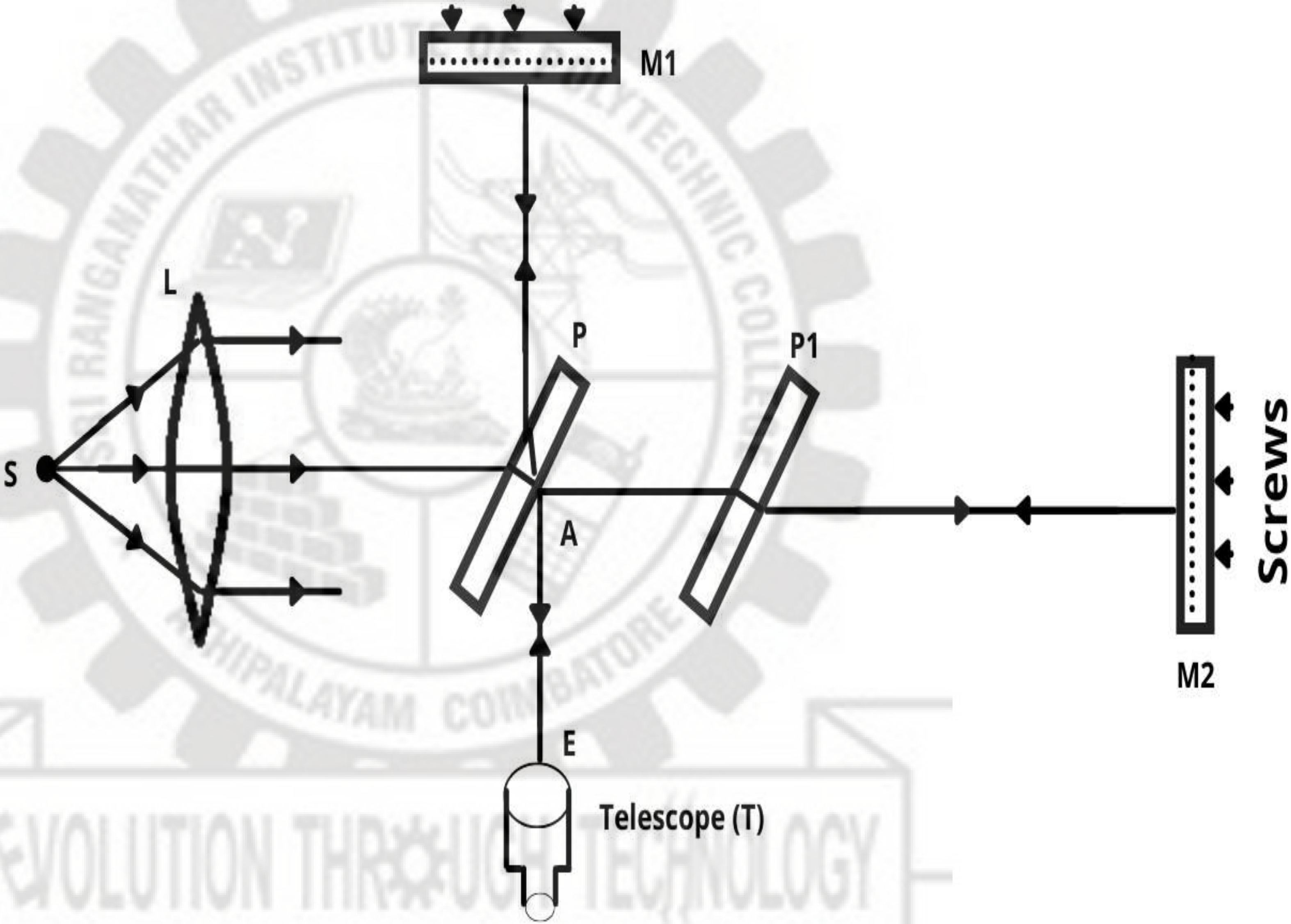


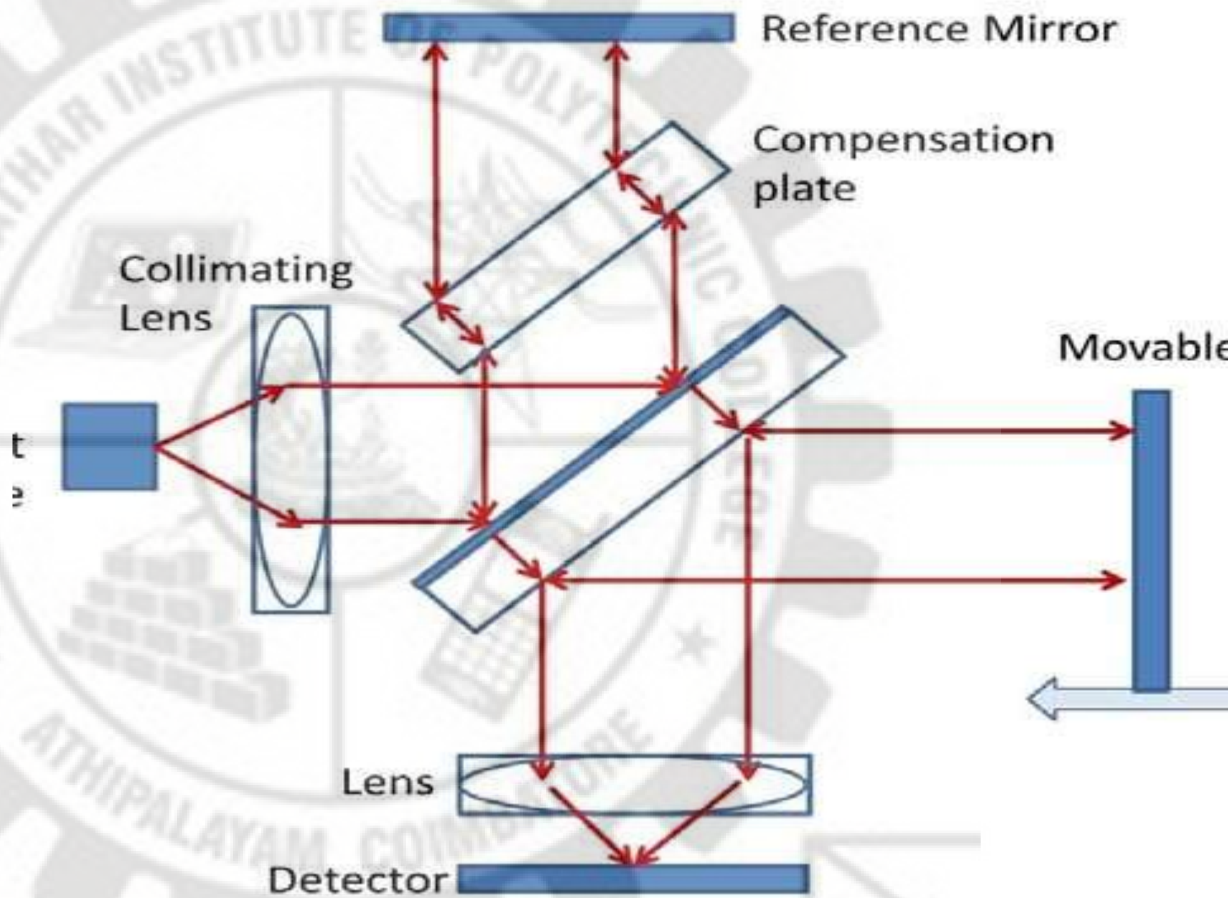
Michelson Interferometer

764 - SRIPC

The Michelson interferometer works by **splitting a beam of monochromatic light into two equal amplitude beams**.

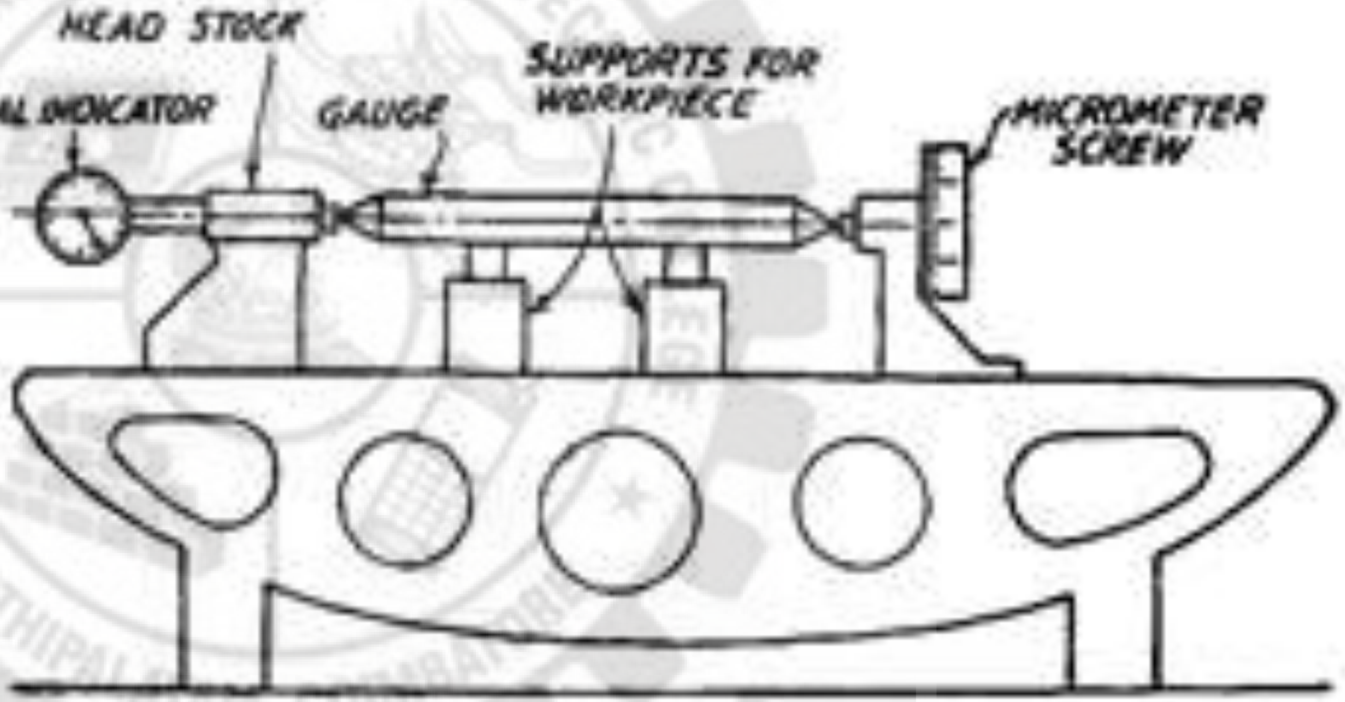
One beam hits a fixed mirror and the other hits a movable mirror giving different beam lengths which converge on a detector screen giving an interference pattern

764 - SRIPC



Schematic of the Twyman-Green Interferometer

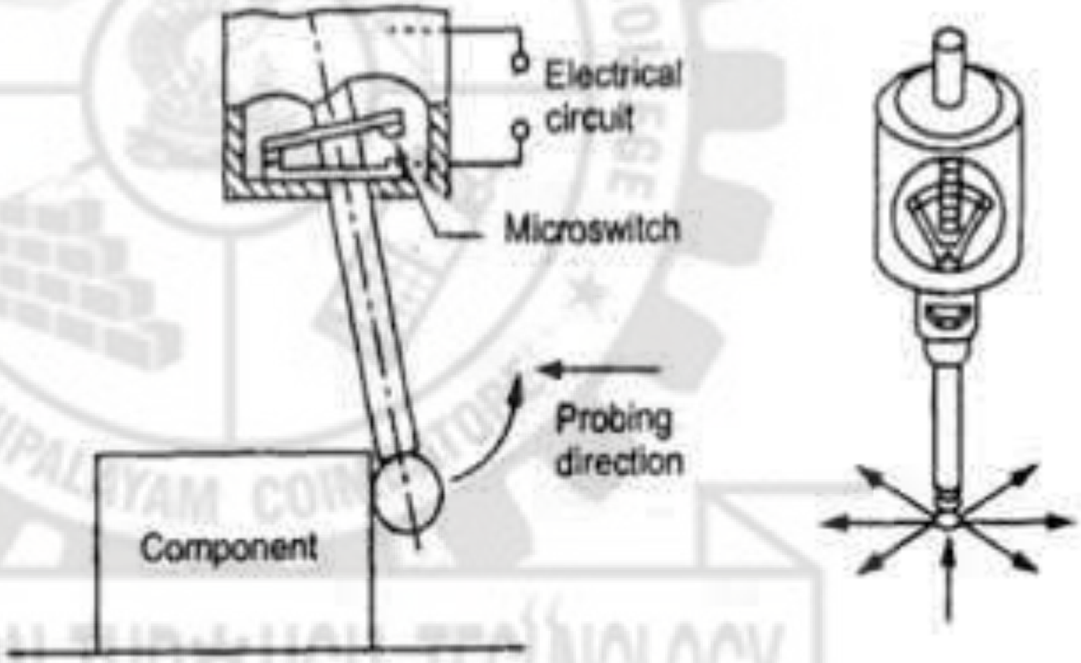
SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
ATHIPALAYAM COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC



Length Bar Measuring Machine

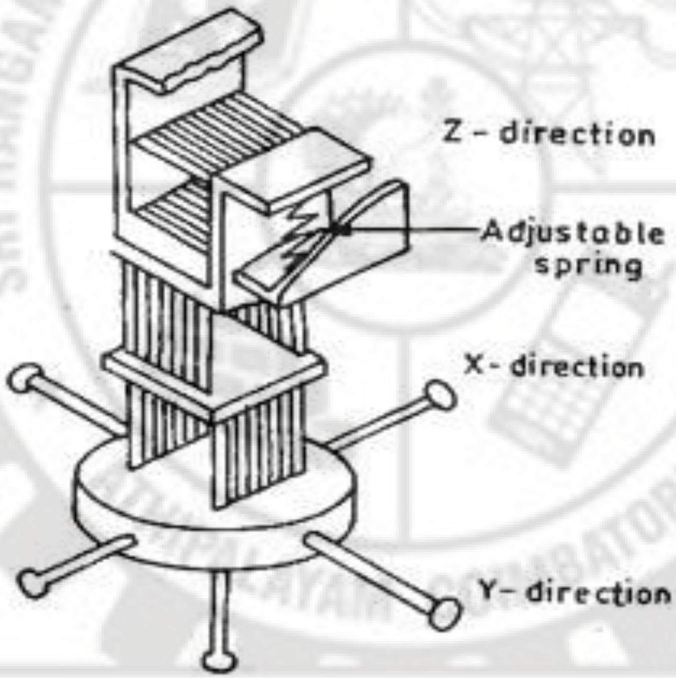
764 - SRIPC

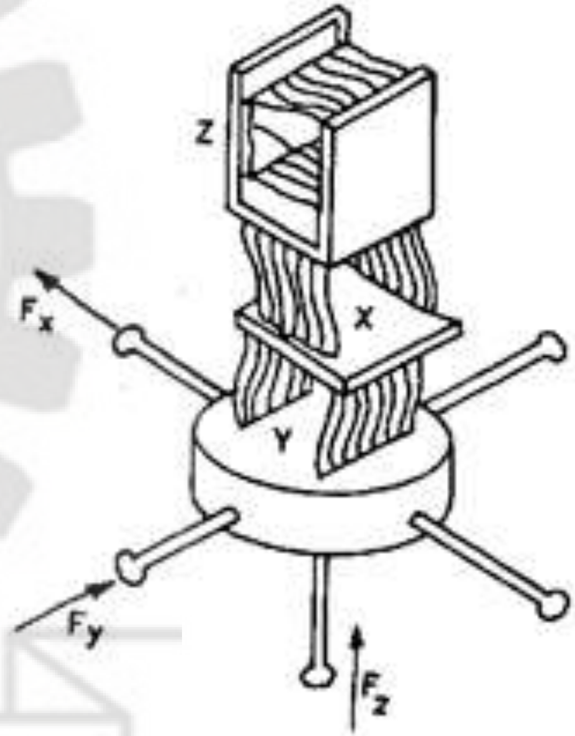
Trigger type probe system



(a) Part section of Probe head (b) Outline of Probe head

764 - SRIPC


Z - direction
Adjustable spring
X - direction
Y - direction


Z
X
Y
F_x
F_y
F_z

764 - SRIPC

UNIT 5 :

