19RAC10-METROLOGY AND MEASUREMENTS

Unit -I
Basic Concepts of Metrology

- ***CALIBRATION – Comparison***
- ***METROLOGY – Science of Measurement***
- ***TRACEABILITY – Unbroken Chain of Comparisons***
- ***UNCERTAINTITY – Error in Measurement***
- ***ACCREDITATION – Third Party Ascertain***
- ***CALIBRATION INTERVAL – Equipment Remains Reliable***

WHAT IS METROLOGY

SCIENCE OF MEASUREMENTS

Everything has to do with measurement

Experiment or test

Designing

Conducting

Analyzing Results

within the Metrology realm

CAN BE SEEN EVERYWHERE

Allowing people to plan their lives and make commercial exchange with confidence

METROLOGY

- ***Metrology Covers Three Main Tasks:***
- ***The definition of internationally accepted units of measurement***
- ***The realization of units of measurement by scientific method***
- ***Establishment of traceability chain in documenting the accuracy of a measurement***

"Metrology is essential in scientific research"

CATEGORIES OF METROLOGY

- ***Scientific Metrology – Development of measurement standards***
- ***Industrial Metrology – To ensure the adequate functioning of measurement instruments used in industry, production & testing laboratories***
- ***Legal Metrology or Weights & Measures – Accuracy of measurement where these have influence on the transparency of economic transactions, health & safety***

AREAS OF INDUSTRIAL METROLOGY

- ***Mechanical Metrology – Realises , maintains and disseminates the national measurement standards in the areas of Mass, Volume, Pressure and Dimension***

- ***Electrical Metrology –– Realises , maintains and disseminates the national measurement standards in the areas of AC/DC, low frequency, time & frequency and temperature***

LEGAL METROLOGY

- ***Services offered by legal metrology are:***
- ***Mass measurements verification: verification of all mass measuring instruments (balances, trade masses etc.)***
- ***Volume measuring instruments : verification of fuel dispensers, tankers , meters etc.***
- ***Prepackaging control :verification of quantities in prepackaged products (mass, volume, length, number etc.)***

Units of Measurement

SI Units published by BIPM(***Bureau of Weights and Measures***)

Base Units...

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Electric current	ampere	A
Luminous intensity	candela	cd
Amount of substance	mole	mol

Metrology Laboratories

- Primary Laboratories NML, NMI, NPL etc
- Reference Laboratories
- Calibration Laboratories

Measurement Uncertainty

“ non-negative parameter characterizing the dispersion of ***the quantity values*** *being attributed to a* ***measurand,*** *based on the information used”*

It arises due to ***the imperfections in the measurement system***

No measurement system is perfect !!!!!

Uncertainty

An estimate of the possible error in a measurement

Type A evaluation

A series of repeated observations is obtained to determine the standard deviation of the measurement result.

Type B evaluation

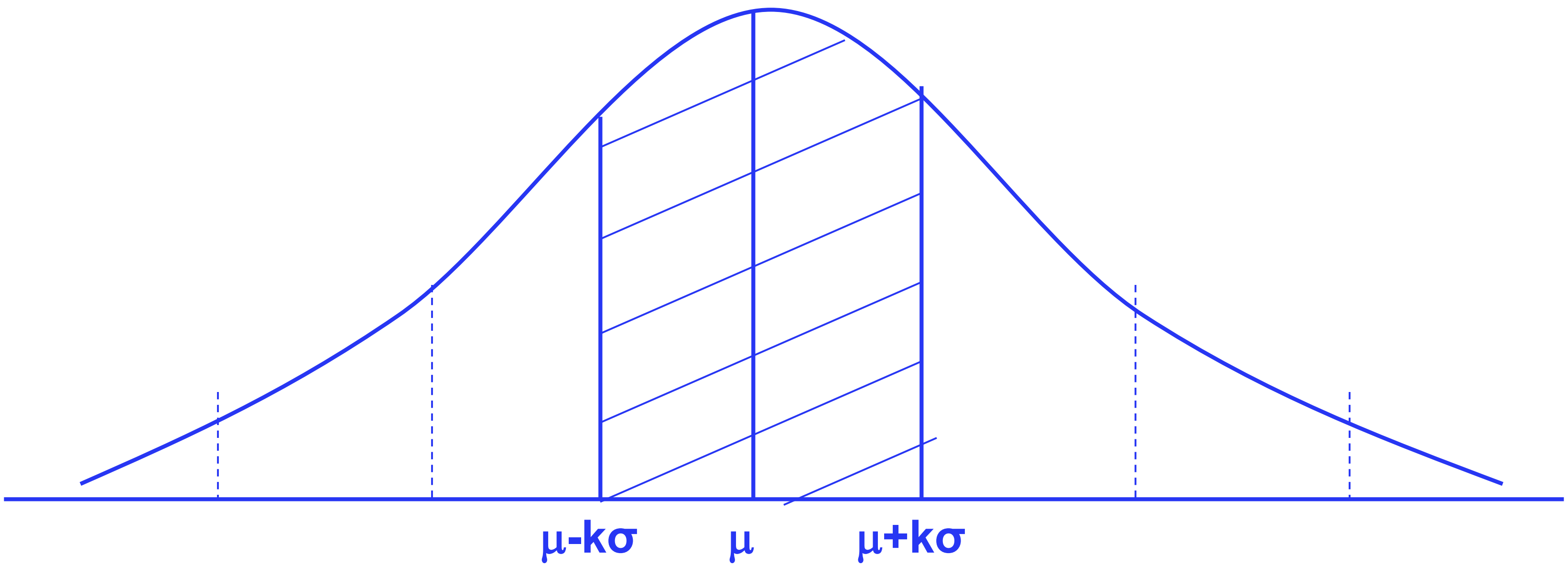
The evaluation is carried out using available information found in calibration reports, certificates, specifications etc.

Expanded Uncertainty

Calculate combined standard uncertainties

Exp. Unc. U = Combined Uncertainty X Coverage factor

Gaussian probability distribution



68% → Within 1σ of mean
95% → Within 2σ of mean
99% → Within 3σ of mean

CALBRATION INTERVALS

What is Calibration interval ???

Period of time of use to ensure the equipment remains reliable

Interval is too short : Calibration $$$$$

Interval too long : Risk of bad measurements

CALBRATION INTERVALS

ISO 17025 Requirements:

- ***Capable of achieving required accuracy***
- ***Comply with specifications relevant to test/calibration method***
- ***Use under established calibration programme***

Therefore need to :

- ***Define required accuracy***
- ***Identify the equipment that can affect it***
- ***Manage all equipment under a calibration programme***

RECOMMENDED CALBRATION INTERVALS

N No single correct answer → Calibration represents an instantaneous snapshot of actual condition

Depend upon

- ❖Level of stress - subjected
- ❖Stability of past calibration
- ❖Allowable tolerance range
- ❖Required accuracy
- ❖Quality Assurance Requirements

Consider influencing factors and existing knowledge : eg

- ***Accuracy sought & consequences of error***
- ***Manufacture's recommendations***
- ***Accommodation & environment***
- ***Purpose and usage***
- ***Maintenance & servicing***
- ***Trends from previous calibration***
- ***Frequency of checks***
- ***Etc. etc. etc. ….***

Ref. - ILAC – G 24 : Guidelines for determination of calibration interval of

measuring instruments

RECOMMENDED PRACTICES

- Calibration at (planned) periodic intervals to ensure acceptable accuracy & reliability
- Shorten the intervals when results of previous calibration suggest it
- May lengthen intervals on basis of demonstrated performance
- Documented procedure for assigning and adjusting calibration intervals
- Fully documented re-calibration system

Unit –II

Linear and Angular Measurements

GAUGES

- Gauges perform an essential services in any scheme of quantity production on an interchangeable basis
- A gauge (or Limit Gauge) is a tool or instrument to measure or compare a component.
- It is employed in the sense of an instrument which having fixed dimension, is used to determine whether the size of some component exceeds or is less than the size of the gauge itself

THE TAYLOR PRINCIPLE

<u>Taylor's Principle lays it down</u>:

1. A GO Gauge will check all the dimensions of the work piece in what is called the maximum metal condition (indicating the presence of the greatest amount of material permitted at a prescribed surface)
2. That NOT GO Gauges shall check only one dimension of the work piece at a time, for the minimum metal conditions (indicating the presence of the least amount of material permitted at a prescribed surface) size

THE TAYLOR PRINCIPLE (Cont..)

- In case of hole, the maximum metal condition obtains when the hole is machined to the low limit of size, & minimum metal condition results when the hole is made to the high limit of size.
- in case of shaft the limits taken would be inverse of hole

Classification of Limit Gauges

- Production gauges are of various types, but there is a little doubt that the majority are in the form of limit gauges.
- These are designed to cover a very wide range of work.
- The general form of limit gauges is of the fixed type. That is to say, gauging contact elements remain fixed during the gauging process.
- Gauging elements, however, may be provided with means for size adjustment

Classification of Limit Gauges (cont..)

Following gauges are the most commonly used in production work. The classification is principally according to the shape or purpose for which each is used.

1. Snap gauges
2. Plug gauges
3. Ring gauges
4. Length gauge
5. Form Comparison Gauge
6. Thickness Gauges
7. Indicating Gauges
8. Pneumatic Gauges

Classification of Limit Gauges (cont..)

