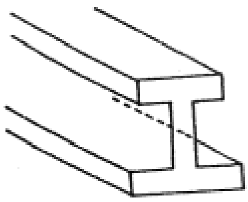
Substituting (1) in (2) $y = \frac{Wal^2}{8YI_g}$

Substituting $I_g = \frac{bd^3}{12}$ for a rectangular beam and W = mg,

$$y = \frac{mgal^2}{8Y(bd^3/12)}$$

$$or \qquad y = \frac{3mgal^2}{2bd^3Y}$$

I-shaped girders



- When a beam is depressed by applying a load, the layers above the neutral axis are elongated whereas the layers below the neutral axis are compressed.
- In which the central layer called neutral axis remains unaltered.
- The compression or elongation is proportional to the distance from the neutral surface.
- It is observed that the stress produced in the beams is maximum at the upper and the lower surfaces of the beam.
- Maximum amount of material will have to be located at these portions of maximum stress.
- The portions in between the top and bottom of the girder may have little stress or nil stress and hence they will be removed.
- A girder in the form of a rectangle or I- shaped will have the same strength.
- This is the reason for using the iron girders in the form of I shaped.
- This provides a high bending moment and thus large amount of material can be saved.

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=VoMrynNIceM
Important Books/Journals for further learning including the page nos.: Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.2.15-2.18

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LECTURE HANDOUTS

L 41

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **V Properties of matter and thermal physics** **Date of Lecture:**

Topic of Lecture: Modes of heat transfer

Introduction :

- When the temperature of a body increases, energy is said to be supplied to a body and is stored in the form of heat energy.
- Heat energy may be given to a body either by conversion of energy from some other form or by transferring heat from some other place.
- The heat energy is transmitted from the region of higher temperature to the region of lower temperature by the processes namely, Conduction, Convection and Radiation

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on Heat and thermodynamics

Detailed content of the Lecture:

Conduction

- When two bodies, one at higher temperature and another at lower temperature are kept in contact with one another, the temperature of the hot body decreases gradually, whereas the temperature of the cold body increases i.e., the heat energy is transferred from a body at higher temperature to a body at lower temperature.
- When the heat is supplied at one end of a metallic rod ,it is observed that the temperature of the other end increases gradually. This shows that the heat energy is transferred from the hotter end to the colder end. This kind of transfer of heat energy is called *thermal conduction*.
- Conduction is possible only in solid materials. Conduction cannot take place in liquids, gases and in vacuum.
- When the temperature at the one end is increases, the molecules start vibrating, collide with the neighbouring molecules and transfer some of their vibrating energy.

- The neighbouring molecules now start vibrating and transfer the energy again. Thus the heat transfers from one end to the other end by vibration without the actual movement of molecules. i.e., the particles remain in their mean positions of equilibrium.
- ***Conduction is the mode of transfer of heat from a hotter part of the body to its colder part, without the actual movement of the particles***.

Convection

- Convection is the process in which heat transfer takes place by the actual movement of heated particles. This is possible only in liquids and gases.
- A beaker containing water or any other liquid is heated by means of a burner. The heat energy is initially supplied to the lower region of the beaker.
- The water in this lower region becomes warmer and its density is decreased. The density of the water in the upper region is comparatively high than the water in the lower region.
- The water with less density in the lower region starts moving upwards replacing by the colder water particles.
- The cold water reaches the lower portion becoming warmer, move upward and again replaced by the cold water.
- It is concluded that the heat is transferred from one region to another region by the actual movement of heated particles of the medium. Such a process is called convection.
- ***Convection is the mode of transfer of heat from one part of the medium to another part by the actual movement of the heated particles.***

Radiation

- The process of conduction and convection requires the presence of material medium between the source and the receiver for the energy transfer.
- However, material medium is not necessary for radiation.
- It can travel through vacuum too. The heat radiations are electromagnetic in nature like light waves.
- The heat reaches from an electric lamp or from the sun is an example for the radiation.
- ***The radiation is the mode of transfer of heat from one body to another body without heating the intervening medium.***

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=FTSBtx5jhaY

https://www.youtube.com/watch?v=MUC098hvqH4

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LECTURE HANDOUTS

L 42

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **V Properties of matter and thermal physics** **Date of Lecture:**

Topic of Lecture: Thermal conductivity, Newton's law of cooling

Introduction :