MEASUREMENT OF

MECHANICAL PARAMETERS

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

FORCE

A) DIRECT MEASUREMENT

B) INDIRECT MEASUREMENT

Force = Mass X Acceleration

F = ma

764 - SRIPC

FORCE

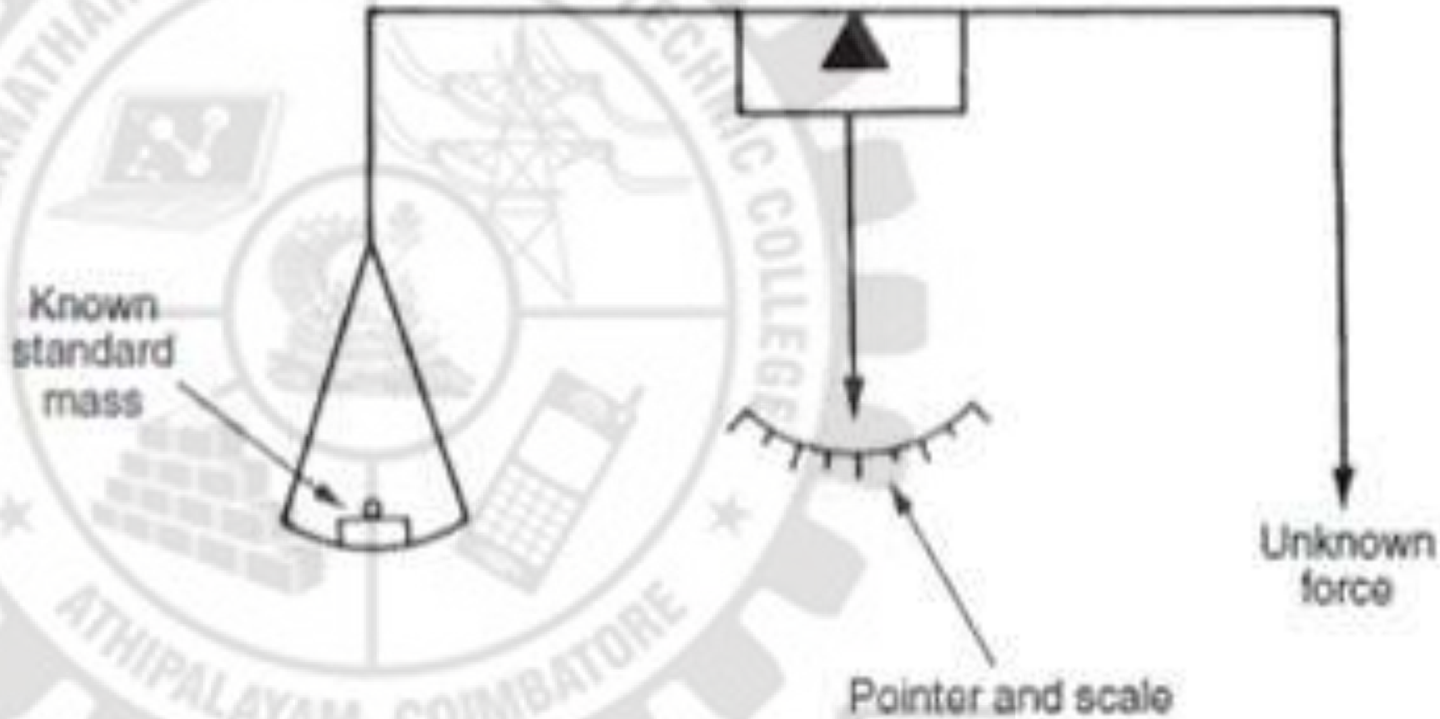
A) DIRECT MEASUREMENT

B) INDIRECT MEASUREMENT

764 - SRIPC

A) DIRECT MEASUREMENT

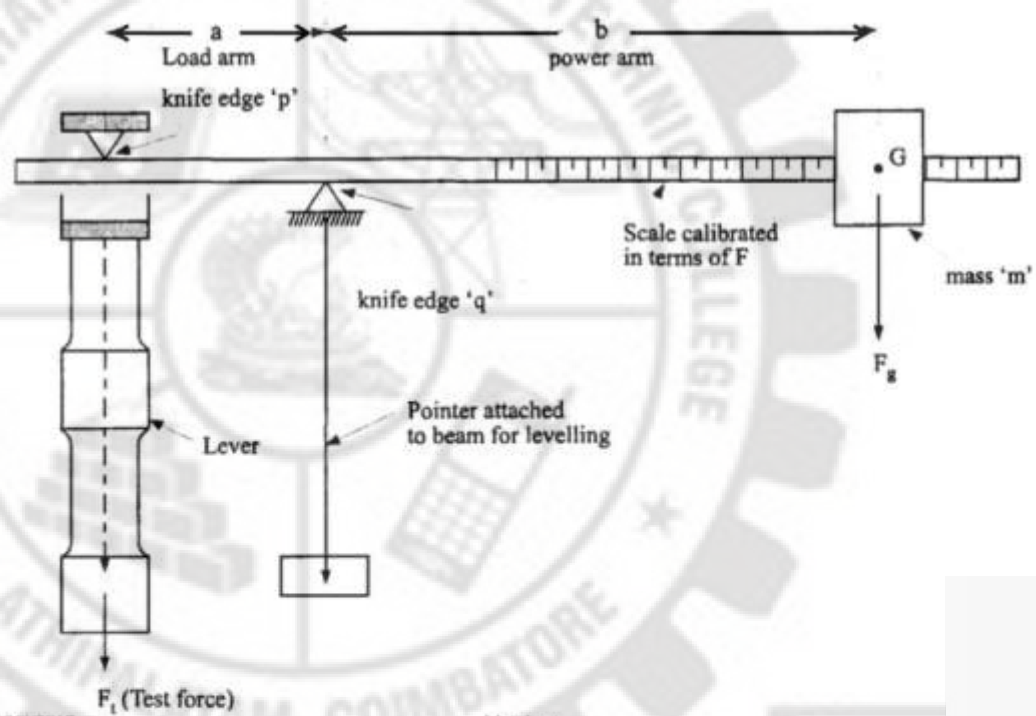
SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
ATHIPALAYAM COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC



Equal arm balance

764 - SRIPC

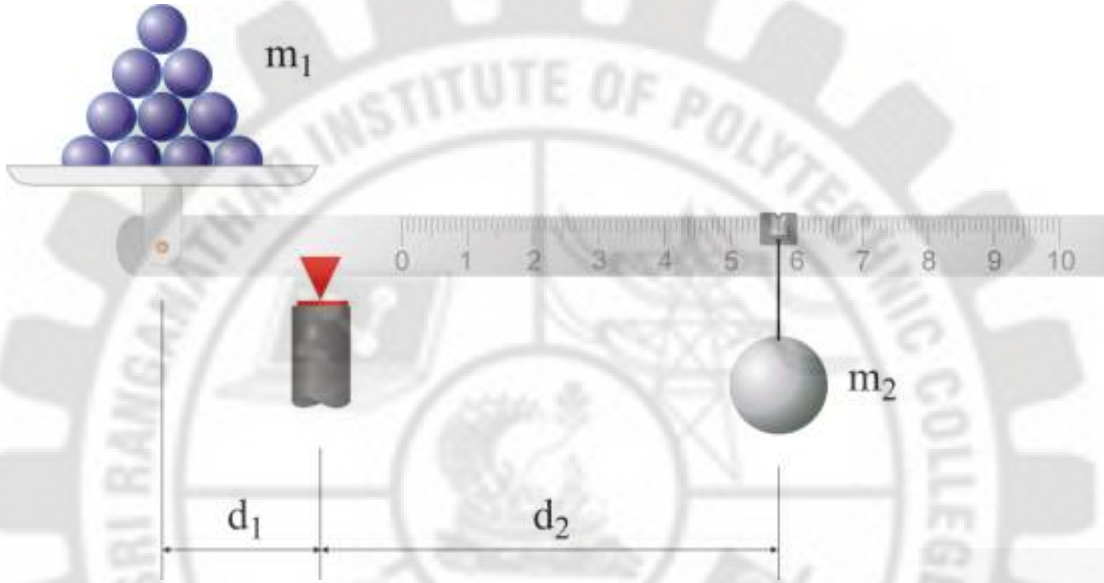
Unequal arm balance:



F1 x a = Fg x b
F1 = (Fg x b) / F1

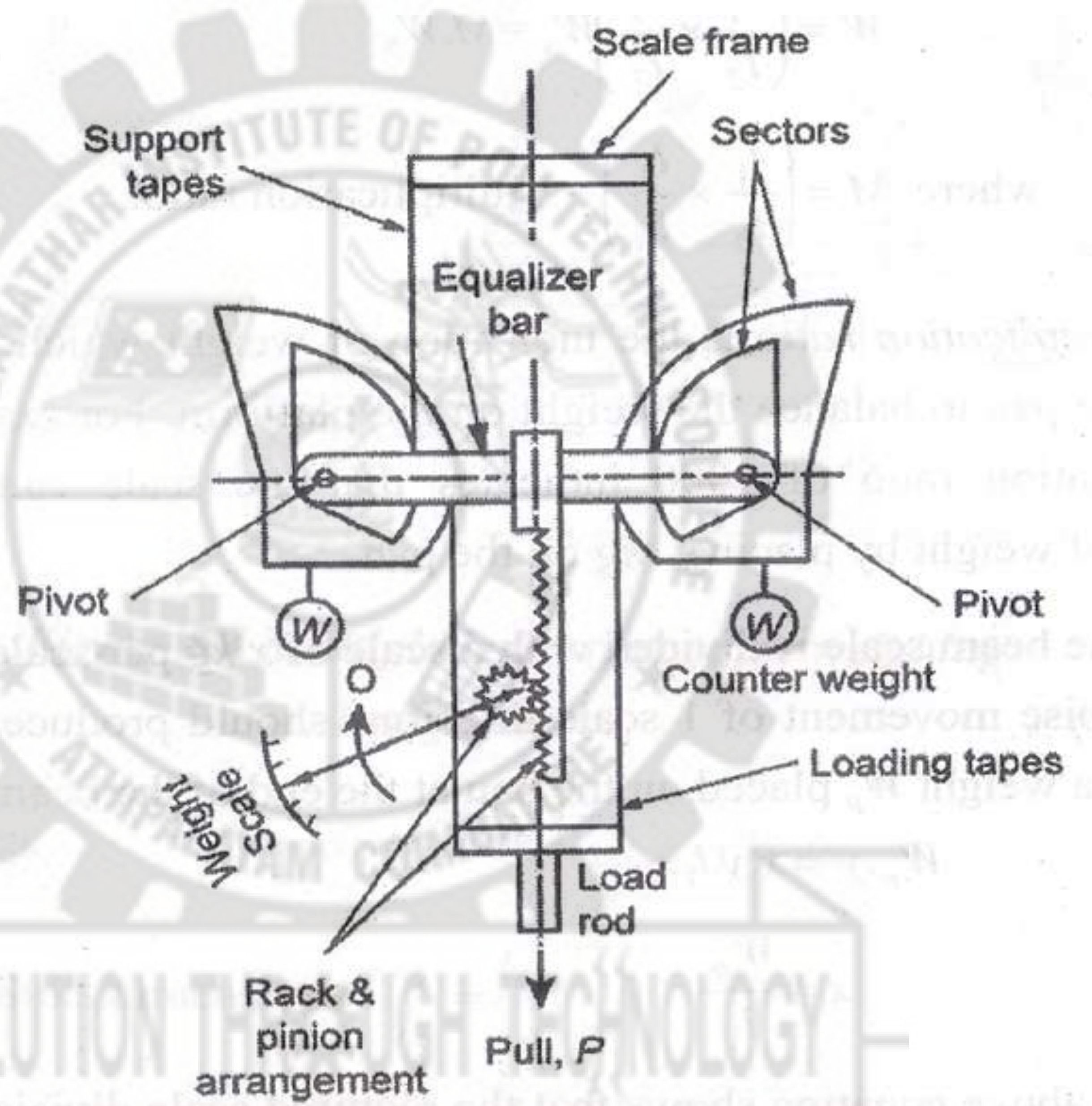
M1 x g x a = Mg x g x b
M1 = (Mg X b) / a

764 - SRIPC



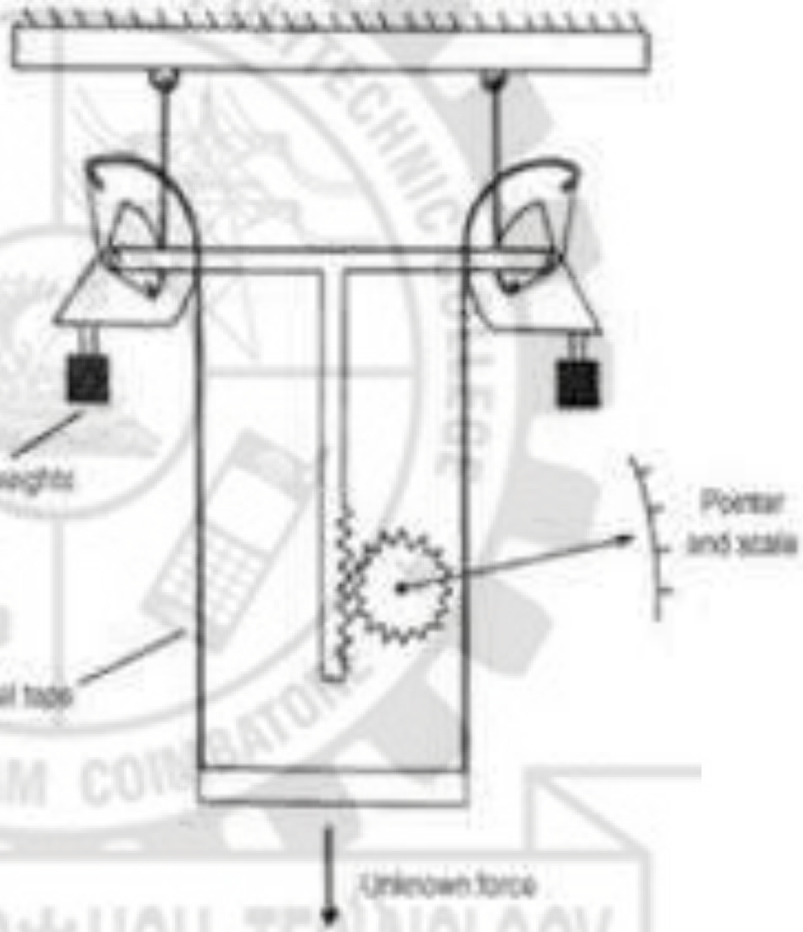
unequal-arm balance

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC



764 - SRIPC

Pendulum Scale



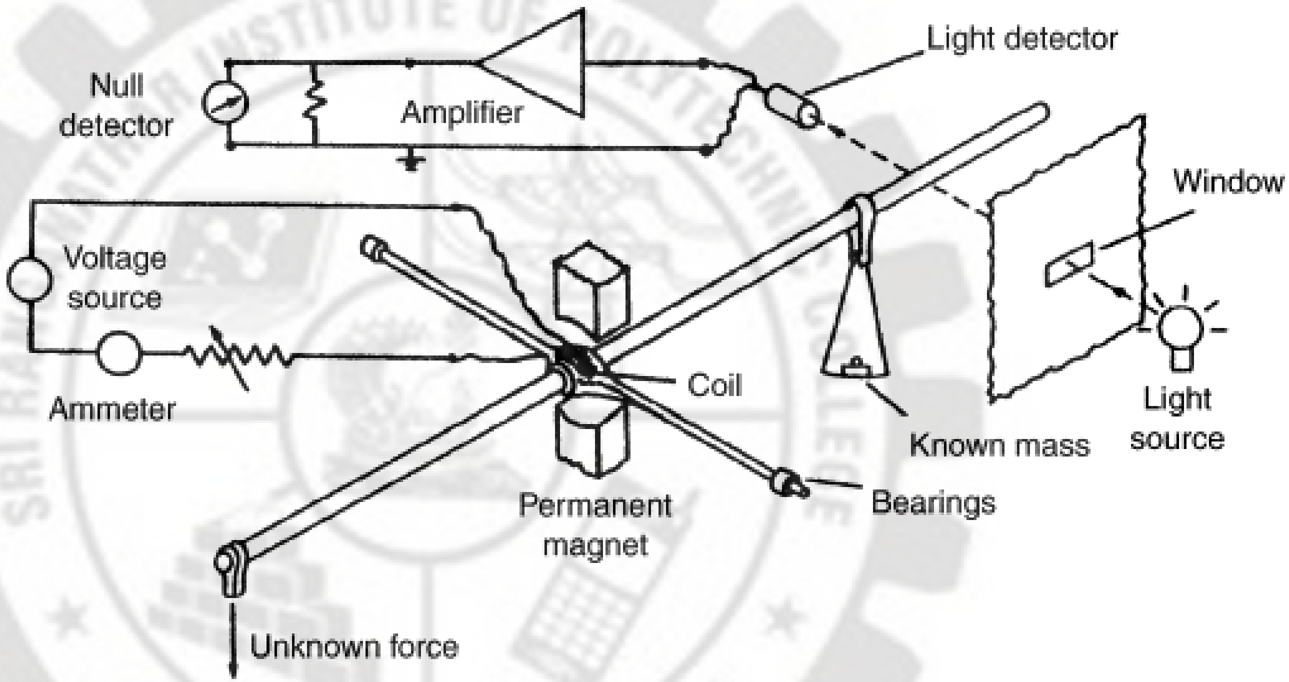
SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
ATHIPALAYAM COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