9. Electric Gauges
10. Electronic Gauges
11. Projecting Gauges
12. Multiple Dimension Gauges

Description of some commonly used gauges:

1. Snap Gauges:
   a. A Snap gauge is used in the measurement of external dimensions,
   b. It consist of a U-shaped frame having jaws equipped with suitable gauging surfaces.
   c. A plan gauge has two parallel jaws or anvils which are made to some standard size & cannot be adjusted
   d. They may be either single-or double -ended

Description of some commonly used gauges: (Cont..)

1. Snap Gauges: (Cont..)
    e. Special forgings & stampings are available commercially for their manufacture, or they may be constructed from gauge plate
    f. Special snap or gap gauges may have to be used for checking the recessed diameters & other features

Snap Or Gap Gauge

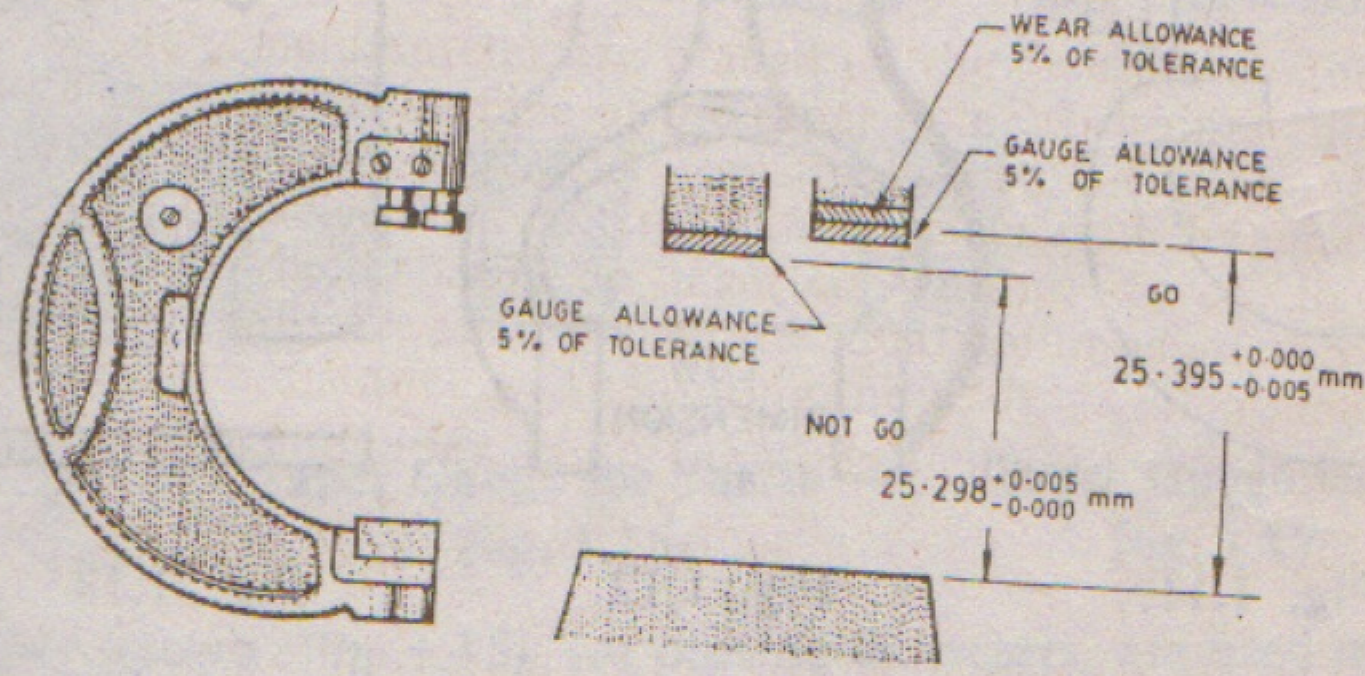


Fig. 1.10 **Snap Gauge**

Description of some commonly used gauges: (Cont..)

2. Plug Gauges:
   - A plain plug gauge is an accurate cylinder used as an internal gauge for size control of holes
   - It is provided with a suitable handle for holding & is made in a variety of styles
   - These gauges may be either single or double ended
   - Double ended plain gauges have “GO” and “NOT GO” members assembled on opposite ends, where as Progressive gauges have both gauging sections combined on one side

Description of some commonly used gauges: (Cont..)

2. Plug Gauges: (cont..)

Possible Forms of Plug Gauges:

a. Solid Type (Double ended)
b. Solid Type (Single ended)
c. Renewable-end type (Double ended)
d. Progressive Type
e. Shell form type (Double ended)
f. Shell form type (Single ended)
g. Bar end Type
h. Special Types