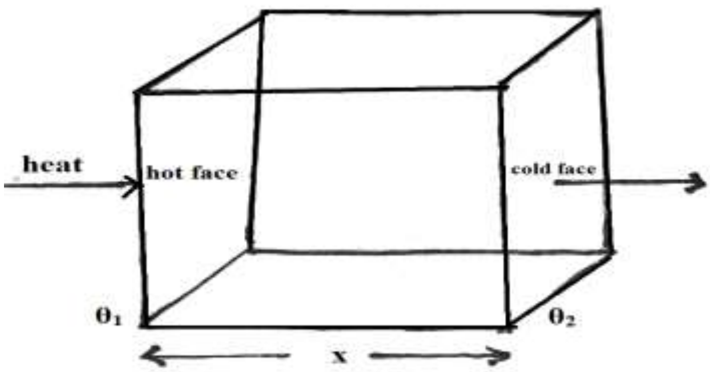
- The co-efficient of thermal conductivity is defined as the quantity of heat flowing is one second through a unit cube of material when its opposite faces are maintained at a temperature difference of 1^oC.
- The unit of thermal conductivity is W/m/k.
- Newton's law of cooling, for a small temperature difference between the body and its surrounding, the rate of cooling of a body is directly proportional to the temperature difference and the surface area.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on Heat and thermodynamics

Detailed content of the Lecture:

Thermal conductivity



- A solid material slab having thickness *x* and area of cross-section A.
- The opposite faces of the cube are maintained at the temperatures θ_1 and θ_2, where $\theta_1 > \theta_2$.
- The heat will start flowing from hot face to cold face and the direction of flow of heat will be normal to the two faces of the slab.
- The quantity of heat conducted (Q) from one face to another depends upon the following factors.

Q $\propto$ Area of cross-section (A)

$\propto$ Temperature difference between the two faces (θ_1- θ_2)

$\propto$ Time of conduction (t)

$\propto$ $1/x$ (inversely proportional to the thickness of the slab x)

In general, the heat conduction

$$Q \propto \frac{A(\theta_1 - \theta_2)t}{x}$$

$$Q = \frac{KA(\theta_1 - \theta_2)t}{x}$$

$$K = \frac{Qx}{A(\theta_1 - \theta_2)t}$$

Where, K is a constant called the coefficient of thermal conductivity of the material of the slab.

If A =1, (θ_1- θ_2) = 1, t =1 and x = 1,

K = Q

Newton's law of cooling

- According to Newton's law of cooling, for a small temperature difference between the body and its surrounding, the rate of cooling of a body is directly proportional to the temperature difference and the surface area.

$$\frac{dT}{dt} = -k(T - T_0)$$

- When dT/dt the rate of cooling, k the constant is depends on the nature of the surface involved and the surrounding temperature, T the temperature of the body and T_0 is the temperature of the surrounding.
- The –ve sign indicates that $T > T_o$ and dT/dt is the negative quantity i.e., temperature decreases with time.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=daJdFXNe99M

https://www.youtube.com/watch?v=brU-cAK0-8Q&vl=en

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.2.21-2.25

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MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS | **L 43**

PHYSICS | **I / I**

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **V Properties of matter and thermal physics** **Date of Lecture:**

Topic of Lecture: Linear heat flow Lee's disc method

Introduction :

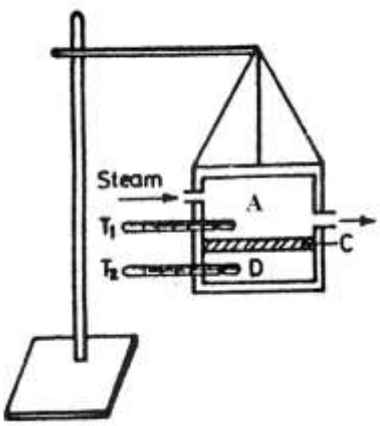
- Linear heat flow: Flow of heat along the linear path of the material
- This method is used to determine the thermal conductivity of poor conductors like glass, wood, cork etc.

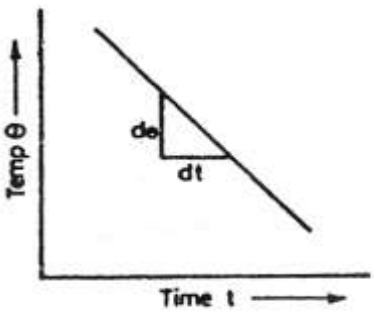
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on Heat and thermodynamics

Detailed content of the Lecture:

Lee's Disc Method





- This method is used to determine the thermal conductivity of p oor conductors like glass, wood, cork etc.
- The apparatus consists of a cylindrical steam chamber A through which steam can be passed. This chamber A is placed over a metallic disc D.
- The given bad conductor (C) having same area of cross – section as that of the disc D, whose thermal conductivity is to be determined is placed between them (A and D).