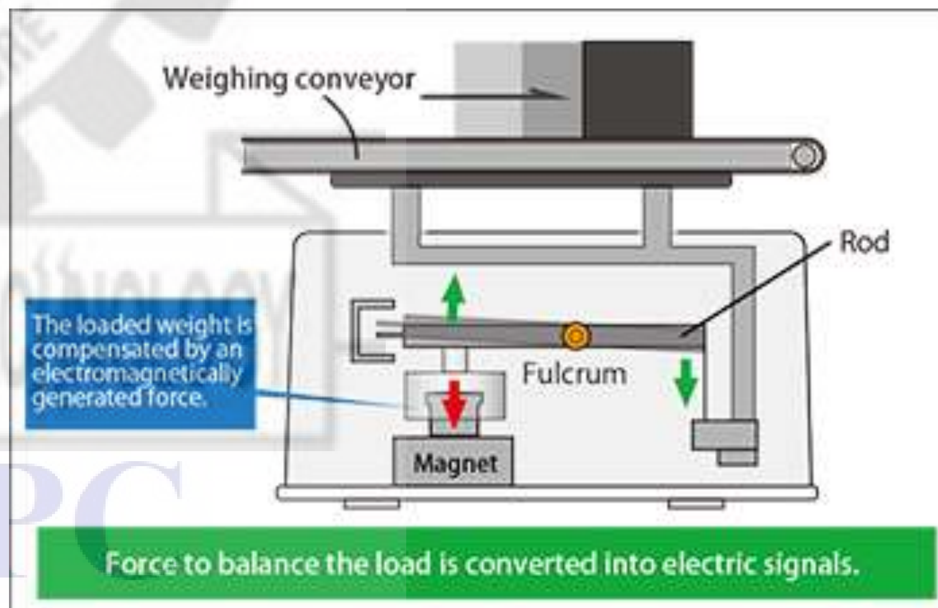
FORCE

B) INDIRECT MEASUREMENT

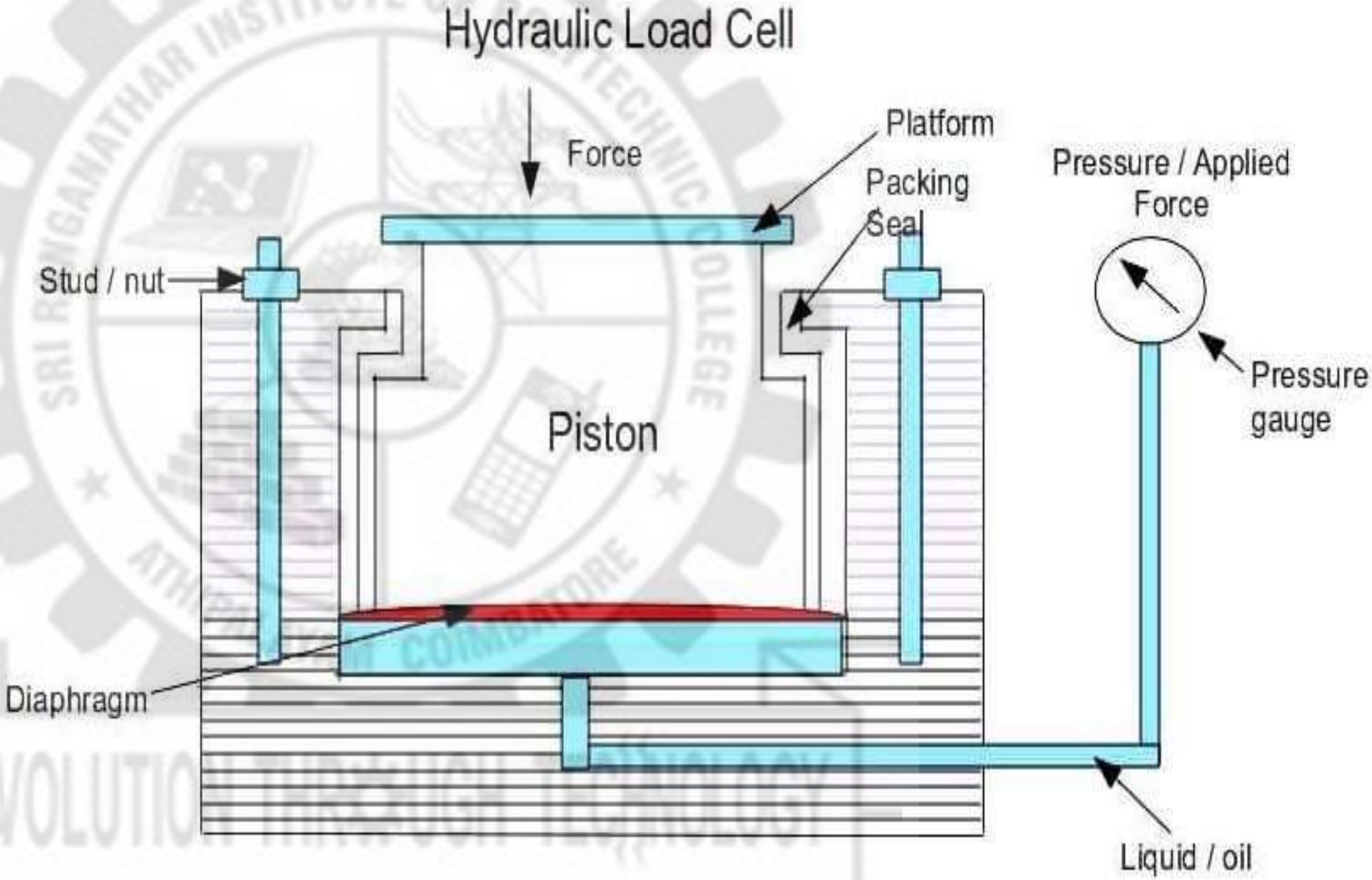
764 - SRIPC

Electromagnetic Balance

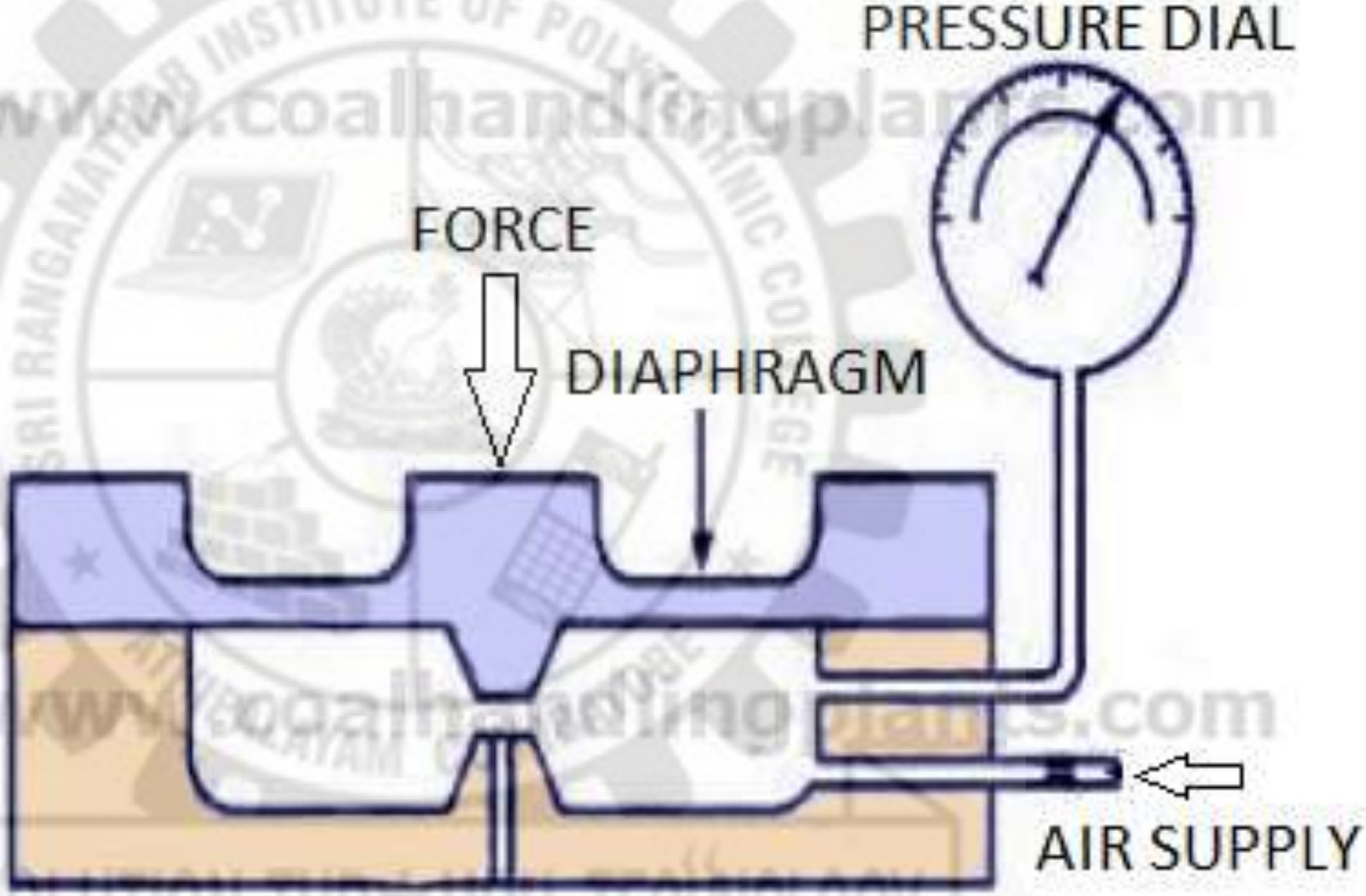




764 - SRIPC


Hydraulic Load Cell
Force
Platform
Packing Seal
Pressure / Applied Force
Stud / nut
Piston
Pressure gauge
Diaphragm
Liquid / oil