Plug Gauge

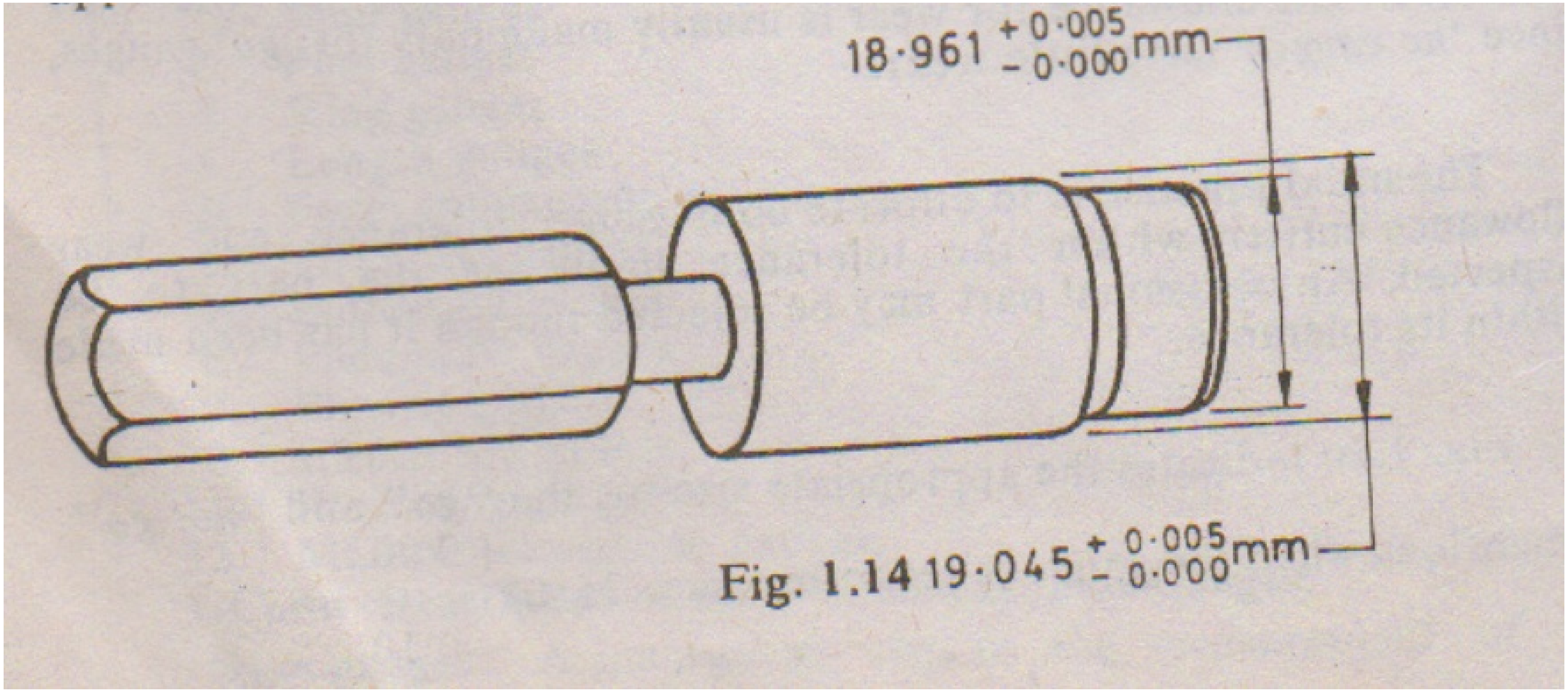


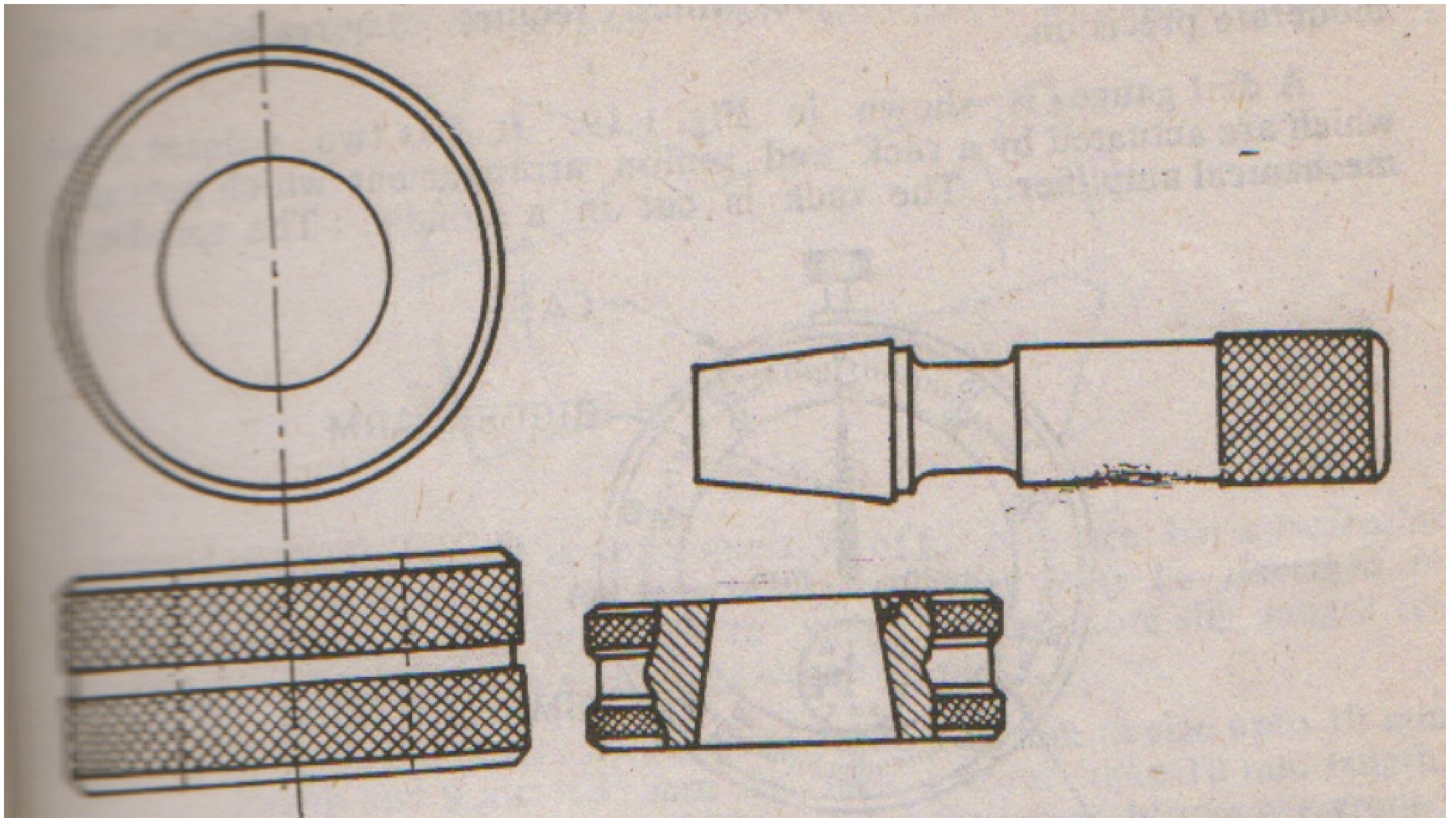
Fig. 1.14

Description of some commonly used gauges: (Cont..)

3. Ring Gauges:
   - Used to gauge outside diameters
   - Used in Pairs as “Go” & “Not Go”

4. Taper Gauges:
   - Taper gauges are not dimensional gauges but rather a means of checking in terms of degrees
   - Their use is a matter more of fitting rather than measuring

Ring, Taper Plug & Taper Hole Gauge



Ring Gauge
Fig. 1.15

Taper Gauge for Shafts
Fig. 1.16

Taper Gauge for Holes
Fig. 1.17

Description of some commonly used gauges: (Cont..)

5. Thickness or Feeder Gauge:
   - It consist of a number of thin blades & is used in checking clearances & for gauging in narrow places
6. Dial Gauge:
   - Dial gauges or Dial Test Indicators are used for checking flatness of surfaces & parallelism of bars & rods
   - They are also used for testing the m/c tools
   - They can also be used for measurement of linear dimensions of jobs which require easy readability & moderate precision