- Two thermometers T_1 and T_2 are inserted, one in the chamber A and other in the metallic disc D. ϑ_1 and ϑ_2 are the temperatures recorded by the thermometers T_1 and T_2 respectively.
- Steam is passed through the chamber and the temperatures recorded by the thermometers T_1 and T_2 are noted after the steady is reached. The heat passing through C in one second is equal to the heat radiated by the exposed surface of C in one second.

$$\therefore \qquad \frac{KA(\theta_1-\theta_2)}{x} = ms\frac{d\theta}{dt}\left[\frac{A+S}{2A+S}\right]$$

- Where, $\left[\frac{A+S}{2A+S}\right]$ is the total area exposed to the surrounding. A is the area of cross section of D or C, S is the area of the curved surface of D.
- $\frac{d\theta}{dt}$ is the rate of cooling at temperature ϑ_2, *m* is the mass and S is the specific heat of the material D.
- The disc C is then removed and makes the disc D in direct contact with the steam chamber A. when the temperature of D reaches about 10^{o}C higher than ϑ_2, the disc D is gently removed and placed over two knife edges.
- The fall of temperature is noted at a frequent interval of time.
- A graph is drawn between temperature and time.
- The value of $\frac{d\theta}{dt}$ at a temperature ϑ_2 is found. By knowing all the values, the thermal conductivity K can be calculated.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=iENG9VnBeP0

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.2.26-2.27

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LECTURE HANDOUTS **L 44**

PHYSICS **I / I**

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **V Properties of matter and thermal physics** **Date of Lecture :**

Topic of Lecture: Radial heat flow, Rubber tube method,

Introduction :

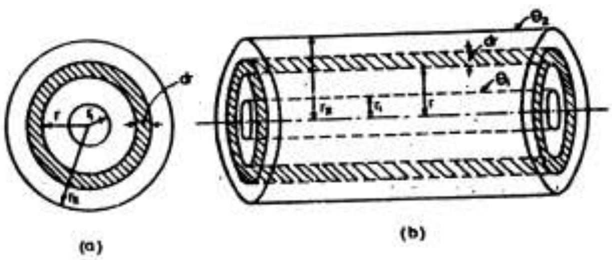
- Radial flow of heat: Flow of heat along the radial distance of the cylindrical tube.

Prerequisite knowledge for Complete understanding and learning of Topic:

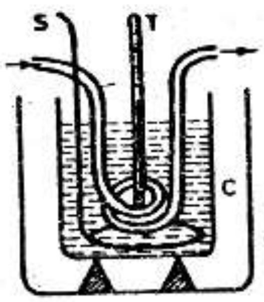
- Basic knowledge on Heat and thermodynamics

Detailed content of the Lecture:

Radial heat flow



(a) (b)



- Thermal conductivity can be determined by radial heat flow method and the quantity of heat flowing per second is determined by using a constant flow calorimeter.
- Calorimeter with stirrer is used for the determination of thermal conductivity of rubber.
- The calorimeter is kept inside the wooden box and the space between them is filled with some insulating material to avoid heat loss.
- Initially an empty calorimeter is weighed (m_1) and then filled with water. The mass of the calorimeter with water is weighed again. The mass of the water is m_2.
- Let 'l' be length of the rubber tube immersed in water. Using thermometer the initial temperature of water is noted as θ_1, Steam is passed through one end of the tube.
- The contents of the calorimeter are stirred well. The heat will flow radially through the wall of the

rubber tube to the outer surface.

- Temperature of water out side the rubber tube is raised. Steam is cut off for a known period of time't'. Now the water is stirred well and the temperature is noted again as θ_2.
- The average temperature of the outer surface is $(\theta_1+\theta_2)/2$. Let r_1 and r_2 be the inner and outer radii of the tube.
- The quantity of heat flowing through the tube per second

$$Q=\frac{(m_1s_1+m_2s_2)(\theta_2-\theta_1)}{t} \quad \text{---------} \ (1)$$

- Where, s_1 and s_2 are the specific heats of calorimeter and water. The thermal conductivity of rubber can be determined using the radial heat flow equation,

$$K=\frac{Q\log(r_2/r_1)}{2\pi lt} \quad \text{------------} \ (2)$$

Substituting the value of Q from equation (1) in equation (2)

$$K=\frac{(m_1s_1+m_2s_2)(\theta_2-\theta_1)\log(r_2/r_1)}{2\pi lt}$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=PkcGgaxujJg

https://www.youtube.com/watch?v=X4OzT-wYC_8

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.2.22-2.23

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LECTURE HANDOUTS

L 45

PHYSICS

I / I

Course Name with Code : **Engineering Physics / 21BSS01**

Course Faculty :

Unit : **V Properties of matter and thermal physics** **Date of Lecture:**

Topic of Lecture: Conduction through compound media (series and parallel)

Introduction :