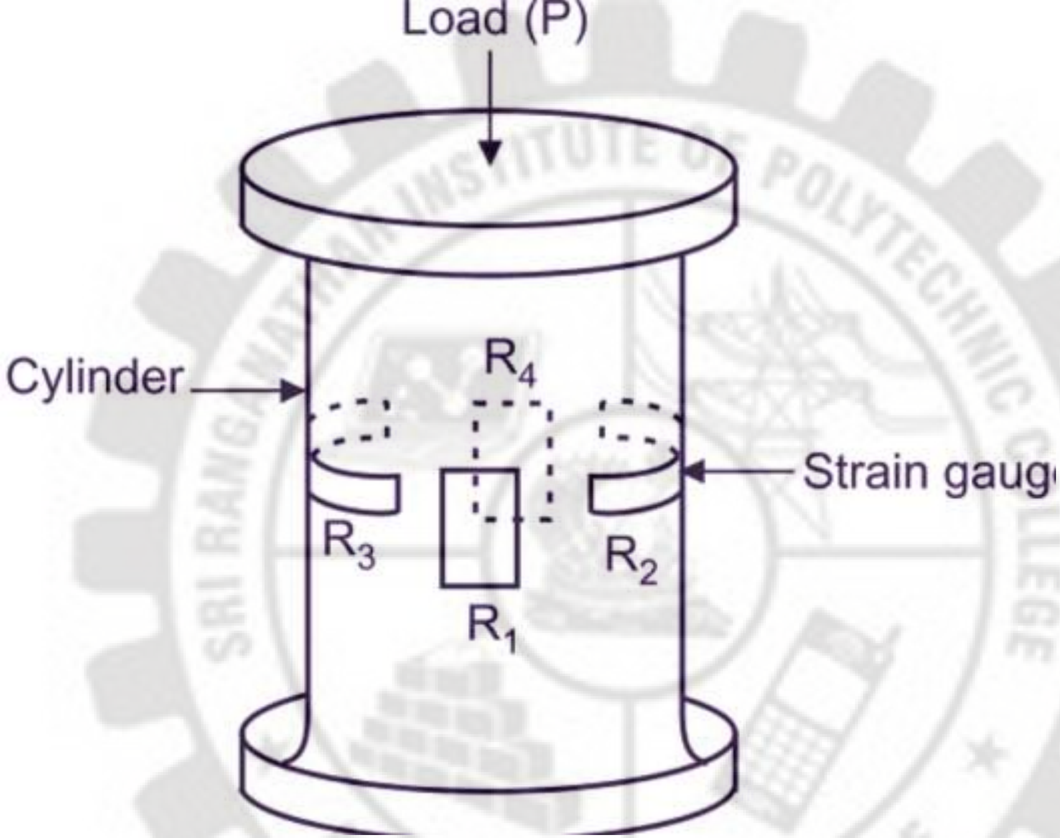
764 - SRIPC

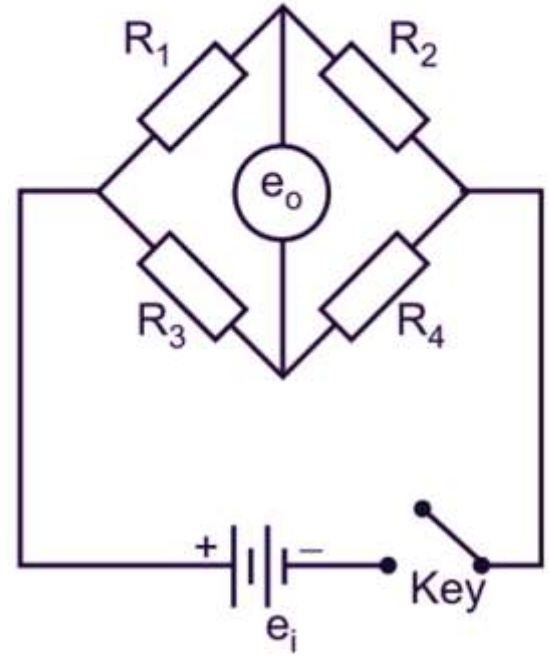


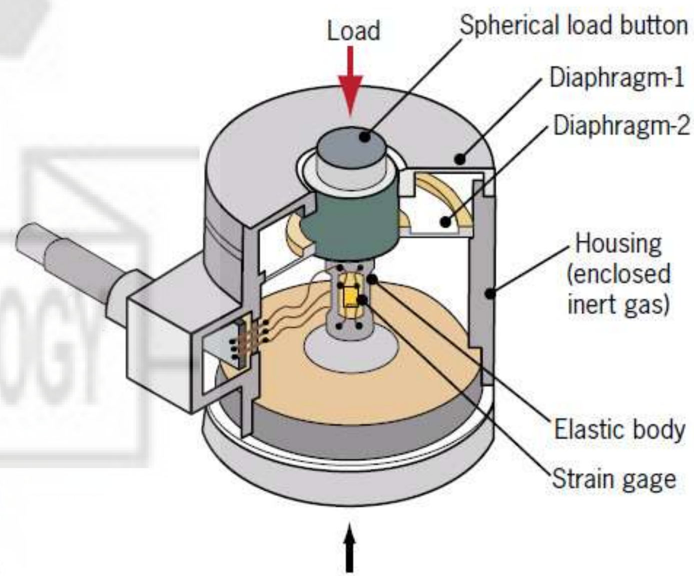
pnuematic load cell

764 - SRIPC

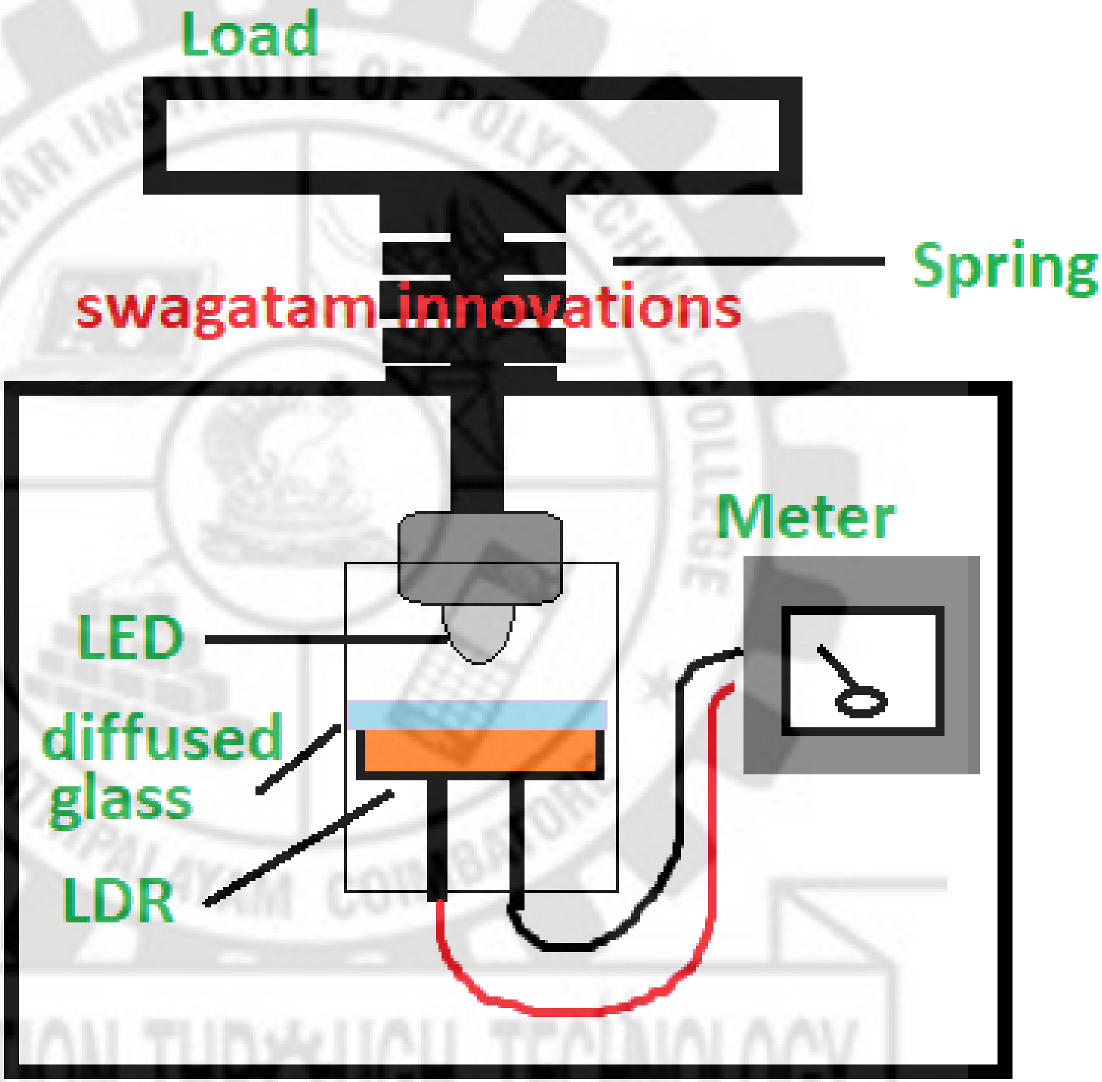
STRAIN GAUGE LOAD CELL



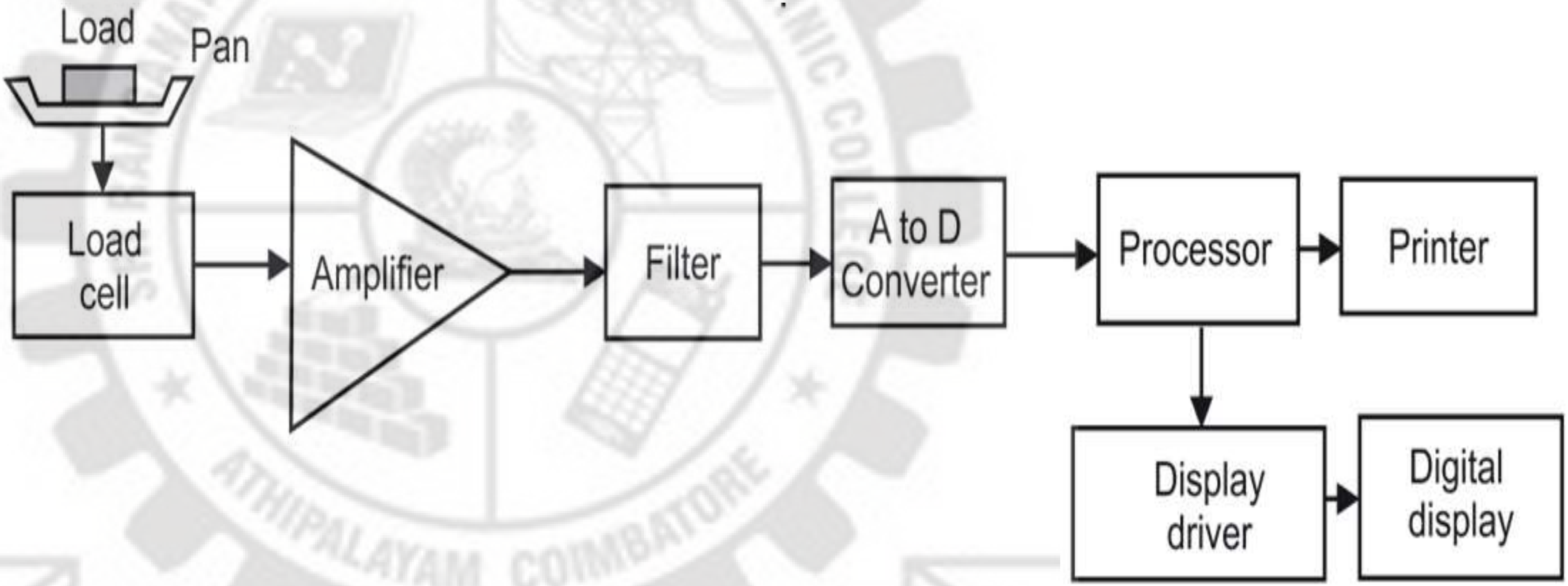




764 - SRIPC

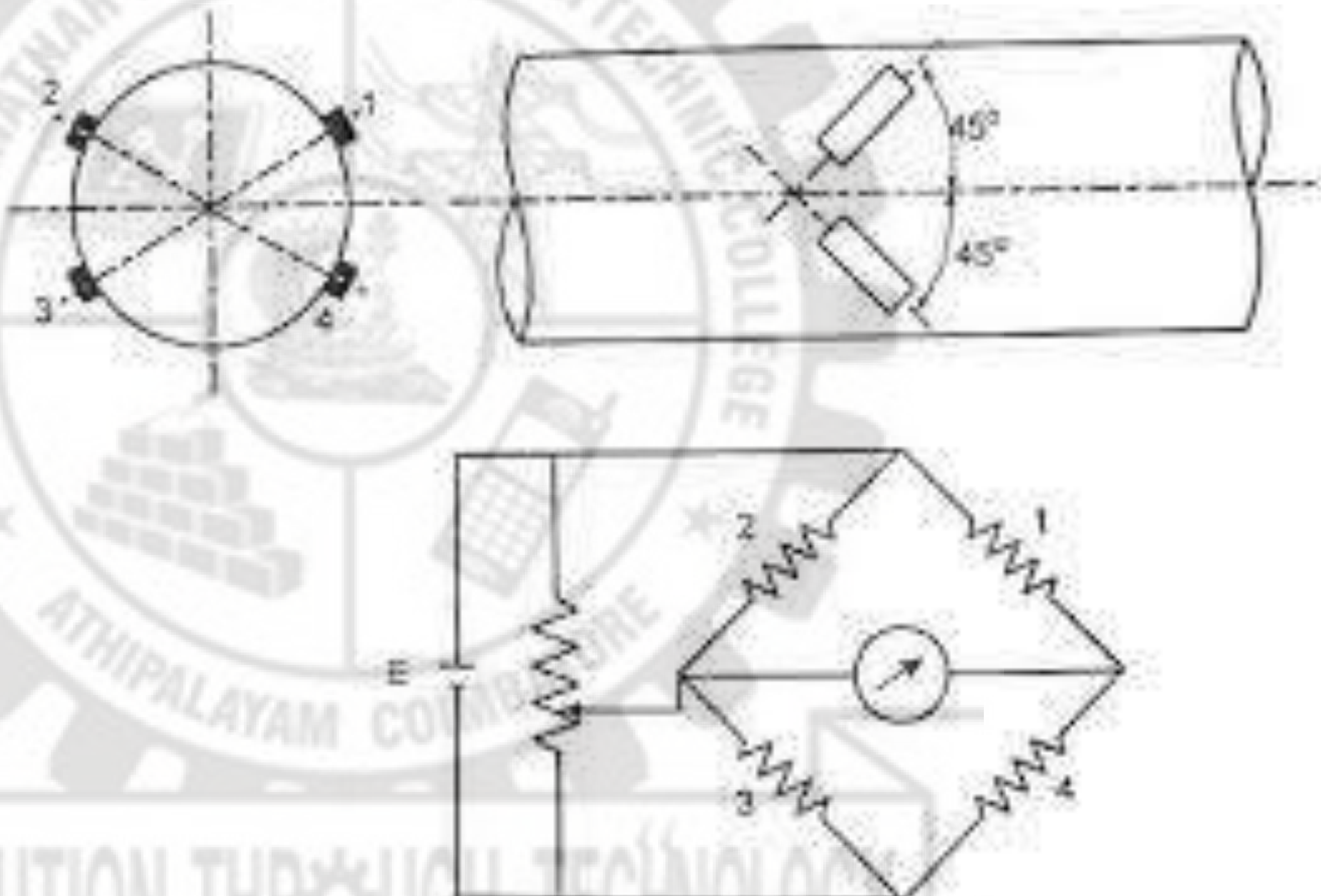

Load
Spring
swagatam innovations
Meter
LED
diffused glass
LDR

764 - SRIPC



ELECTRONIC WEIGHING SYSTEM

764 - SRIPC



TORSION METER

SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
ATHIPALAYAM COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

MEASUREMENT OF

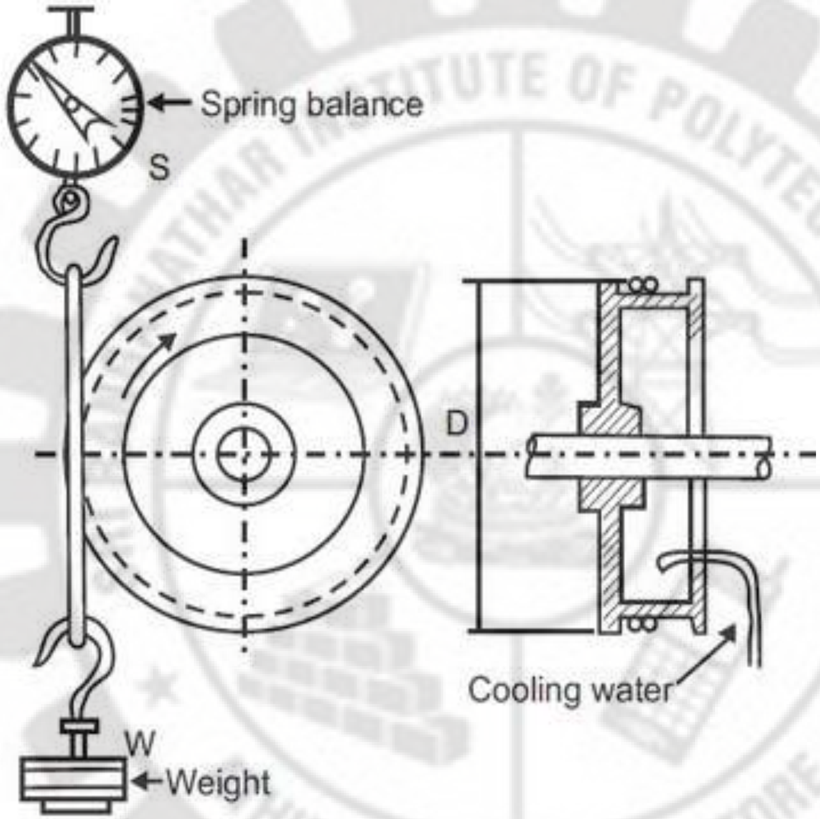
POWER

SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
ATHIPALAYAM COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

POWER =

$$2\pi NT / 60$$

764 - SRIPC



W = Weight at the rope (N)
S = Spring balance reading (N)
N = Engine Speed (rpm)
D = Diameter of the brake wheel (m)
d = Diameter of the rope (m)
(D+d) = effective diameter of the brake wheel

Torque = force x distance

$$= (W-S) \times (D - d)/2$$

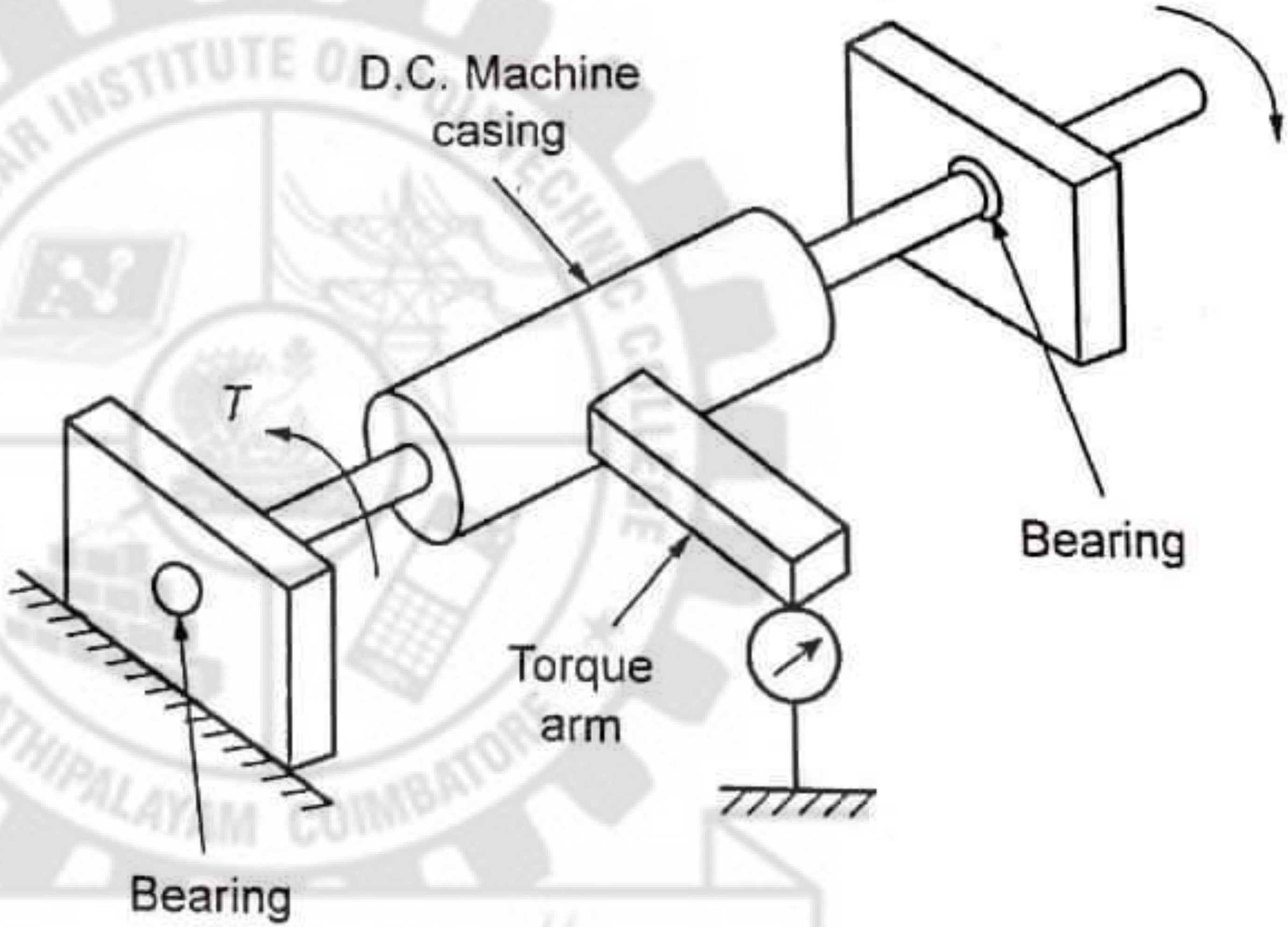
$$\text{Brake Power} = \frac{2 \pi N (W-S) \times (D - d)/2}{60}$$