Thickness Gauge

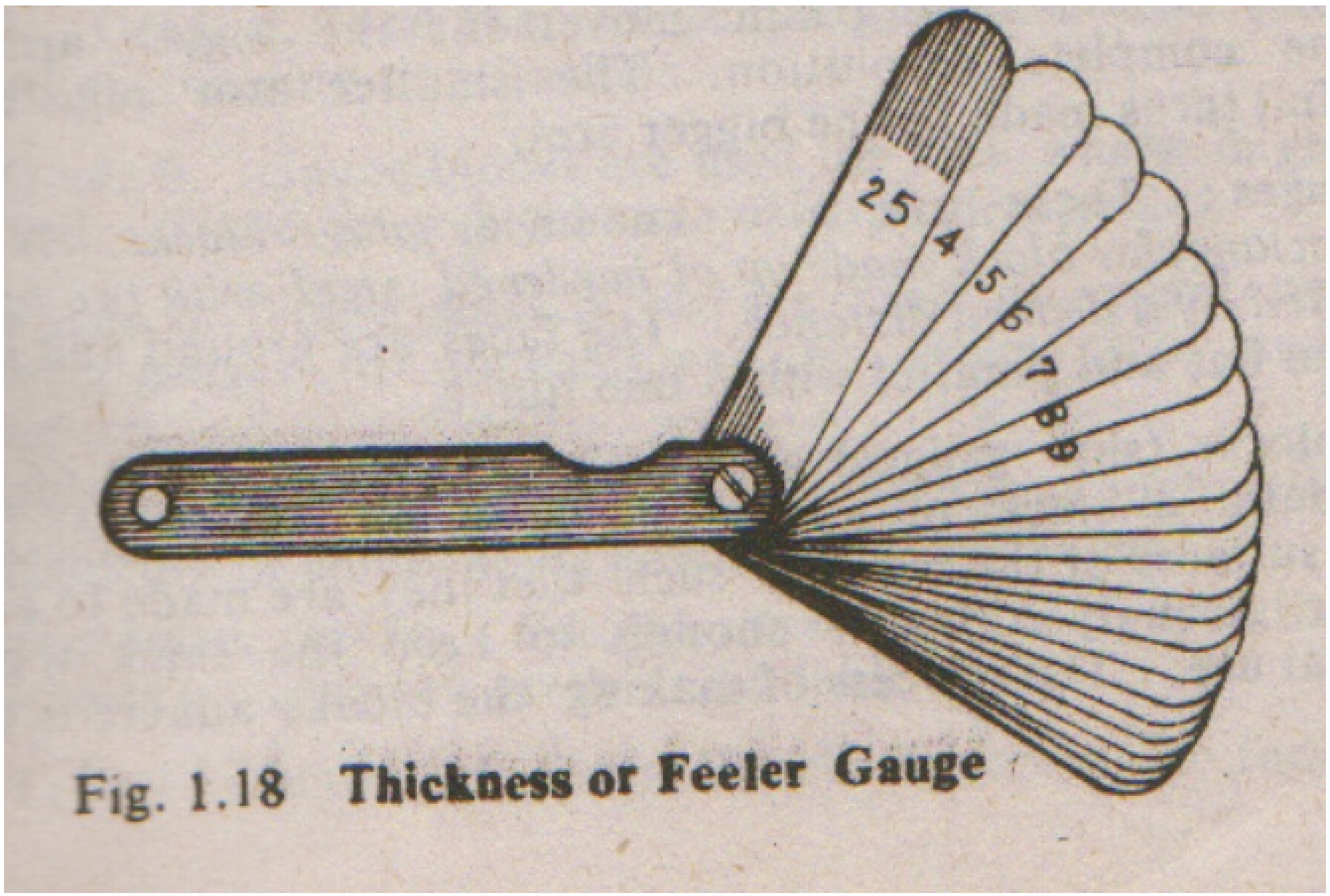


Fig. 1.18 **Thickness or Feeler Gauge**

Dial Gauge

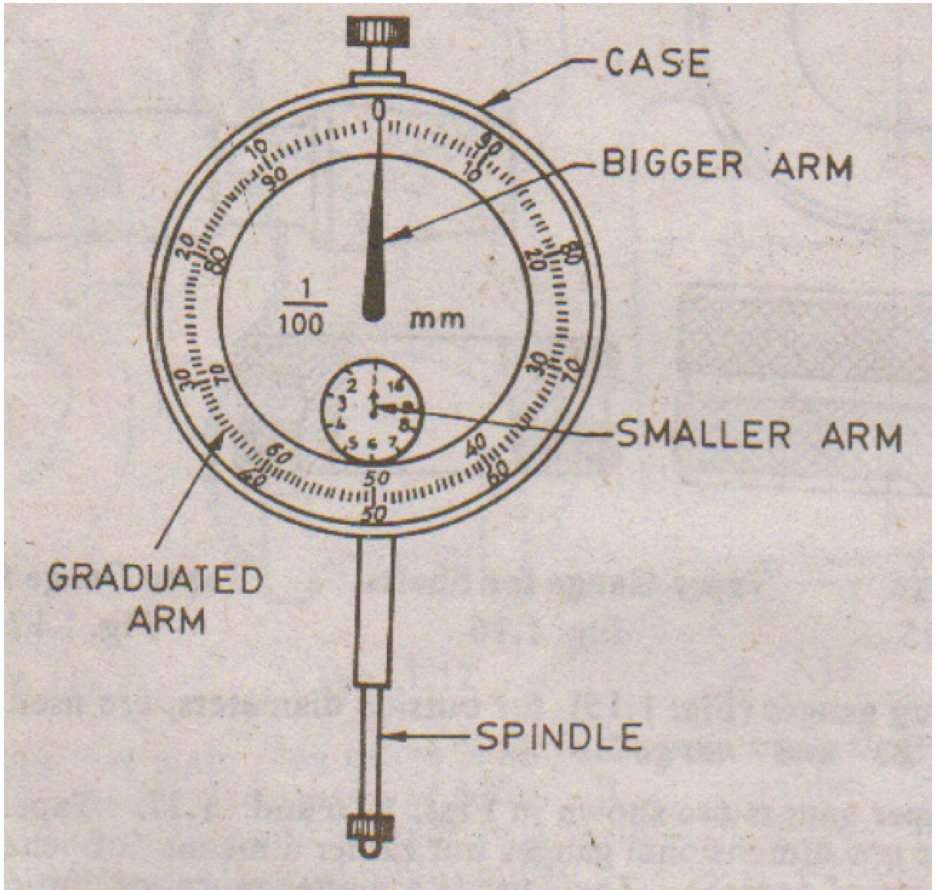


Fig. 1.19 Dial Gauge

Unit -III

Advances in Metrology

Lecture Contents

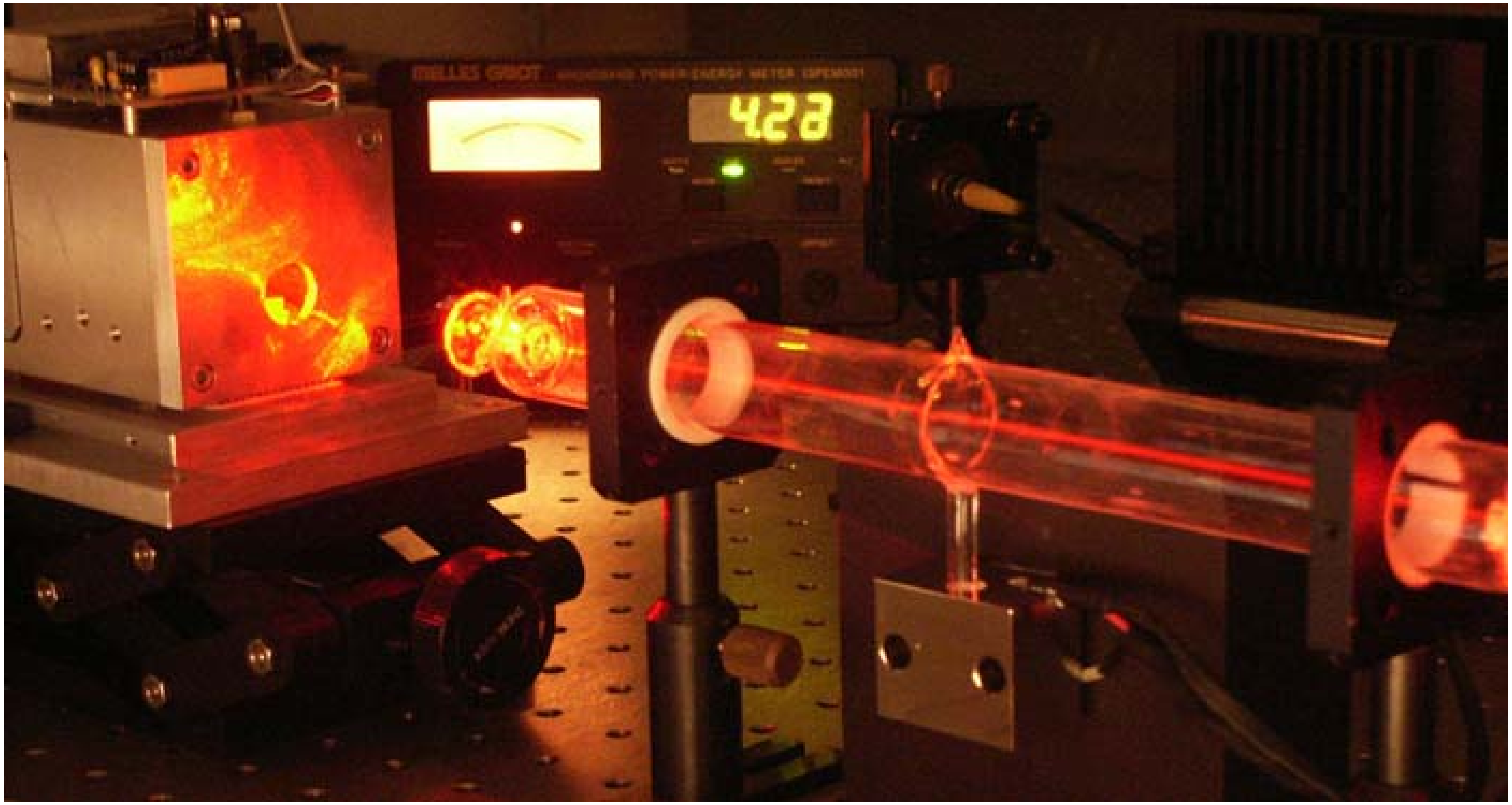
- Definition of lasers
- Emission and absorption of radiation
- Population Inversion
- Semiconducting lasers
- Materials used for semiconducting laser
- Laser for fibre optics communication
- Quantum Well devices

Laser

Objectives (by the end of the lectures on laser student will be…)

1. Able to state the definition of laser
2. Able to state the principle of population inversion
3. Able to explain the principle of semiconducting laser
4. Familiarise with the concept of light simulation and polarisation
5. Able to list down all materials criteria and materials selection for a given semiconducting laser compound.
6. Able to highlight several examples of the application of laser.

Diode Laser



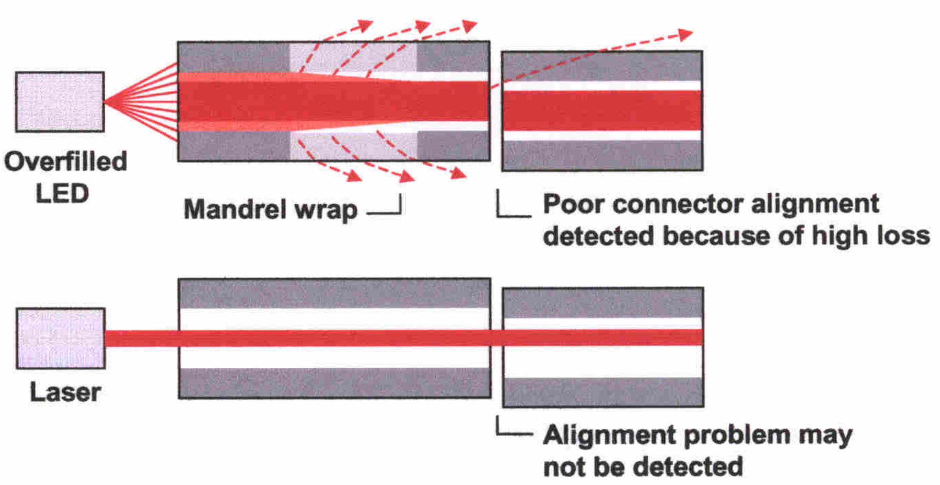
1. Definition of laser

- A laser is a device that generates light by a process called STIMULATED EMISSION.
- The acronym LASER stands for Light Amplification by Stimulated Emission of Radiation
- Semiconducting lasers are multilayer semiconductor devices that generates a coherent beam of monochromatic light by laser action. A coherent beam resulted which all of the photons are in phase.

Application of Laser – Fibre Optics

- An example of application is for the light source for fibre optics communication.
- Light travels down a fibre optics glass at a speed, = c/n, where n = refractive index.
- Light carries with it information
- Different wavelength travels at different speed.
- This induce dispersion and at the receiving end the light is observed to be spread. This is associated with data or information lost.
- The greater the spread of information, the more loss
- However, if we start with a more coherent beam then loss can be greatly reduced.

Fibre Optics Communication

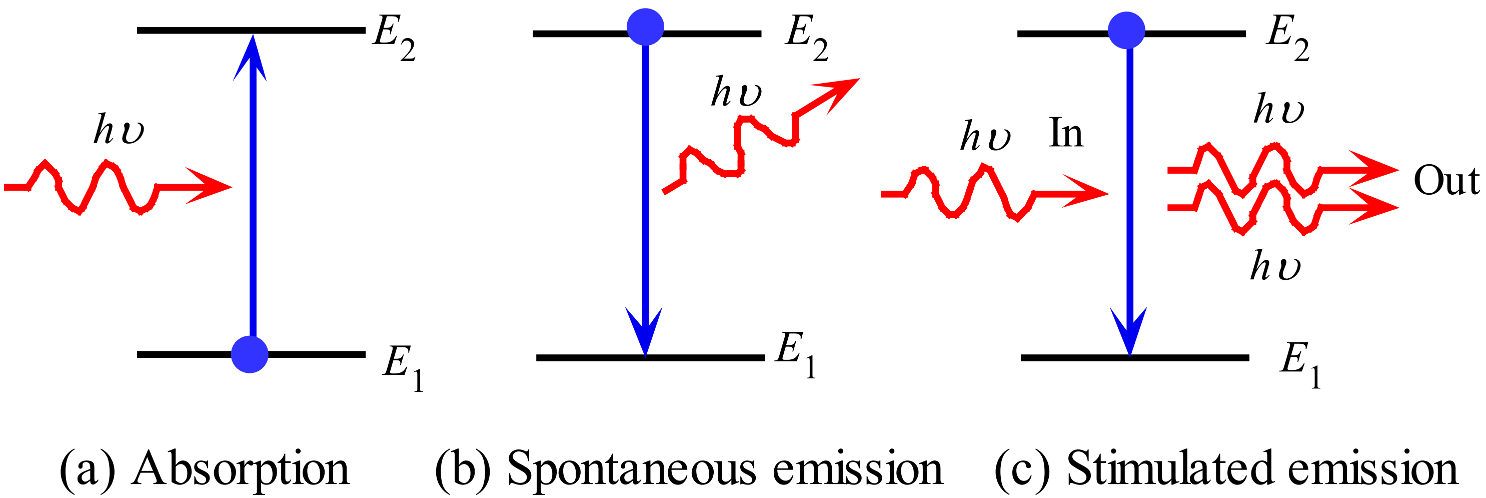


Background Physics

- In 1917 Einstein predicted that:
  - under certain circumstances a photon incident upon a material can generate a second photon of
    - Exactly the same energy (frequency)
    - Phase
    - Polarisation
    - Direction of propagation
  - In other word, a coherent beam resulted.