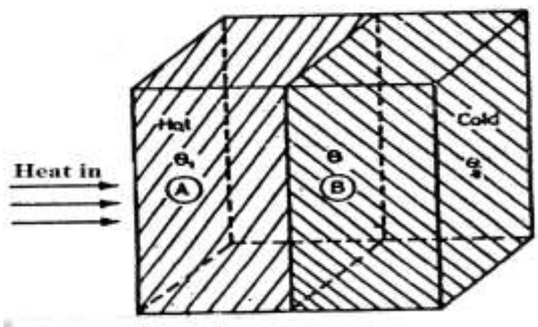
- Conduction of heat through compound media is the flow heat through more than one media, it may be joined together in series or parallel mode.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge on Heat and thermodynamics

Detailed content of the Lecture:

Conduction through compound media (bodies in series)



- Consider a slab made of two different materials A and B of thickness x_1 and x_2.
- Let ϑ_1 and ϑ_2 are the temperatures of the end faces of the slab and ϑ is the temperature of the common surface.
- K_1 and K_2 are the thermal conductivity of the materials A and B respectively.
- The heat is assumed to flow from A to B i.e., $\vartheta_1 > \vartheta_2$.
- When the steady state is reached, the same amount of heat will flow across any cross-section of a slab.

- For the material A,The amount of heat flowing, $Q = \dfrac{K_1 A(\theta_1 - \theta)}{x_1}$

- For the material B,

  The amount of heat flowing, $Q = \dfrac{K_2 A(\theta - \theta_2)}{x_2}$

  In the steady state condition,

$$Q = \frac{K_1 A(\theta_1 - \theta)}{x_1} = \frac{K_2 A(\theta - \theta_2)}{x_2}$$

$$\frac{K_1 A\theta_1}{x_1} - \frac{K_1 A\theta}{x_1} = \frac{K_2 A\theta}{x_2} - \frac{K_2 A\theta_2}{x_2}$$

$$\frac{K_1 A\theta_1}{x_1} + \frac{K_2 A\theta_2}{x_2} = \frac{K_2 A\theta}{x_2} - \frac{K_1 A\theta}{x_1}$$

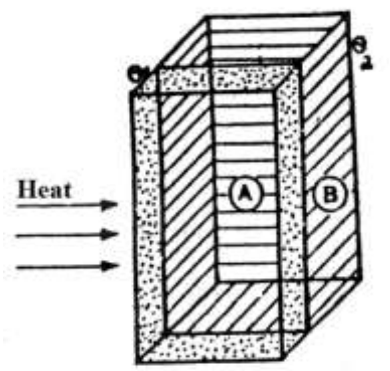
$$or \quad \frac{K_1 A\theta_1}{x_1} + \frac{K_2 A\theta_2}{x_2} = \left[\frac{K_2}{x_2} + \frac{K_1}{x_1}\right]\theta$$

$$or \quad \sum \frac{K_1\theta_1}{x_1} = \sum \frac{K_1}{x_1}\theta$$

$$\theta = \frac{\sum K_1\theta_1/x_1}{\sum K_1/x_1}$$

By substituting the values, the heat flowing through a compound section can be calculated.

Conduction through compound media (bodies in parallel)



- Consider a slab made of two different materials arranged in parallel as shown in Figure.
- Let K_1 and K_2 are the thermal conductivities of two materials of thickness x_1 and x_2 respectively.

- ϑ_1 and ϑ_2 are the temperatures of two opposite faces. A_1 and A_2 are the area of cross-section of the materials.
- The amount of heat flowing (Q_1) across the material of cross-section A_1 is

$$\frac{K_1 A_1(\theta_1 - \theta_2)t}{x_1}$$

- The amount of heat flowing (Q_2) across the material of cross-section A_2 is

$$\frac{K_2 A_2(\theta_1 - \theta_2)t}{x_2}$$

- The total heat flowing will be the sum of these two heats.
- Total heat flowing in *t* seconds through the compound media Q,

$$= \frac{K_1 A_1(\theta_1 - \theta_2)t}{x_1} + \frac{K_2 A_2(\theta_1 - \theta_2)t}{x_2}$$

$$= (\theta_1 - \theta_2)t\left(\frac{K_1 A_1}{x_1} + \frac{K_2 A_2}{x_2}\right)$$

$$= (\theta_1 - \theta_2)t\sum \frac{K_i A_i}{x_i}$$

$$\text{rate of heat flow } = \frac{Q}{t} = (\theta_1 - \theta_2)\sum \frac{K_i A_i}{x_i}$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=R-5McNR2274

Important Books/Journals for further learning including the page nos.:

Sudarmozhi.G., Engineering Physics I , Bharath Publishers , 2015, Page no.2.22-2.25

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