$$= \frac{\pi N (W-S) \times (D - d)}{60} \text{ watts}$$

$$= \frac{\pi N (W-S) \times (D - d)}{60 \times 1000} \text{ kW}$$

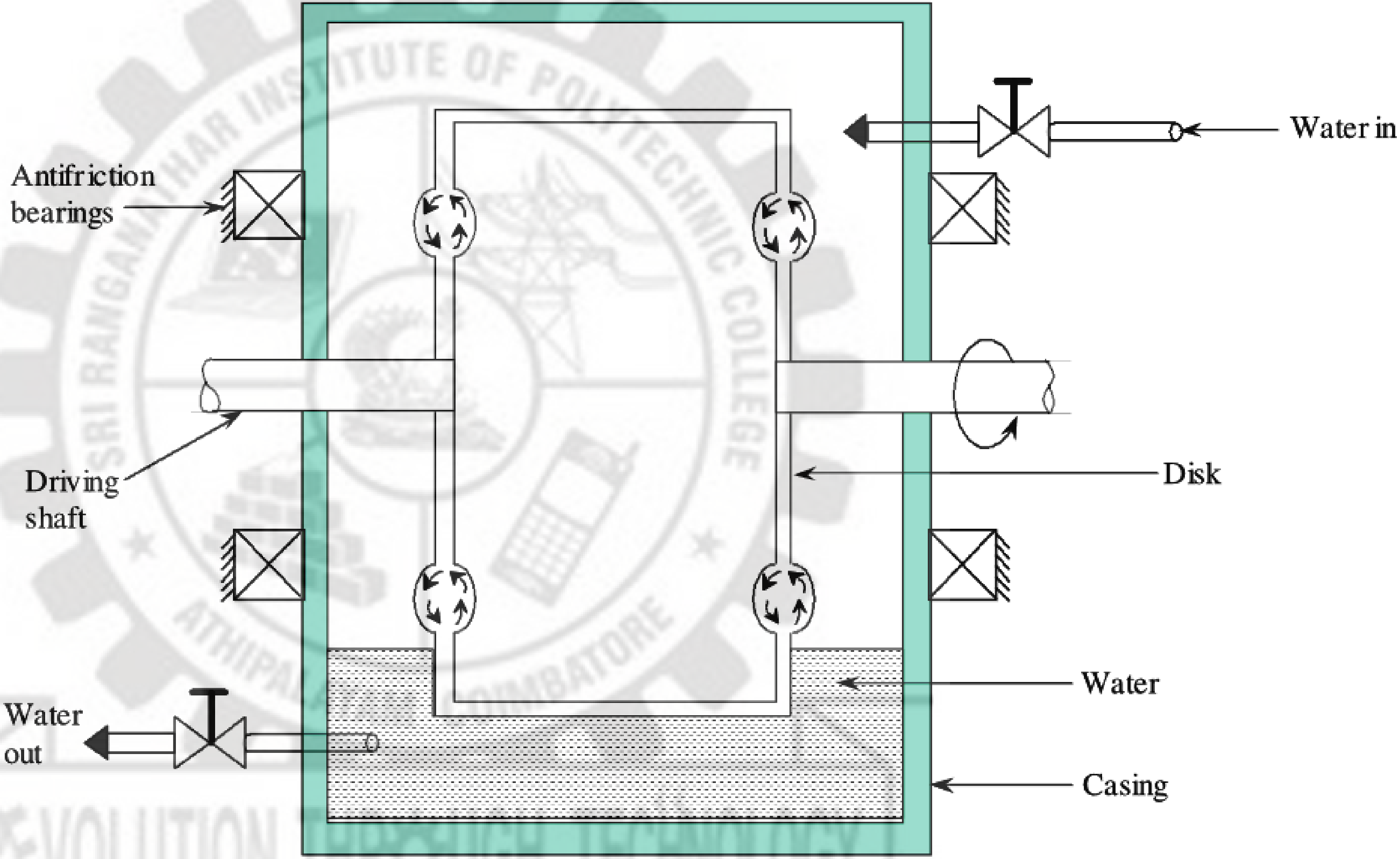
Rope brake dynamometer

764 - SRIPC



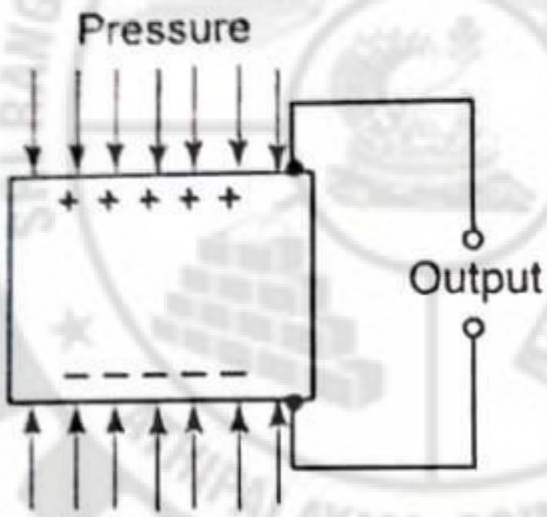
DC dynamometer

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

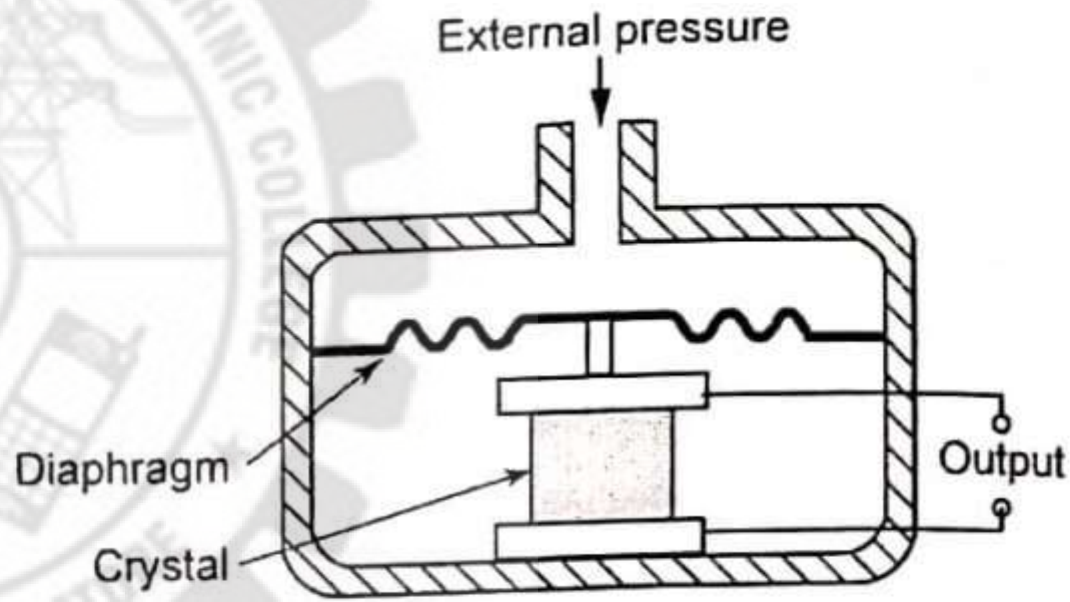


hydraulic dynamometer

764 - SRIPC

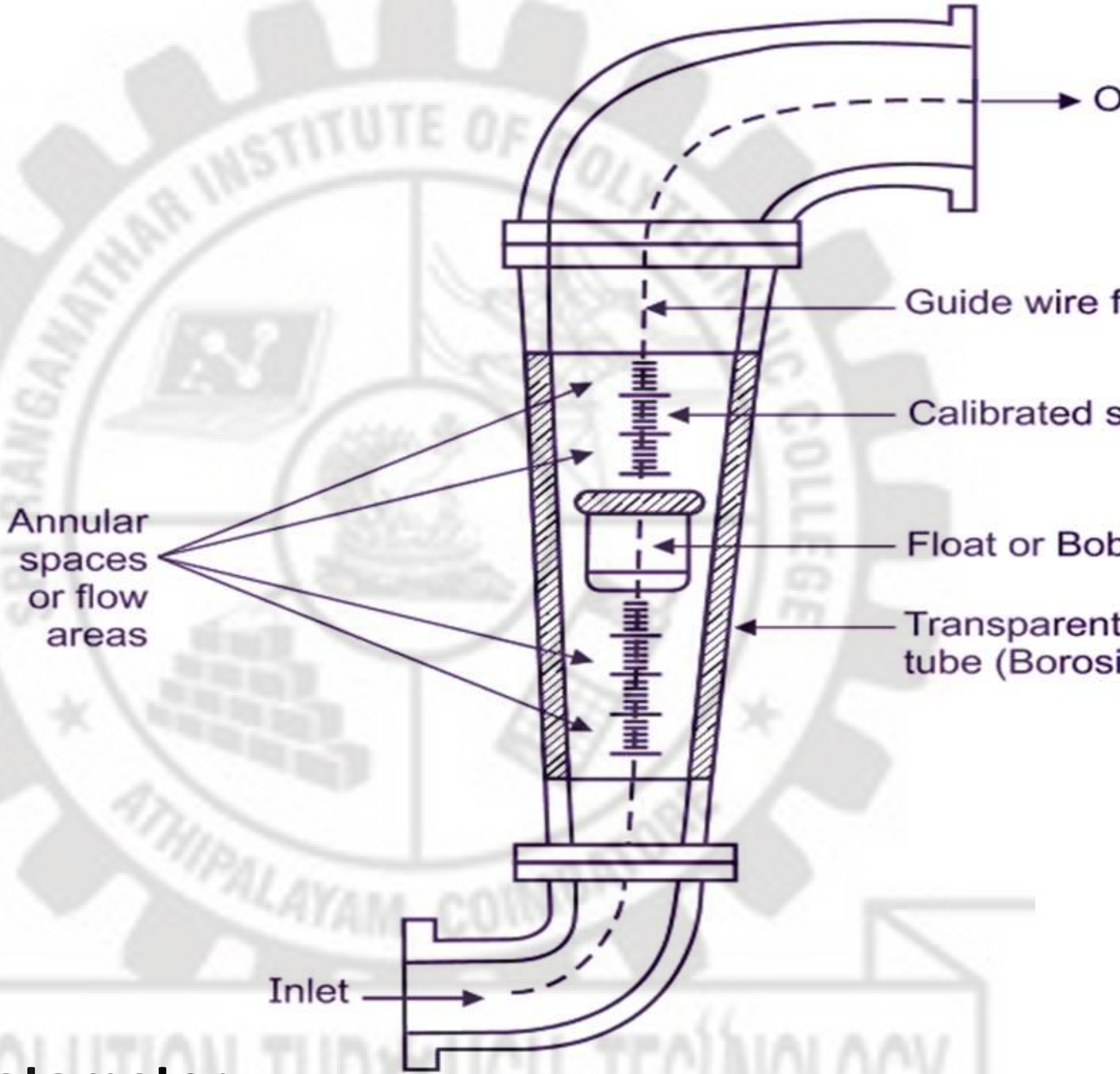


(a) Piezoelectric effect



(b) Piezoelectric pressure sensor

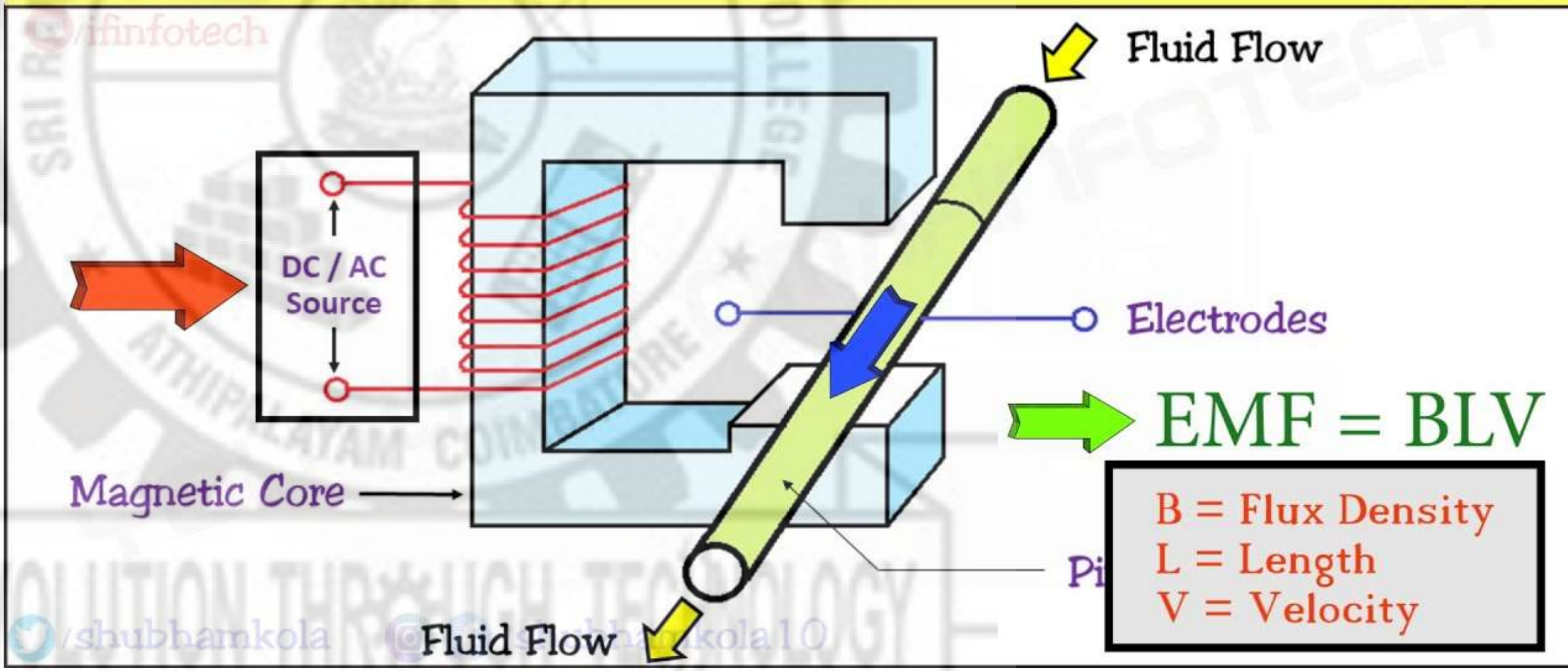
764 - SRIPC



rotameter

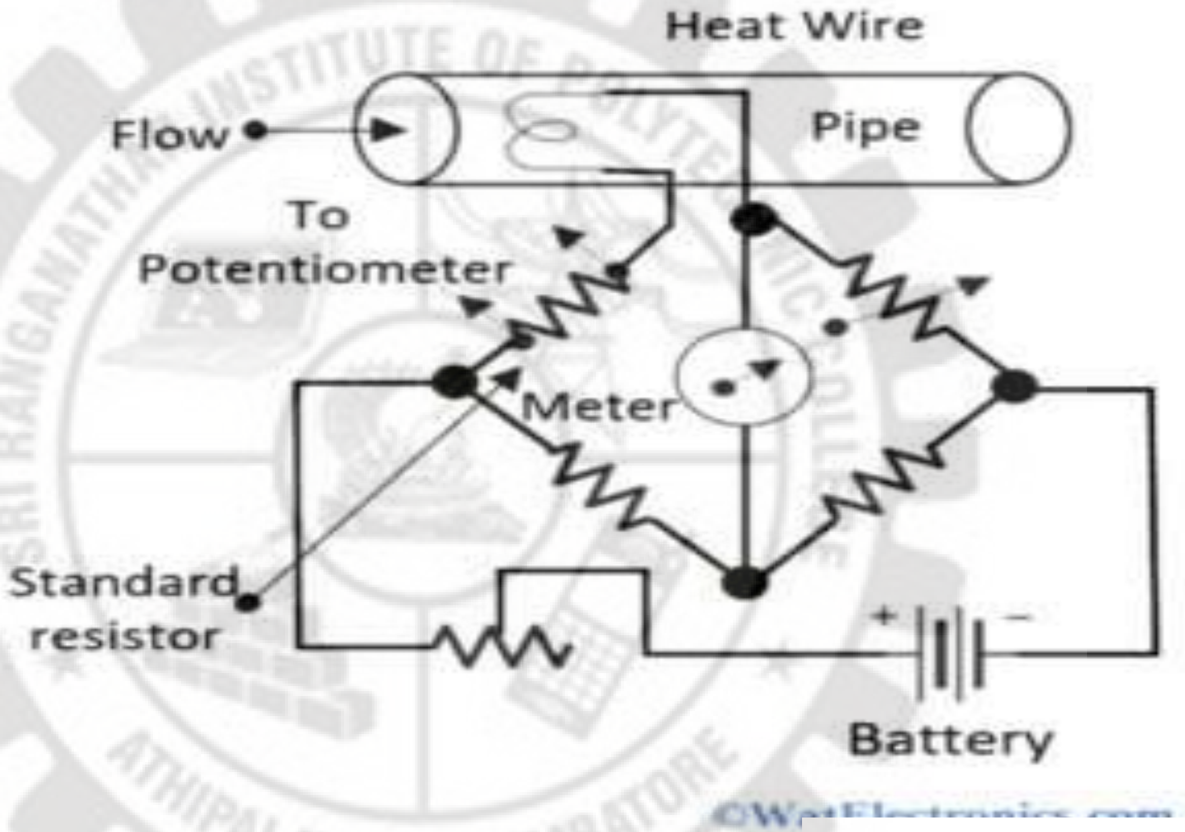
764 - SRIPC

Electromagnetic Flow meter

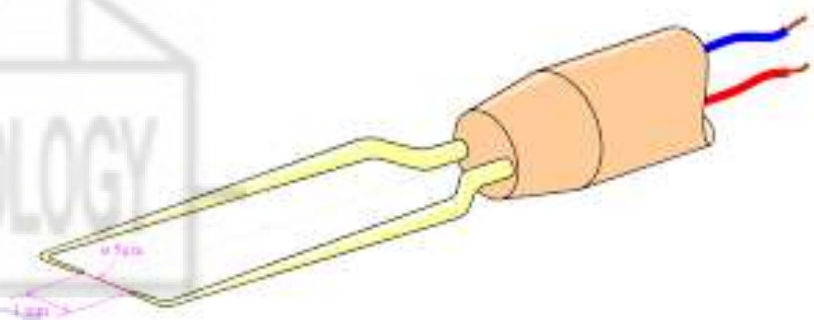


764 - SRIPC

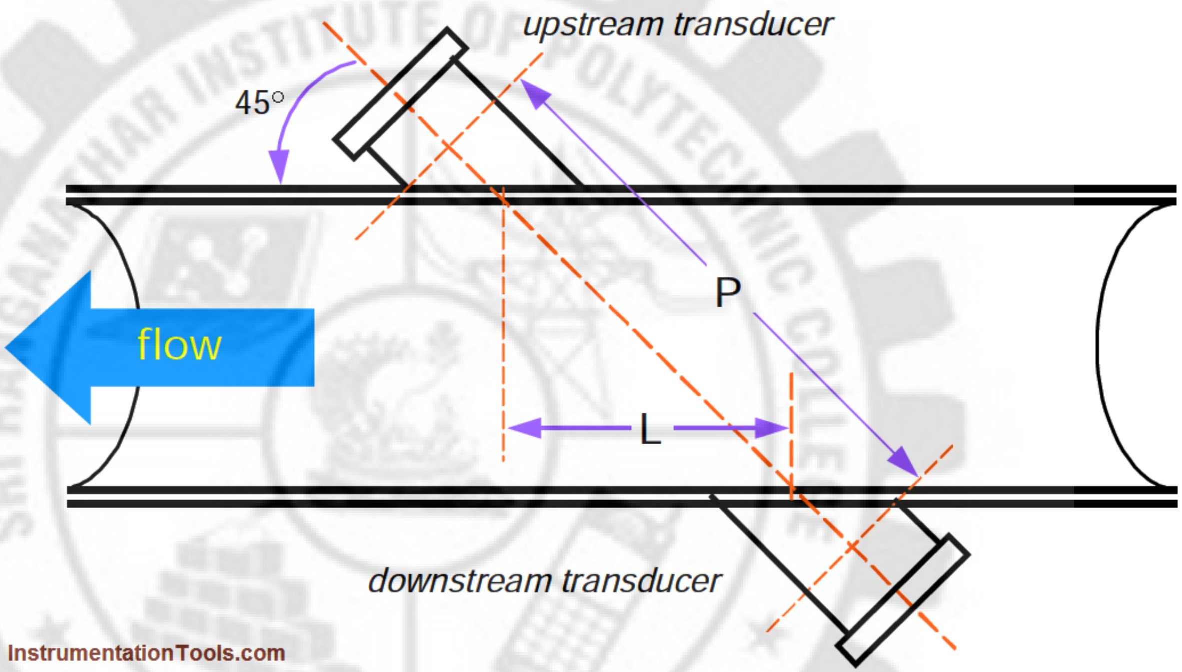
SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
ATHIPALAYAM COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

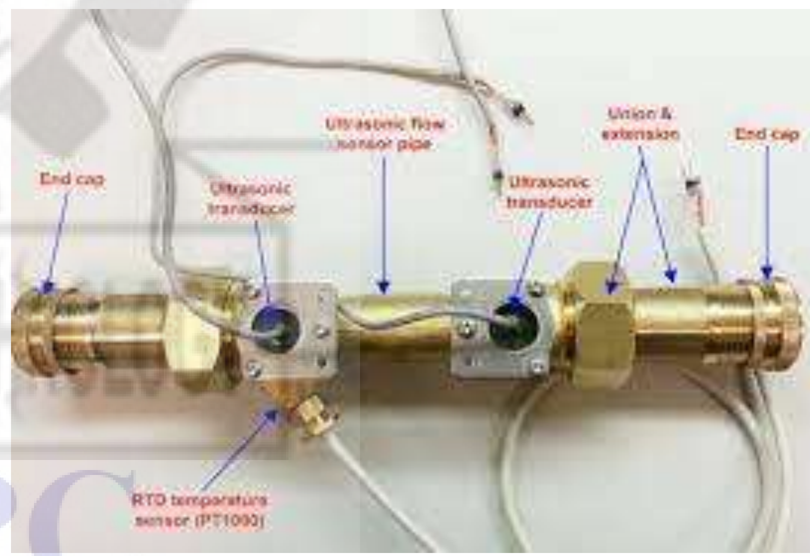


hot wire anemometer



764 - SRIPC

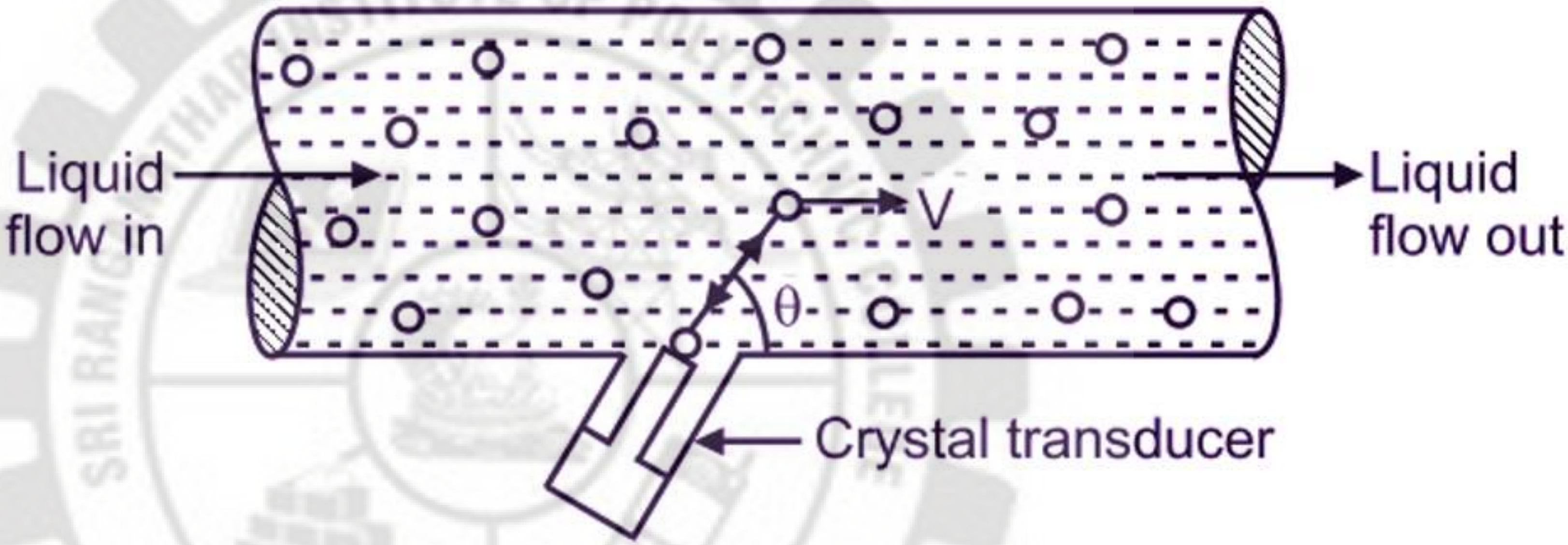




Ultrasonic Flow Meter-

Transit Time Method

764 - SRIPC



Ultrasonic Flow Meter-

Doppler Method

764 - SRIPC

Unit 2
Linear and Angular Measurement

764 - SRIPC

Syllabus

Definition of metrology

- Linear measuring instruments: Vernier, micrometer and interval measurement- Slip gauges and classification. Interferometer, optical flats and limit gauges Comparators: Mechanical, pneumatic and electrical types, applications.
- Angular measurements: -Sine bar, optical bevel protractor ,Taper measurements

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Definition

- *Metrology* is the name given to the science of pure measurement.
- *Engineering Metrology* is restricted to measurements of length & angle

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Linear and Angular Measurement

- The Linear Measurement includes measurements of length, diameters, heights and thickness
- The Angular measurement includes the measurement of angles or tapers

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Measurements

- Measurement systems are mainly used in industries for quality control.
- Often widely using measurements are
  - Linear Measurement
  - Angular measurement