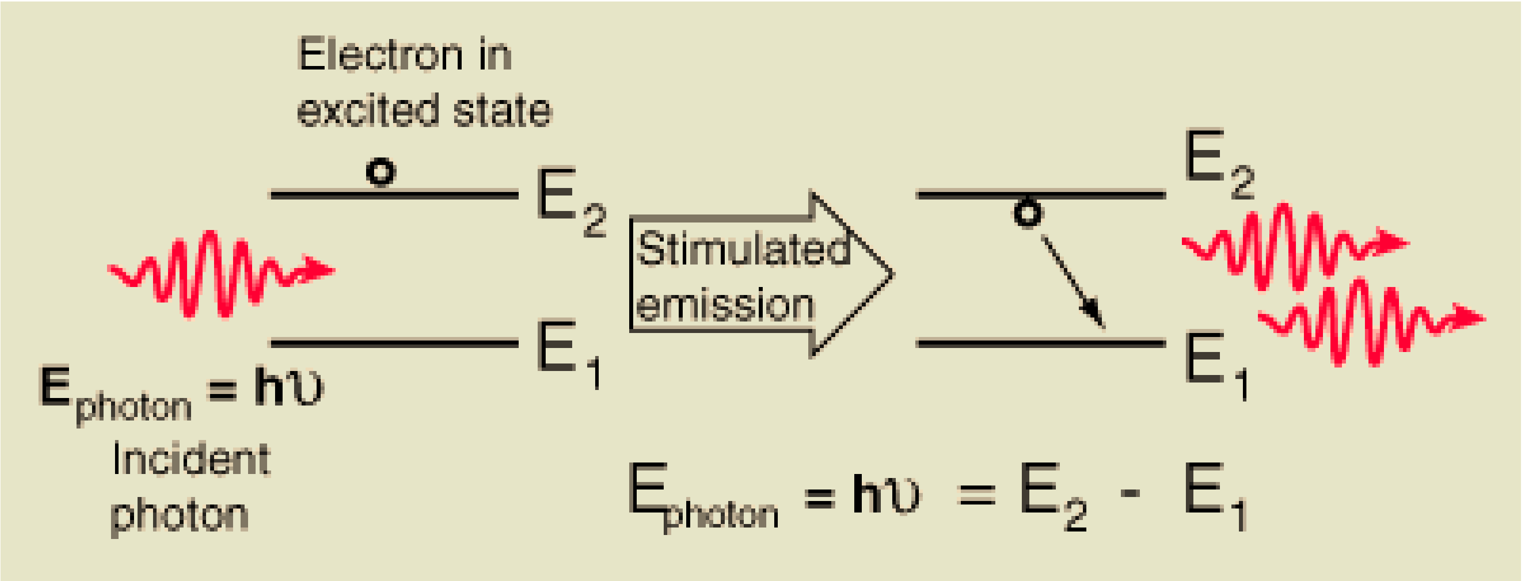
Stimulated Emission

- Consider the ‘stimulated emission’ as shown previously.
- Stimulated emission is the basis of the laser action.
- The two photons that have been produced can then generate more photons, and the 4 generated can generate 16 etc… etc… which could result in a cascade of intense monochromatic radiation.



Absorption, spontaneous (random photon) emission and stimulated emission.

Stimulated Emission



- In a system, all three mechanisms occur.
- However the stimulated emission is very very sluggish compared to the spontaneous emission
- We need to have a much stimulated emission as possible for lasing action
- How?
- Refer to the board for the derivation of the Einstein’s

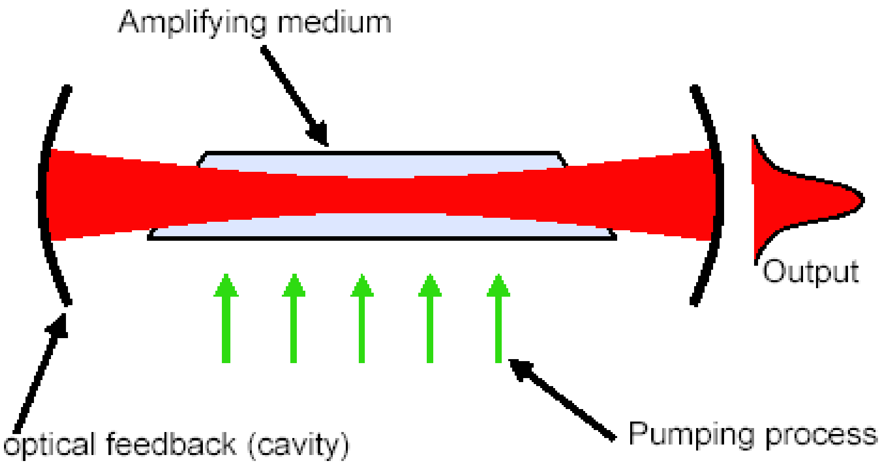
Absorption of Light Through a Medium

- Light or photon must be absorbed in order for us to have a lasing action
- $I(x) = I(o) \exp(-\alpha x)$

Optical Feedback

- The probability of photon producing a stimulated emission event can be increased by reflecting back through the medium several times.
- A device is normally fashioned in such a way that the 2 ends are made highly reflective
- This is term an oscillator cavity or Fabry Perot cavity

Therefore in a laser....



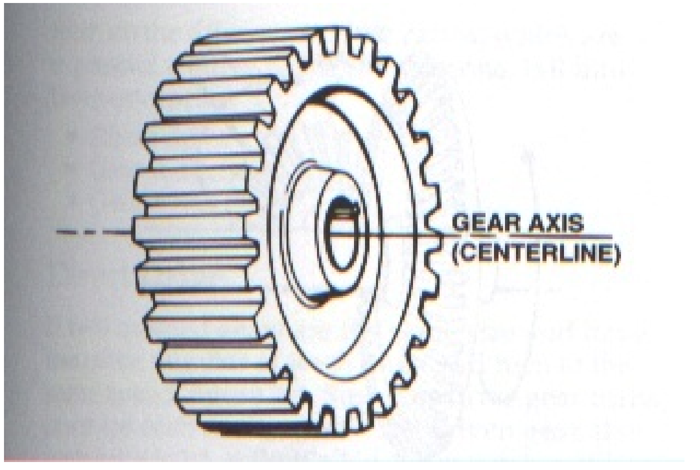
Three key elements in a laser

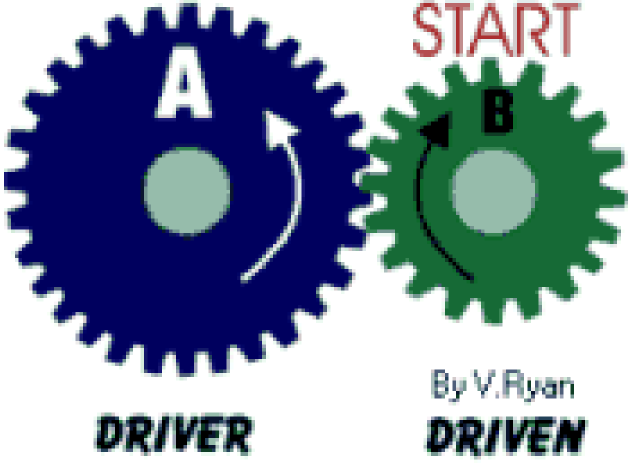
- Pumping process prepares amplifying medium in suitable state
- Optical power increases on each pass through amplifying medium
- If gain exceeds loss, device will oscillate, generating a *coherent*output

Unit –IV
Form Measurement

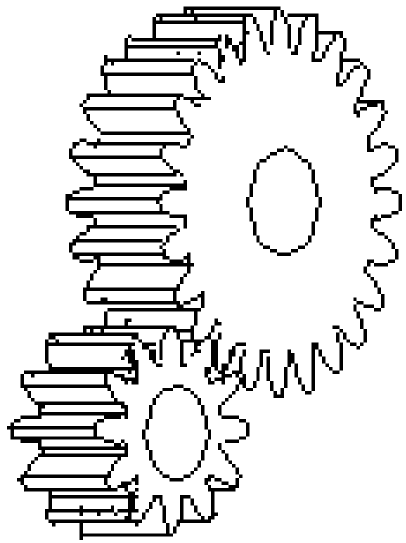
SPUR GEAR

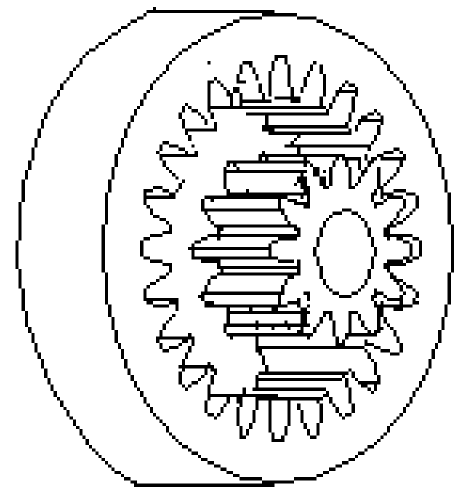
- Teeth is parallel to axis of rotation
- Transmit power from one shaft to another parallel shaft
- Used in Electric screwdriver, oscillating sprinkler, windup alarm clock, washing machine and clothes dryer