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

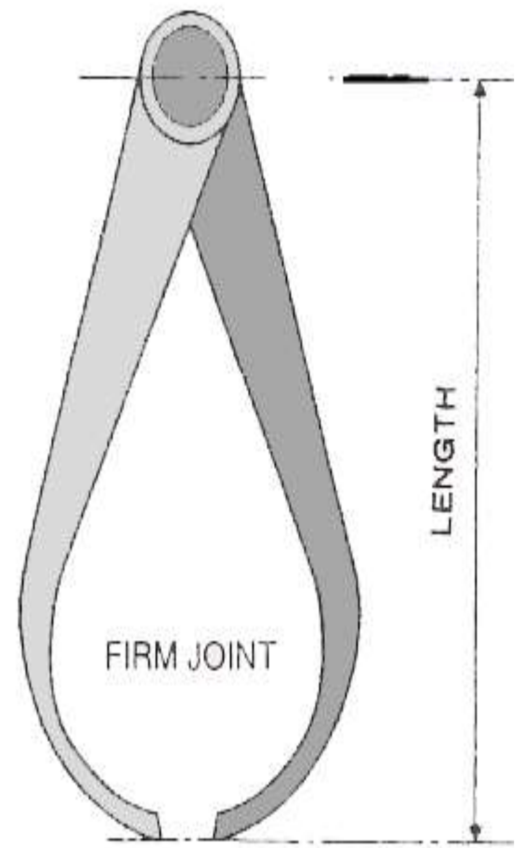
Dimensions

- A very common measurement is that of dimensions, i.e., length, width, height of an object
- Dimensions of the measuring instruments are classified as follows
  - Low resolution devices (up to 0.25mm)
  - Medium resolution devices (up to 0.0025mm)
  - High resolution devices (less than microns)

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Low resolution devices

- Steel rule
- Steel rule with assistance of
  - Calipers
  - Dividers &
  - Surface gauges
- Thickness gauges



764 - SRIPC

Medium resolution devices

- Micrometer
- Micrometer with assistance of
  - Telescoping
  - Extendable ball gauges
- Vernier calipers
- Dial indicators
- Microscope

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

High resolution devices

- Gauge blocks
- Gauge block with assistance of
  - Mechanical comparator
  - Electronic comparator
  - Pneumatic comparator
  - Optical flats

764 - SRIPC

Linear Measuring Instruments

- Vernier caliper
- Micrometer
- Slip gauge or gauge blocks
- Optical flats
- Interferometer
- Comparators

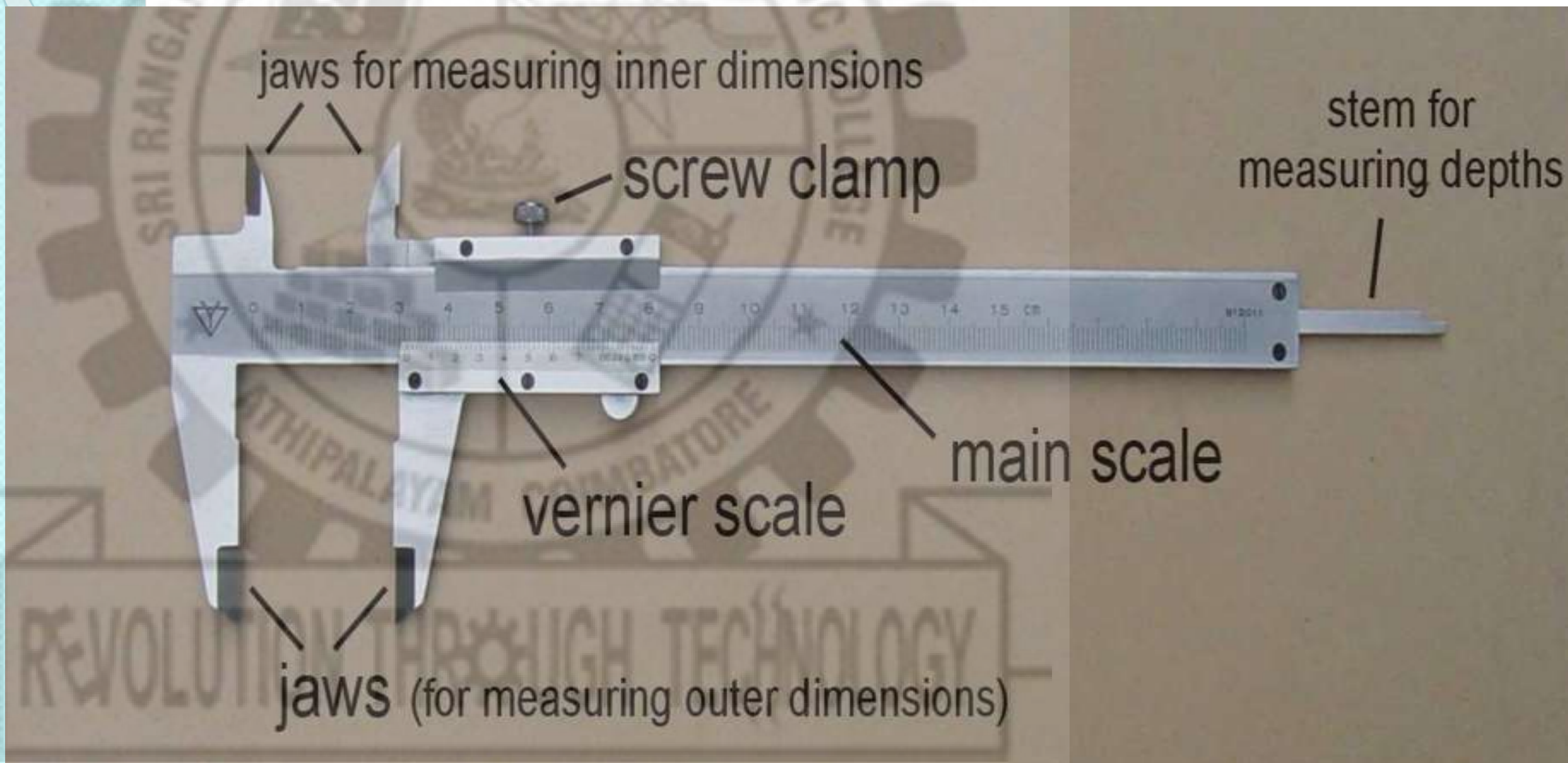
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Vernier caliper

- Components of vernier calipers are
  - Main scale
  - Vernier scale
  - Fixed jaw
  - Movable jaw
- Types of vernier calipers
  - Type A vernier caliper
  - Type B vernier caliper
  - Type C vernier caliper

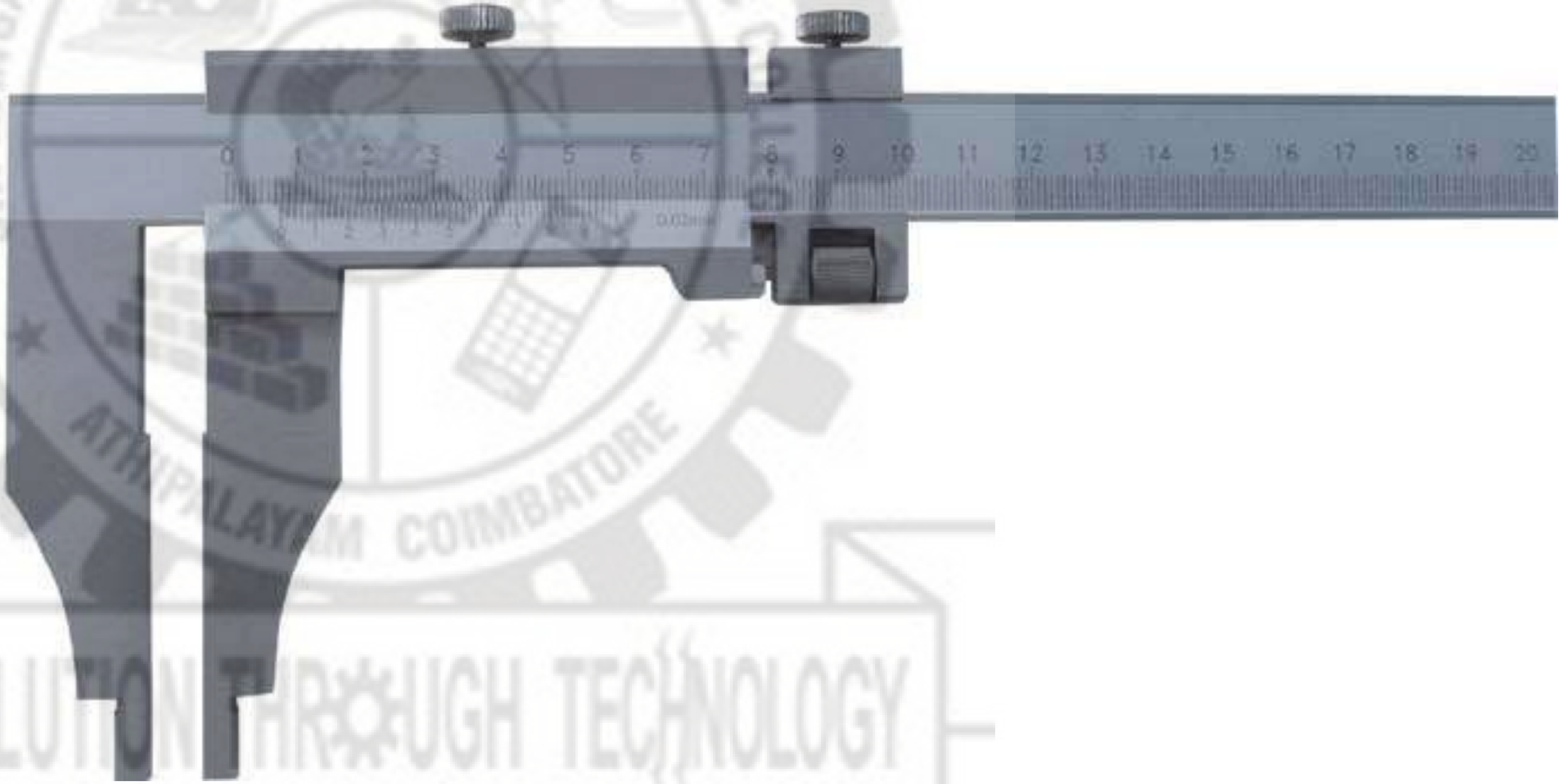
764 - SRIPC

Type A Vernier Caliper



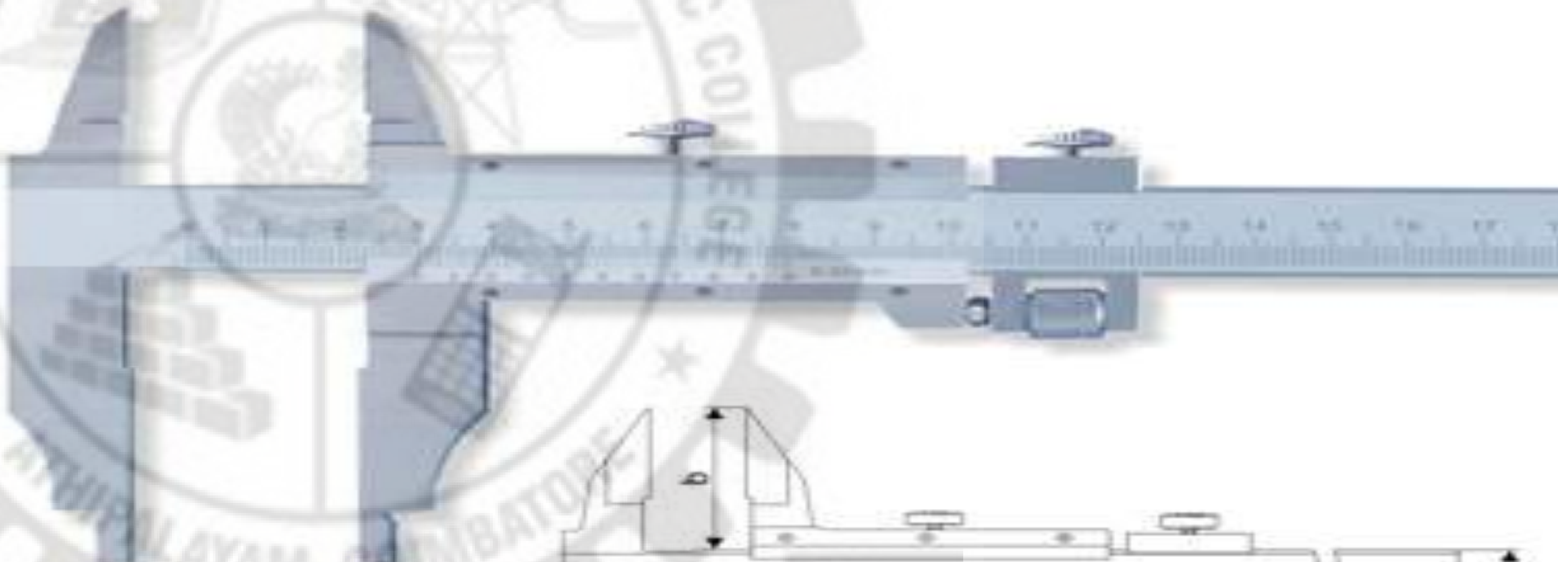
764 - SRIPC

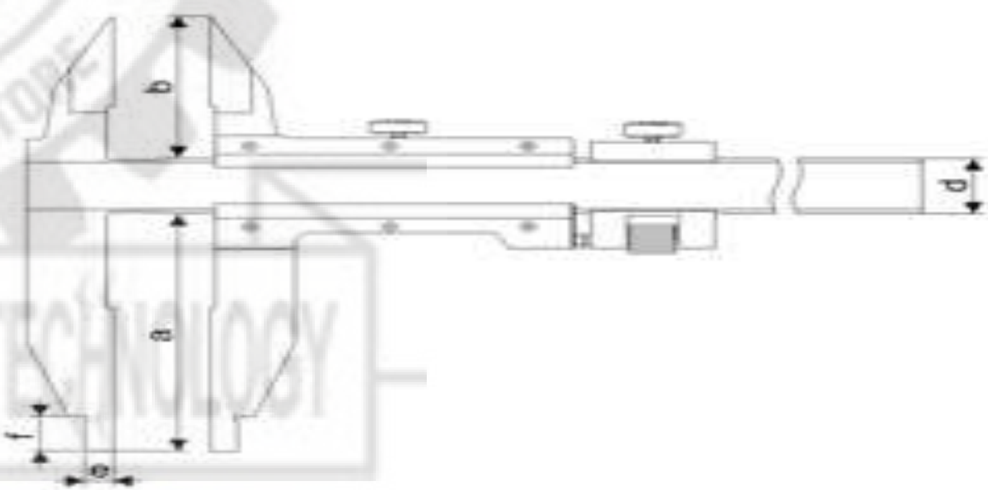
Type B Vernier Caliper



REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Type C Vernier Caliper





REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

VERNIER CALIPER

- Vernier calipers are available in size of 150 mm, 225 mm, 900 mm and 1200 mm.
- The selection of the size depends on the measurements to be taken.
- Vernier calipers are precision instruments, and extreme care should be taken while handing them.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Vernier caliper

VERIER CALIPER WITH 0.02MM LEAST COUNT IS GENERLY USED IM WORK SHOP.

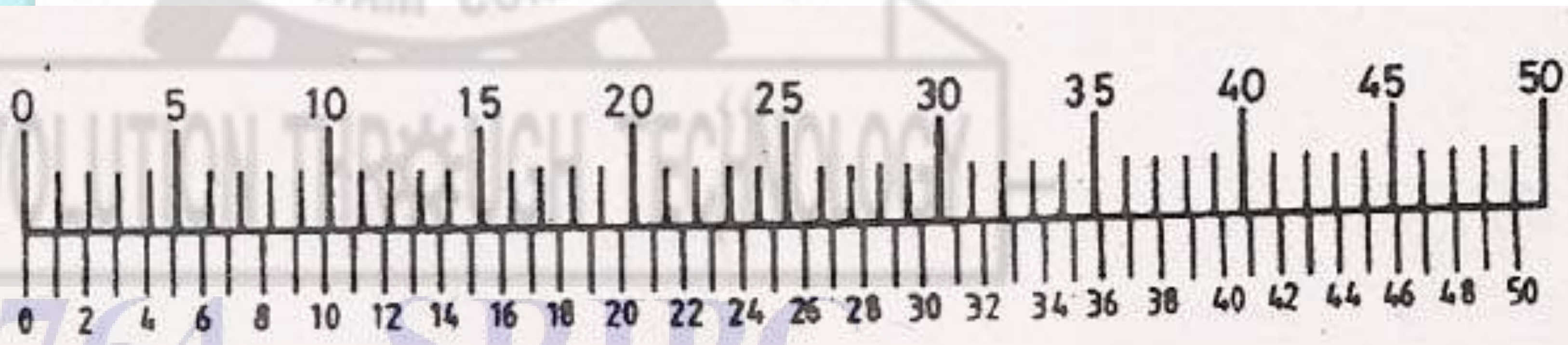
In this Vernier caliper main scale division (49mm) are divided in to 50 equal part in the Vernier scale.

i.e. 1 main scale division (MSD) =1 mm

1. Vernier scale division (VSD) =49\50 mm

Least count is 1mm – 49\50 =1\50 mm

THE DIFFERENCE BETWEEN 1.MSD and 1. VSD=0.02MM



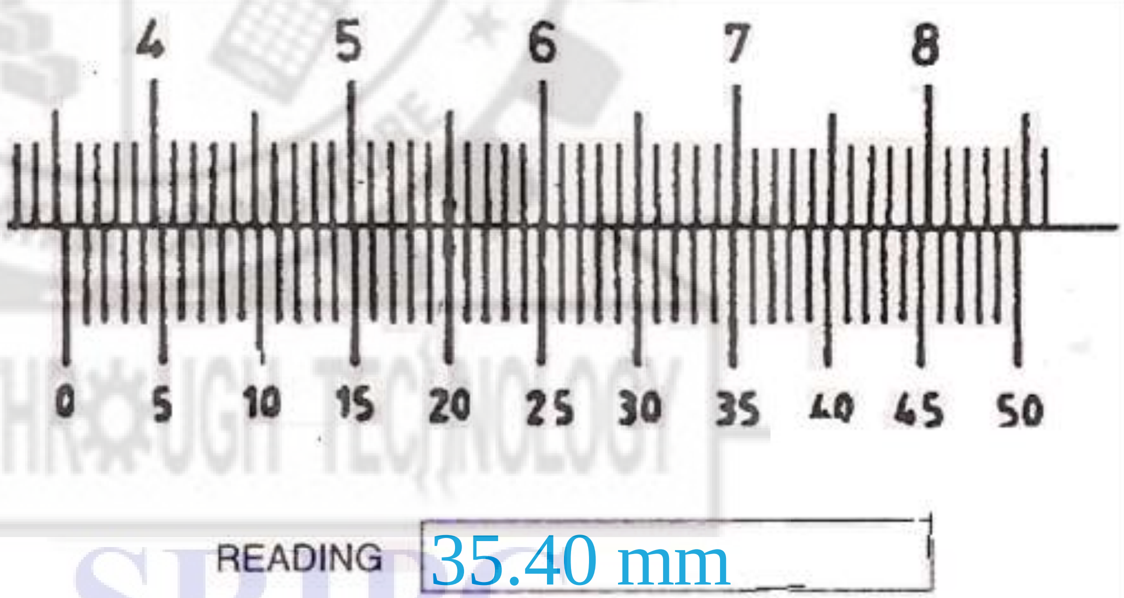
764 - SRIPC

Example

Main scale reading =35mm

The vernier division coinciding with the main scale is the 20th division. Value=20 multiplied by 0.02=0.40mm.

Total reading is 35mm+0.40= 35.40mm



764 - SRIPC

Vernier Depth Gauge

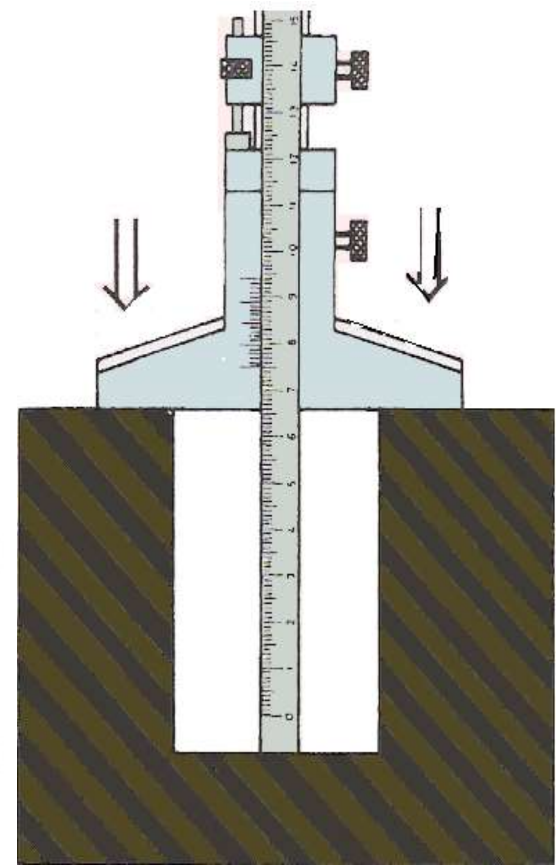
A vernier depth is very commonly used precision instrument for measuring depth of holes recesses, slot and step.

Its construction and method of reading are similar to those of a vernier caliper.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

VERNIER DEPTH GAUGE

- Base
- Graduated beam
- Clamping screw
- Fine adjustment mechanism
- Vernier scale



764 - SRIPC

VERNIER HEIGHT GAUGE

The main parts of a vernier height gauge and their function are given.

1.base

2. beam

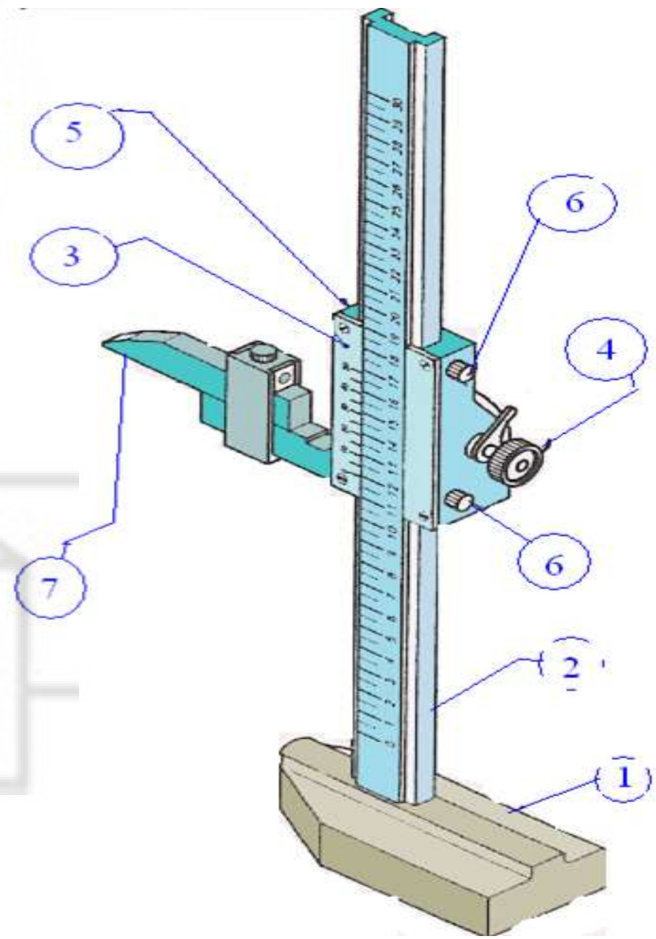
3.vernier slide

4. fine setting device

5. vernier plate

6. locking screws

7. scriber



764 - SRIPC

MICRO METER

A micro meter is a precision instrument used to measure a job, generally within an accuracy of 0.01mm.Micrometer used to take the outside measurements are know as outside micrometer.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

PARTS OF MICROMETER

Frame

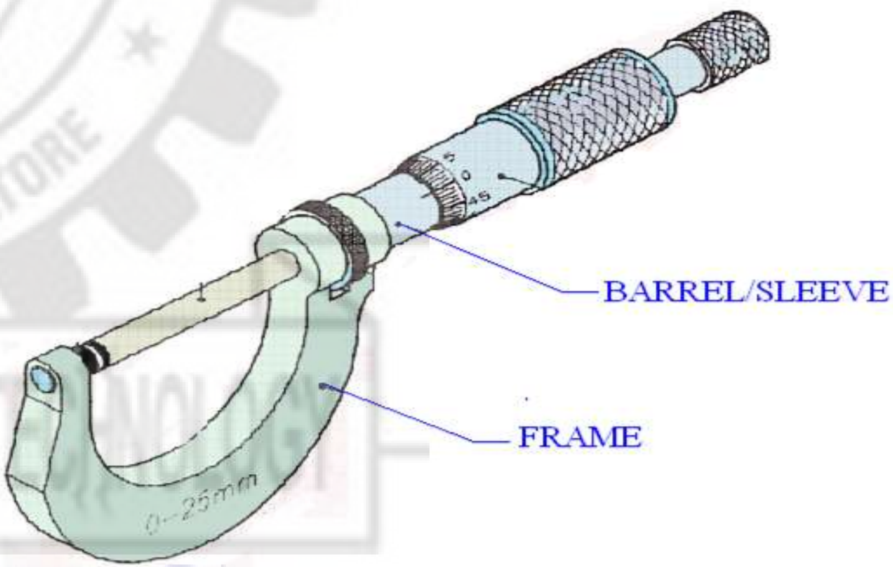
Anvil and spindle

Screwed spindle

Graduated sleeve or barrel

Ratchet or friction stop

Spindle clamp



764 - SRIPC

Interval measurements

- Slip gauges
- Interferometer
- Optical flats and limit gauges
- Comparators

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

SLIP GAUGE

- Slip gauges are rectangular blocks of steel having a cross-section of about 30 by 10 mm
- Normal set

Range	Step	Pieces
1.001 to 1.009	0.001	9
1.01 to 1.09	0.01	9
1.1 to 1.9	0.1	9
1 to 9	1	9
10 to 90	10	9
	Total	45

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

- Special Set

Range	Step	Pieces
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
1.5 to 9.5	0.5	19
10 to 90	10	9
	Total	86

764 - SRIPC

Classification

- AA slip gauges
- A slip gauges and
- B slip gauges

SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
ATHIPALAYAM COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

- AA slip gauges
  - Master slip gauges
  - Accurate to plus or minus two microns per meter
- A slip gauges
  - Reference purpose
  - Type A is guaranteed accurate up to plus or minus four microns per meter
- B slip gauges
  - Working slip gauges
  - Type 'B' for plus or minus eight microns per meter

764 - SRIPC

Classes

- *Grade 2*
- *Grade 1*
- *Grade 0*
- *Grade 00*
- *Calibration grade*

764 - SRIPC

Grade 2

- This is the workshop grade
- Typical uses include setting up machine tools, positioning milling cutters and checking mechanical width.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Grade I

- Used for more precise work, -tool room.
- Typical uses include setting up
  - Sine bars and sine tables
  - Checking gap gauges and
  - Setting dial test indicators to zero

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Grade 0

- This is more commonly known as the Inspection grade
- Inspection Department only who have access to this grade of slips

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Grade 00

- This grade would be kept in the Standard Room and would be kept for work of the highest precision only.
- Determination of any errors present in the workshop or Grade 2 slips.

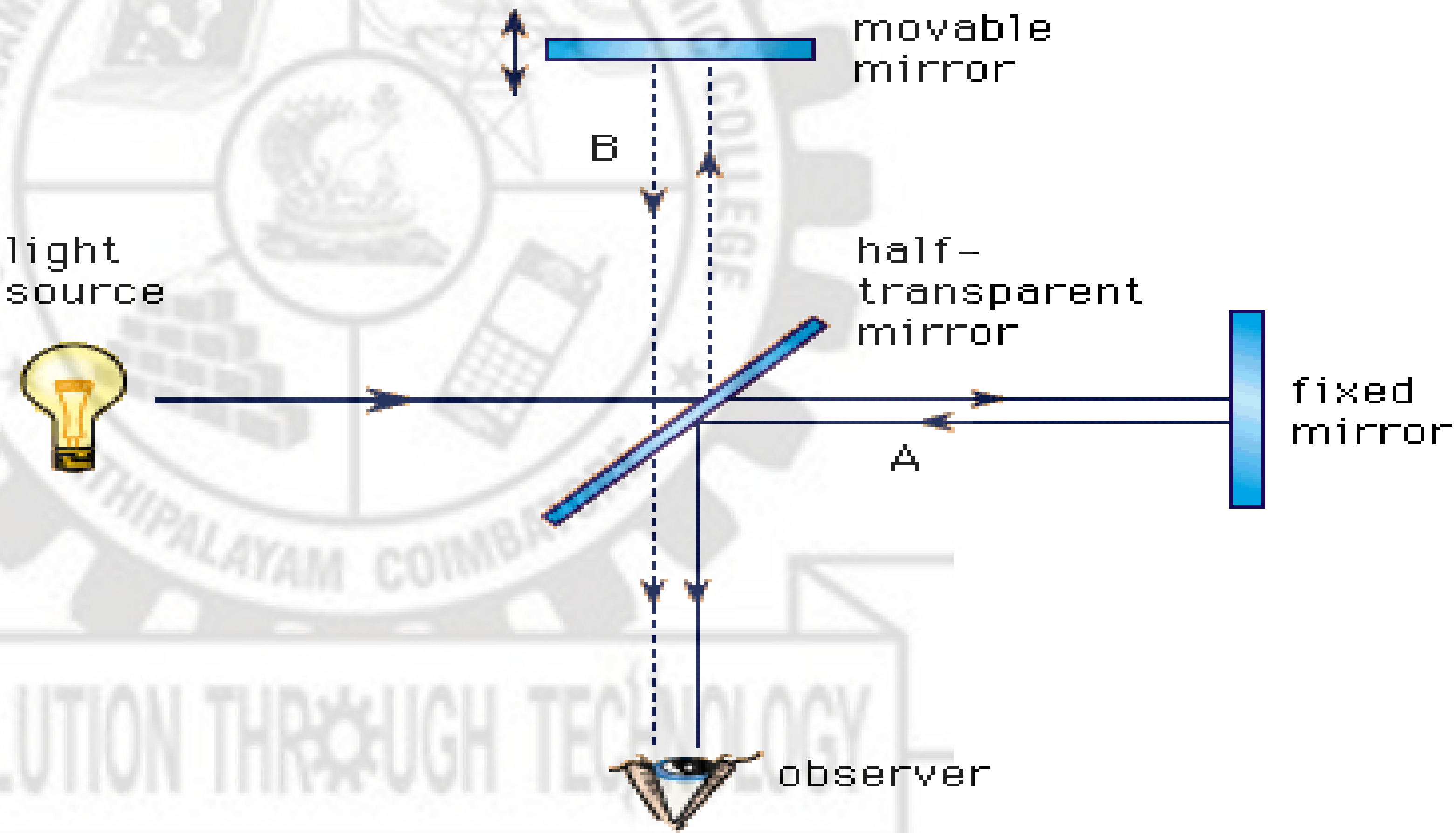
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Calibration grade

- Calibration grade are used for calibration of slip gauges, other measuring instruments

764 - SRIPC

Interferometer

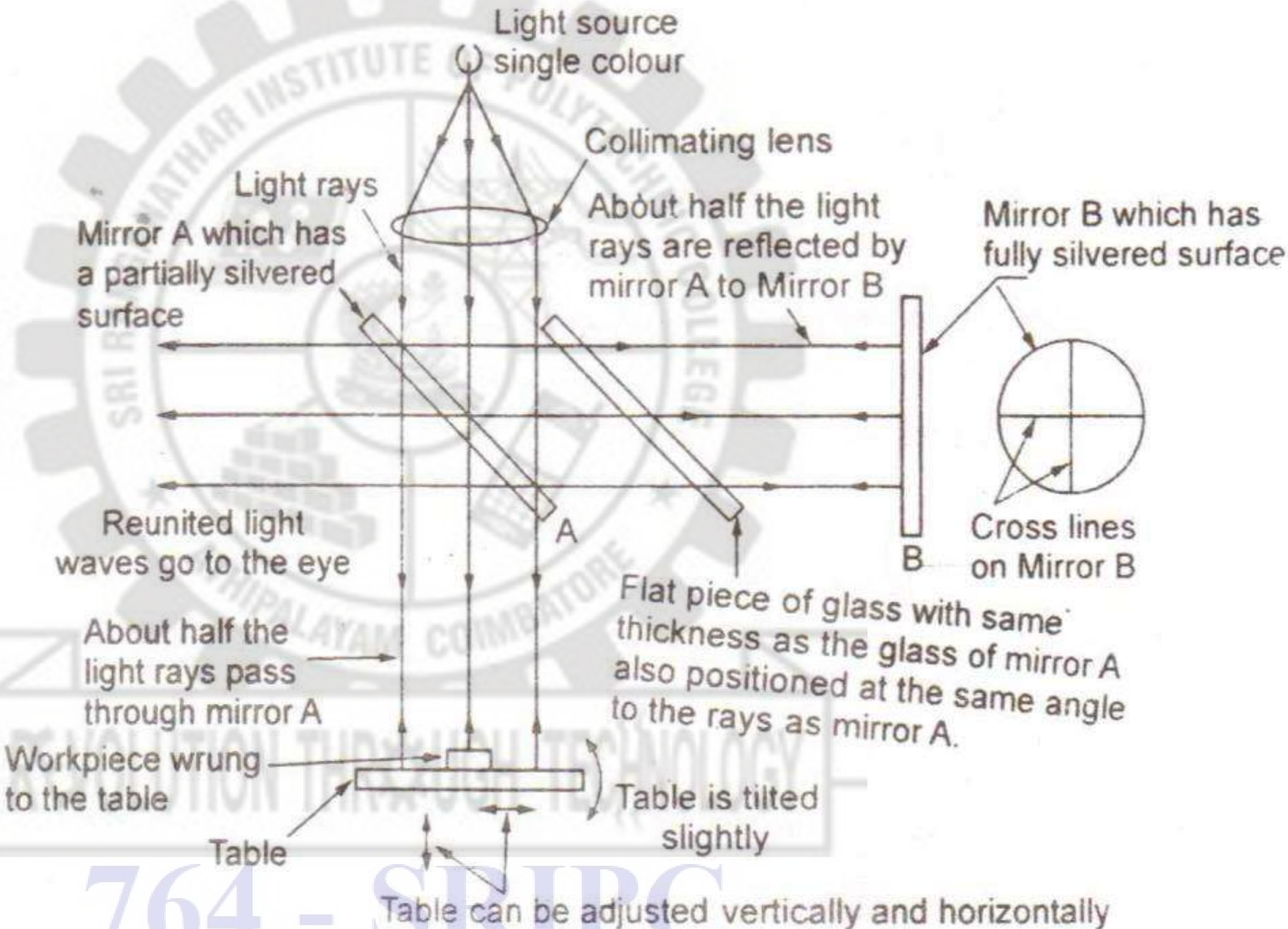


764 - SRIPC

Principle

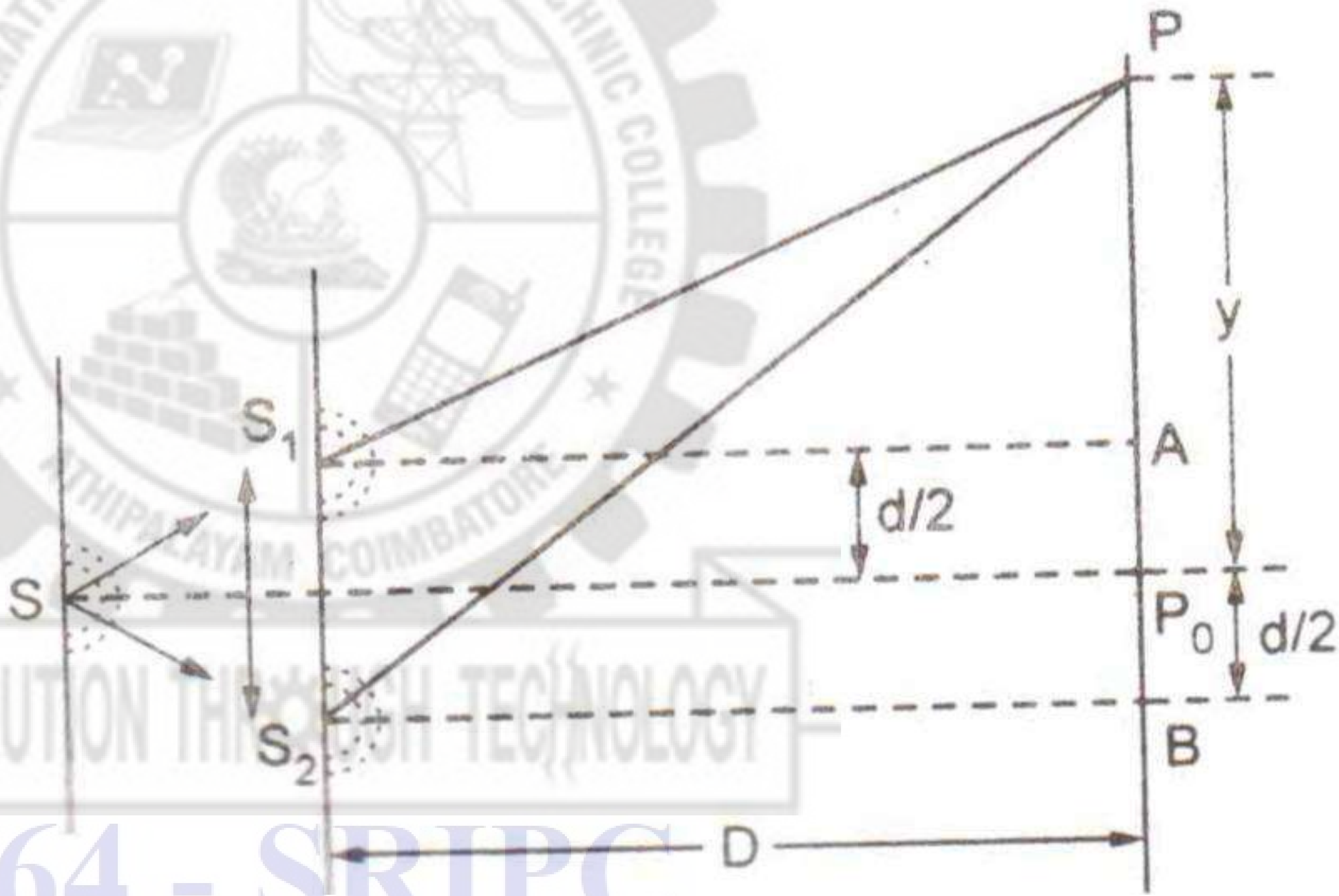
- Interferometers are optical instruments used for measuring flatness
- Determining minute differences in length by direct reference to the wavelength of light.