External and Internal spur Gear…





Helical Gear

- The teeth on helical gears are cut at an angle to the face of the gear
- This gradual engagement makes helical gears operate much more smoothly and quietly than spur gears
- One interesting thing about helical gears is that if the angles of the gear teeth are correct, they can be mounted on perpendicular shafts, adjusting the rotation angle by 90 degrees

Helical Gear…

Rack and pinion

- Rack and pinion gears are used to convert rotation (From the pinion) into linear motion (of the rack)

- A perfect example of this is the steering system on many cars

Bevel gears

- Bevel gears are useful when the direction of a shaft's rotation needs to be changed
- They are usually mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well
- The teeth on bevel gears can be straight, spiral
- locomotives, marine applications, automobiles, printing presses, cooling towers, power plants, steel plants, railway track inspection machines, etc.

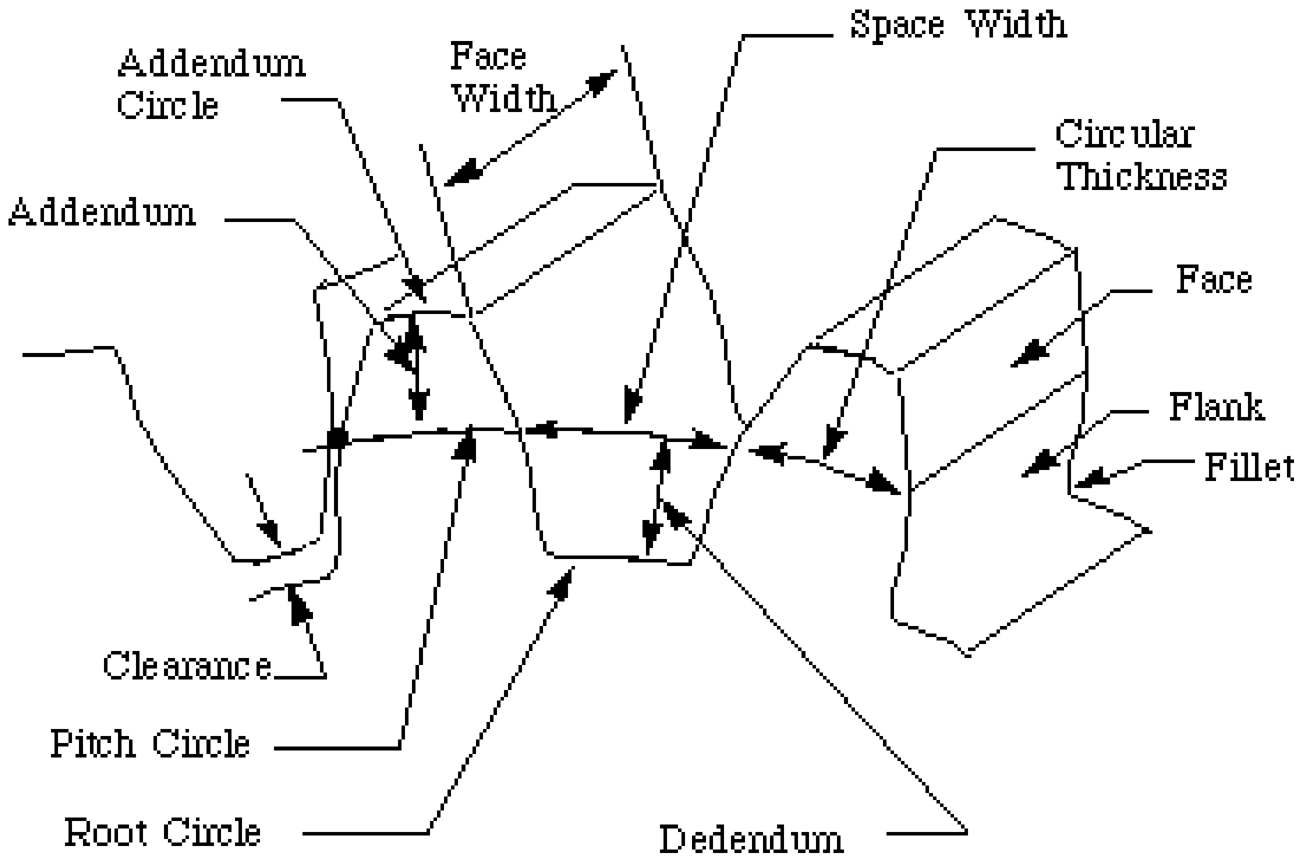
Straight and Spiral Bevel Gears

WORM AND WORM GEAR

- Worm gears are used when large gear reductions are needed. It is common for worm gears to have reductions of 20:1, and even up to 300:1 or greater
- Many worm gears have an interesting property that no other gear set has: the worm can easily turn the gear, but the gear cannot turn the worm
- Worm gears are used widely in material handling and transportation machinery, machine tools, automobiles etc

WORM AND WORM GEAR

NOMENCLATURE OF SPUR GEARS



NOMENCLATURE….

- Addendum circle: A circle bounding the ends of the teeth, in a right section of the gear.
- Root (or dedendum) circle: The circle bounding the spaces between the teeth, in a right section of the gear.
- Addendum: The radial distance between the pitch circle and the addendum circle.
- Dedendum: The radial distance between the pitch circle and the root circle.
- Clearance: The difference between the dedendum of one gear and the addendum of the mating gear.

NOMENCLATURE….

- Face of a tooth: That part of the tooth surface lying outside the pitch surface.
- Flank of a tooth: The part of the tooth surface lying inside the pitch surface.
- Circular thickness (also called the tooth thickness): The thickness of the tooth measured on the pitch circle. It is the length of an arc and not the length of a straight line.
- Circular pitch (Pc) : The width of a tooth and a space, measured on the pitch circle.

$$P_c = \frac{\pi D}{N}$$

NOMENCLATURE….

- Diametral pitch (Pd): The number of teeth of a gear unit pitch diameter. The diametral pitch is, by definition, the number of teeth divided by the pitch diameter. That is,

$$P_d = \frac{N}{D}$$

Where

Pd = diametral pitch

N = number of teeth

D = pitch diameter

- Module (m): Pitch diameter divided by number of teeth. The pitch diameter is usually specified in inches or millimeters; in the former case the module is the inverse of diametral pitch.

$$m = D/N$$

GEAR TRAINS

- A gear train is two or more gear working together by meshing their teeth and turning each other in a system to generate power and speed
- It reduces speed and increases torque
- Electric motors are used with the gear systems to reduce the speed and increase the torque

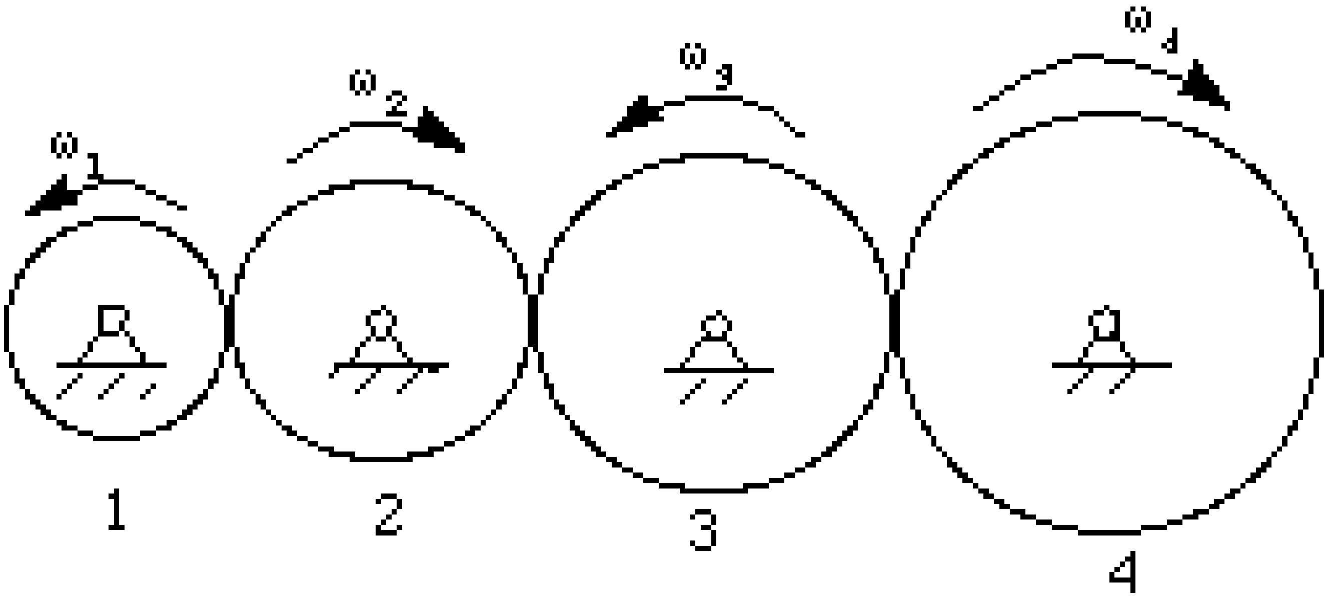
Types of Gear Trains

- Simple gear train
- Compound gear train
- Planetary gear train

Simple Gear Train

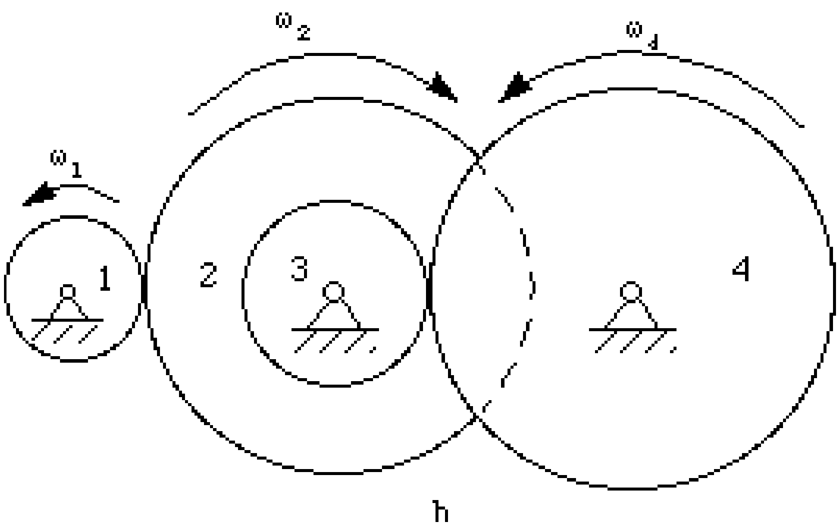
- The most common of the gear train is the gear pair connecting parallel shafts. The teeth of this type can be spur, helical
- Only one gear may rotate about a single axis

Simple Gear Train

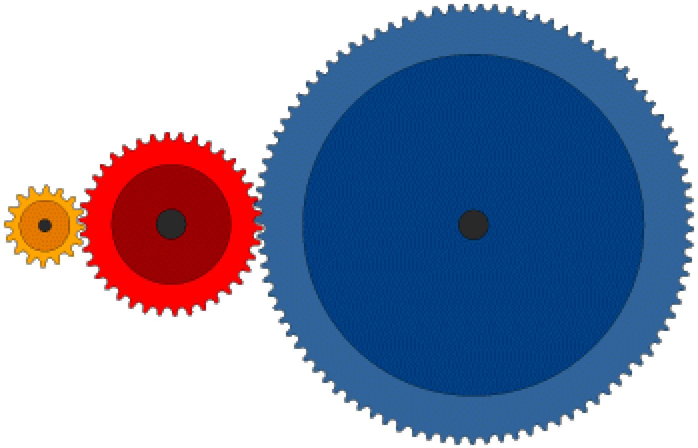


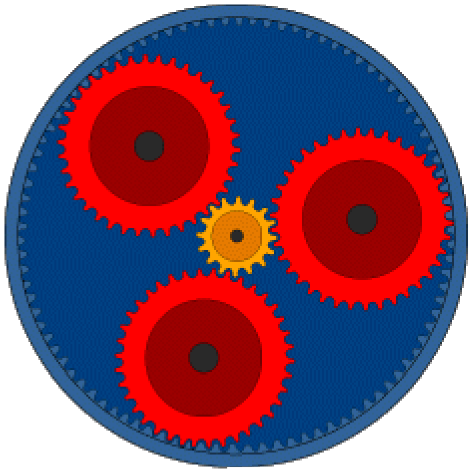
Compound Gear Train

- For large velocities, compound arrangement is preferred
- Two or more gears may rotate about a single axis



Planetary Gear Train (Epicyclic Gear Train)





Planetary Gear Train...

- In this train, the blue gear has six times the diameter of the yellow gear
- The size of the red gear is not important because it is just there to reverse the direction of rotation
- In this gear system, the yellow gear (the sun) engages all three red gears (the planets) simultaneously
- All three are attached to a plate (the planet carrier), and they engage the inside of the blue gear (the ring) instead of the outside.

Planetary Gear Train…

- They have higher gear ratios.
- They are popular for automatic transmissions in automobiles.
- They are also used in bicycles for controlling power of pedaling automatically or manually.
- They are also used for power train between internal combustion engine and an electric motor

Unit-V
Measurements of Power ,Flow and Temperature

Blackbody

- An ideal emitter of electromagnetic radiation
  - opaque
  - non-reflective
  - for practical blackbodies $\varepsilon = 0.9$
- Cavity effect
  - em-radiation measured from a cavity of an object

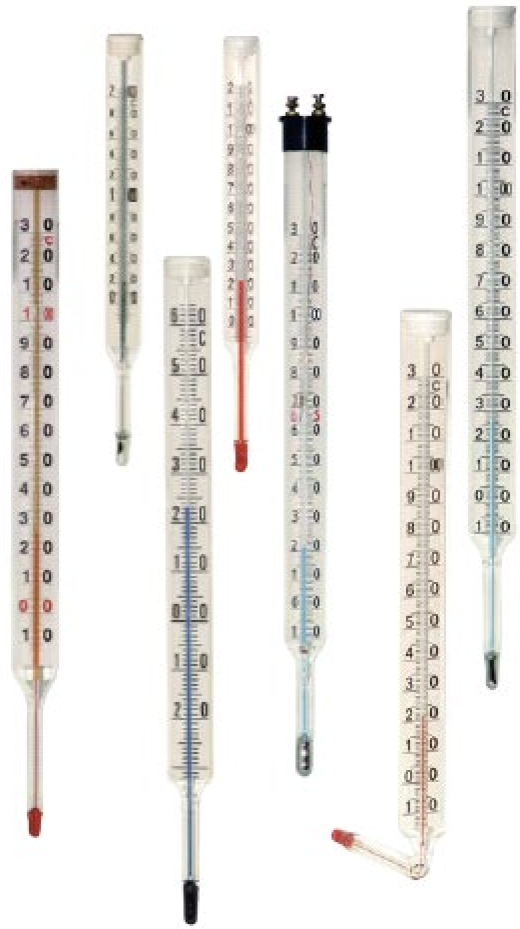
Unit -5

Temparature Measurements

Outline

1. Liquid-in-glass thermometres
2. Bimaterial thermometres
3. Electrical thermometres
4. IR-thermometres
5. Pyrometres
6. Summary
7. Other measurement methods

Liquid-in-glass thermometres



Liquid-in-glass thermometres

- The “traditional” thermometres
- Measurement scale from -190 °C to +600 °C
- Used mainly in calibration
  - Mercury: -39 °C … +357 °C
  - Spirit: -14 °C … +78 °C

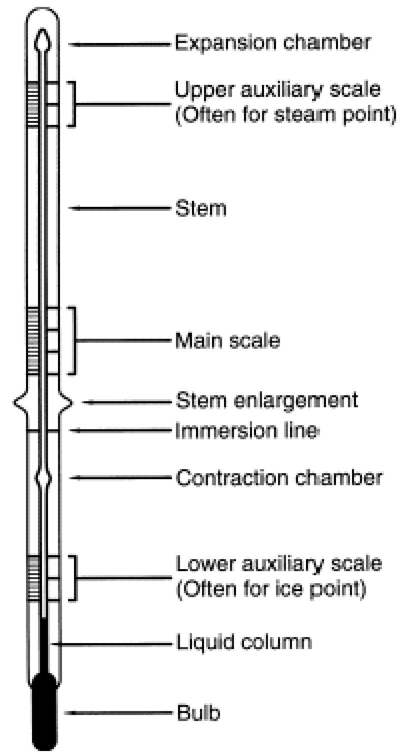
Functionning method

- Method is based on the expansion of a liquid with temperature
  - The liquid in the bulb is forced up the capillary stem

- Thermal expansion:

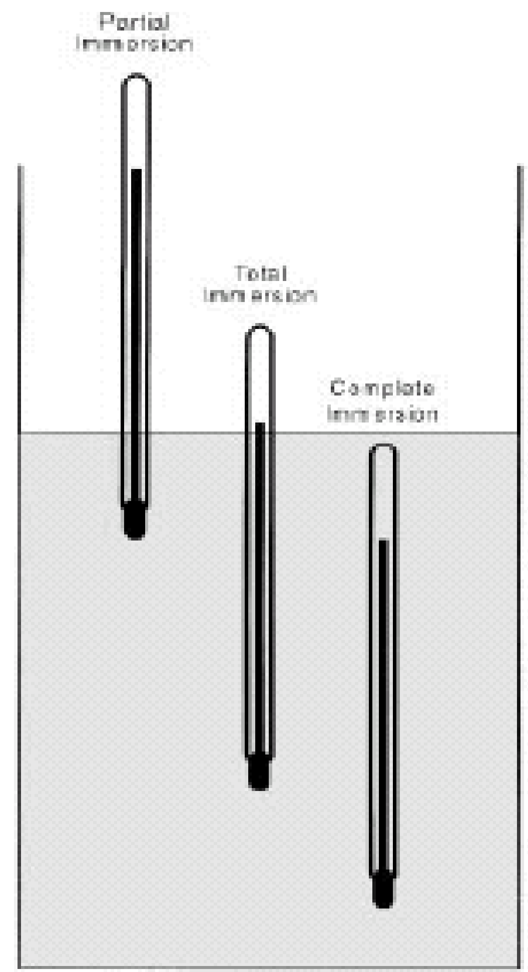
$$V = V_0(1 + \gamma T)$$

Structure


Expansion chamber
Upper auxiliary scale
(Often for steam point)
Stem
Main scale
Stem enlargement
Immersion line
Contraction chamber
Lower auxiliary scale
(Often for ice point)
Liquid column
Bulb

Causes of inaccuraties

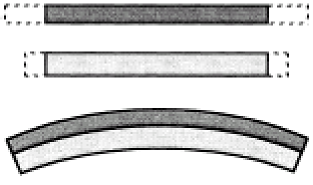
- Temperature differences in the liquid
- Glass temperature also affects
- The amount of immersion (vs. calibration)



Bimaterial thermometres

- Method based on different thermal expansions of different metals
  - Other metal expands more than other: twisting
  - Inaccurary ± 1 ° C
  - Industry, sauna thermometres

Bimaterial thermometres



Electrical thermometres

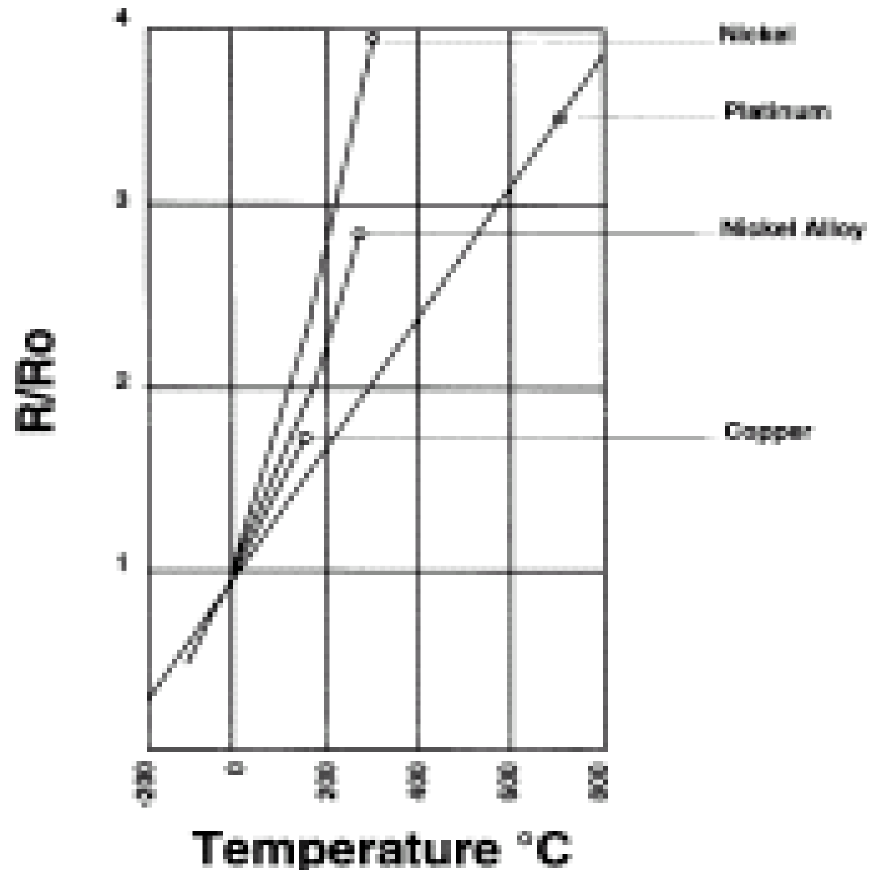
Electrical thermometres

- Resistive thermometres
  - Resistivity is temperature dependent

$$R(T) = R_0(1 + \alpha T)$$

  - Materials: Platinum, nickel

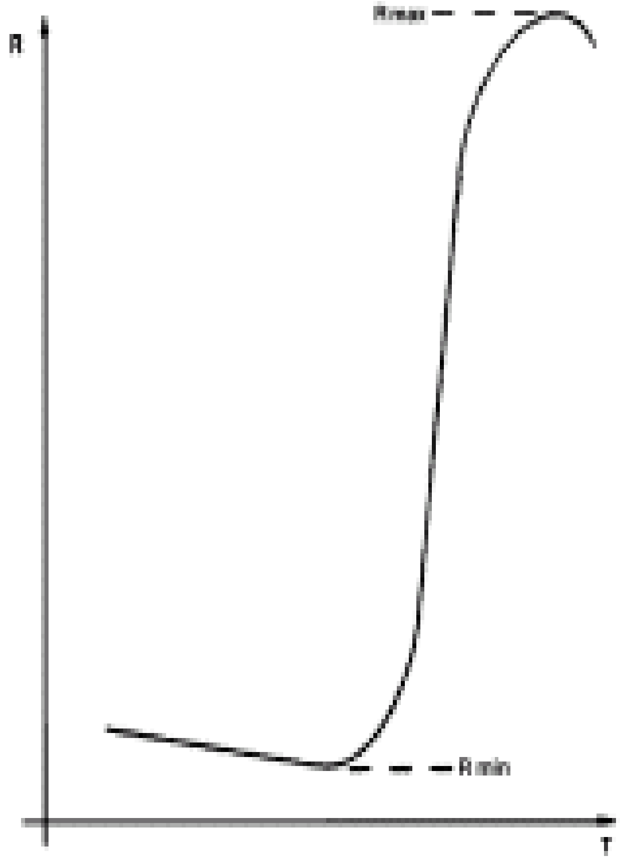
Characteristic resistances



Thermistor thermometres

- Semiconductor materials
- Based on the temperature dependence of resistance
- Thermal coefficient non-linear, 10 times bigger than for metal resistor
- NTC, (PTC): temperature coefficient's sign

Example of a characteristic curve



Limitations of electrical thermometres

- Sensor cable's resistance and its temperature dependency
- Junction resistances
- Thermal voltages
- Thermal noise in resistors
- Measurement current
- Non-linear temperature dependencies
- Electrical perturbations
- Inaccuracy at least ± 0.1 °C

Infrared thermometers

Thermal radiation

- Every atom and molecule exists in perpetual motion
- A moving charge is associated with an electric field and thus becomes a radiator
- This radiation can be used to determine object's temperature

Thermal radiation

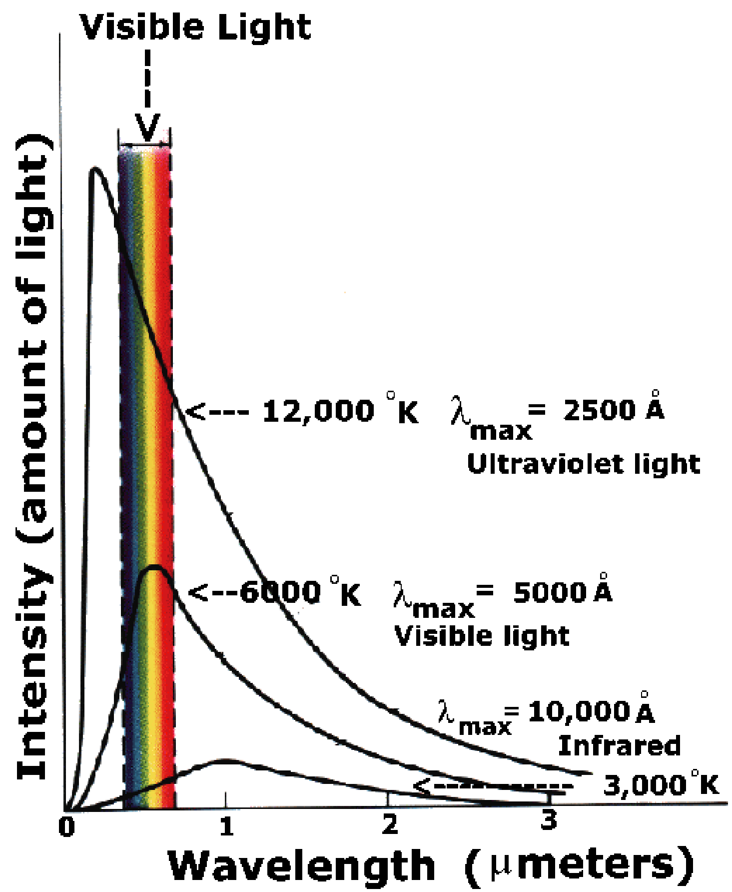
- Waves can be characterized by their intensities and wavelengths
  - The hotter the object:
    - the shorter the wavelength
    - the more emitted light
- Wien's law:

$$\lambda_{\max} T = 0.2896 cmK$$

Planck's law

$$F(\lambda) = \frac{1}{\lambda^5} \frac{2hc^2}{e^{\frac{hc}{\lambda kT}} - 1}$$

Magnitude of radiation at particular wavelength (λ) and particular temperature (T).
h is Planck's constant and c speed of light.



Blackbody

- An ideal emitter of electromagnetic radiation
  - opaque
  - non-reflective
  - for practical blackbodies $\varepsilon = 0.9$
- Cavity effect
  - em-radiation measured from a cavity of an object

ME 6504 METROLOGY AND MEASUREMENTS

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