764 - SRIPC


Light source
single colour
Collimating lens
Light rays
Mirror A which has
a partially silvered
surface
About half the light
rays are reflected by
mirror A to Mirror B
Mirror B which has
fully silvered surface
A
B
Cross lines
on Mirror B
Reunited light
waves go to the eye
Flat piece of glass with same
thickness as the glass of mirror A
also positioned at the same angle
to the rays as mirror A.
About half the
light rays pass
through mirror A
Workpiece wrung
to the table
Table is tilted
slightly
Table
Table can be adjusted vertically and horizontally

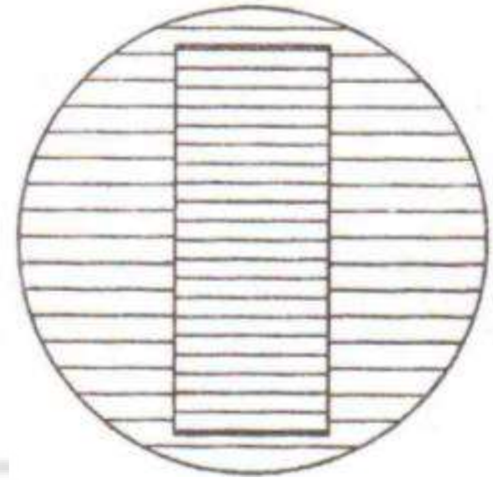
764 - SRIPC

Principle of interferometer



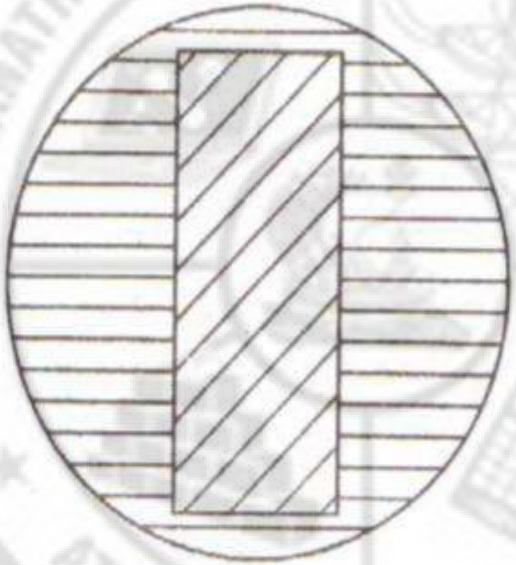
764 - SRIPC

Fringes

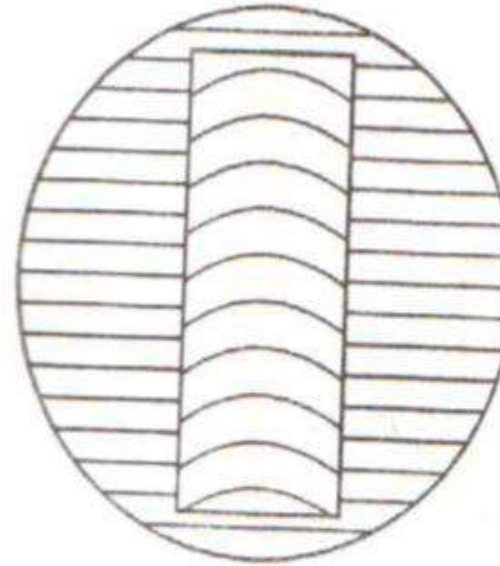


REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

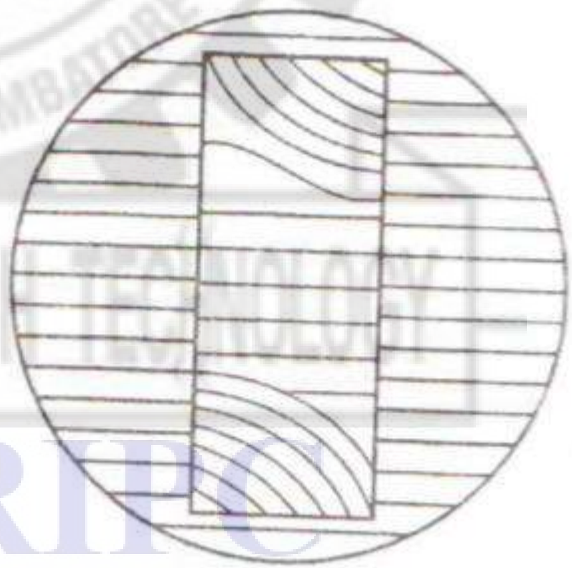
Fringes



a



b



c

764 - SRIPC

Fringes

- A
  - Here the error is indicated by the amount by which the fringes are out of parallelism with those on the base plate
- B
  - If the work piece is concave or convex, fringe pattern will be as shown in Figure (b).
- C
  - The surface is flat with slight rounding off at the corner

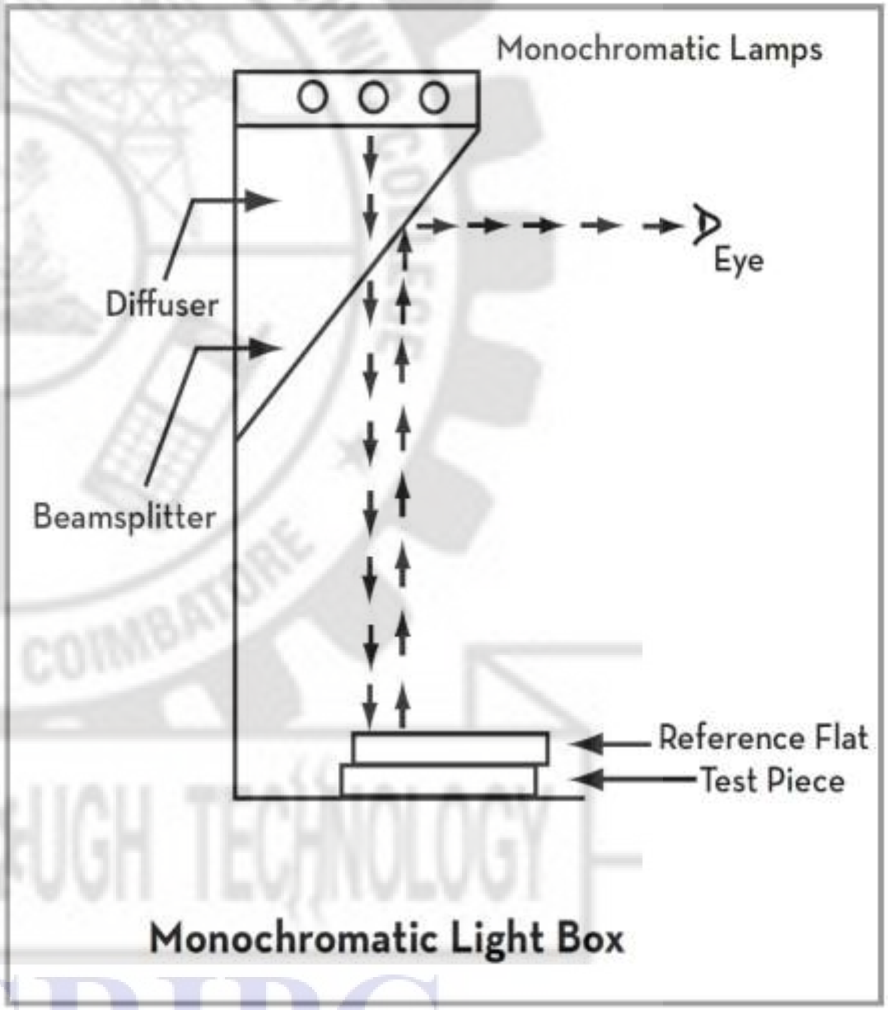
764 - SRIPC

Optical flats

- Optical flats can be used to measure the flatness
  - An optical reference flat of known quality
  - A monochromatic light box
  - Solvent and cleaning material

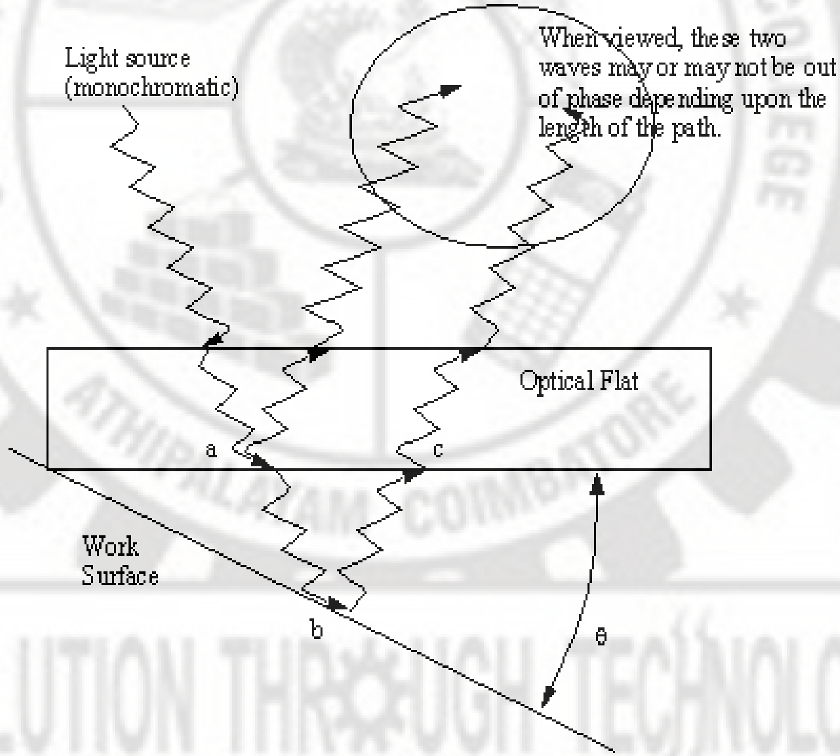
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Typical setup of optical flat



764 - SRIPC

Working



764 - SRIPC

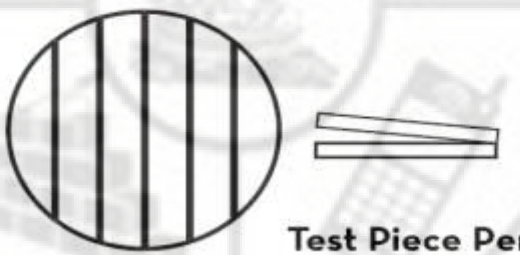
Fringe Pattern

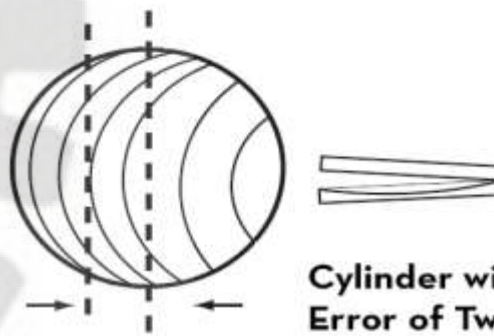
- Air wedges
  - *Flatness error of zero*
  - *Cylinder with flatness error of two fringes*
- Contact method
  - *Convex Cylinder*
  - *Concave Cylinder*
  - *Convex Sphere*
  - *Concave Sphere*
  - *Convex Spheroid*
  - *Concave Spheroid*
  - *Saddle*
  - *Highly Irregular*

764 SRIPC

Air wedge

- *Flatness error of zero (a)*





(a) *(b)*

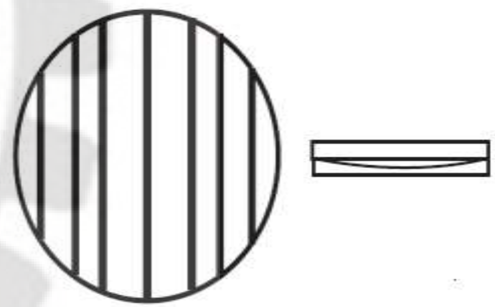
- *Cylinder with flatness error of two fringes (b)*

764 - SRIPC

Contact method

- *Convex Cylinder*

Convex Cylindrical Surface

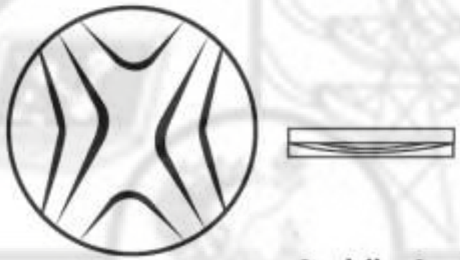


Concave Cylindrical Surface

- *Concave Cylinder*

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

- Saddle



Saddle Surface

- *Highly Irregular*

Highly Irregular Surface

764 - SRIPC

Application

- Front and rear surface mirrors
- gauge blocks
- Bearings
- Seals and
- Anvils

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Limit gauges

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Gauges

- Basic dimension: exact size of part from which all limiting variations made
- Limits: maximum and minimum dimensions
- Tolerance: permissible variation of part
  - unilateral: one direction only
  - Bilateral: both plus and minus (two directions)
- Allowance: intentional difference in dimensions of mating parts

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Fixed Gauges

- Used for inspection purposes
  - Provide quick means of checking specific dimension
- Easy to use and accurately finished to required tolerance
  - Generally finished to ten times the tolerance designed to control

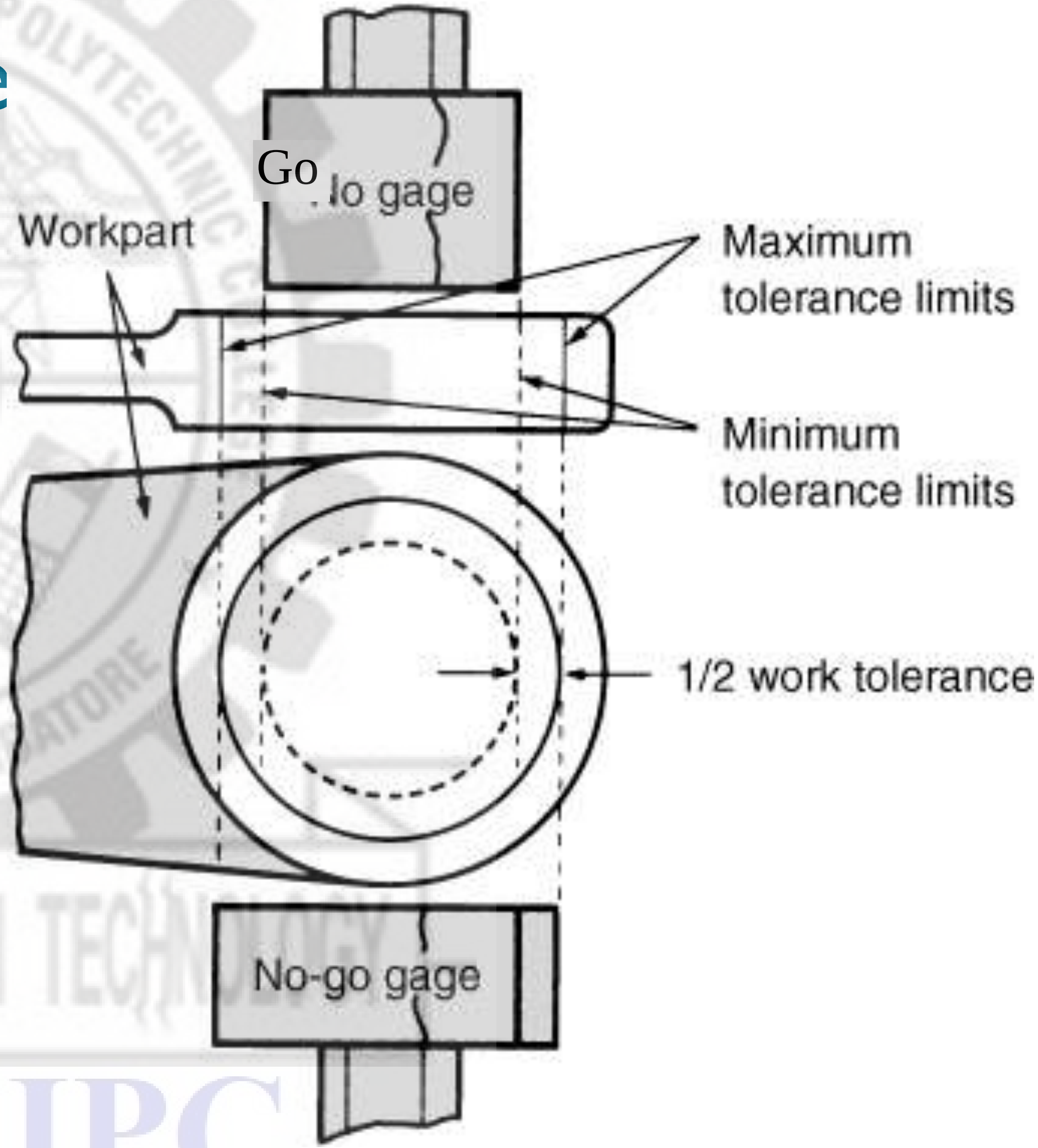
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Cylindrical Plug Gauge

Dimensions usually stamped on handle at each end.

"go" end longer than "no-go" for easy identification

Many made with carbide tips to increase gauge life



764 - SRIPC

Cylindrical Plug Gauges

764 - SRIPC

Cylindrical Plug gauge

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Plain Ring Gauges

- Used to check outside diameter of pieces
- Ground and lapped internally to desired size
  - Size stamped on side of gauge
- Outside diameter knurled and "no-go" end identified by annular groove on knurled surface
- Precautions and procedures similar to those outlined for a plug gauge

Plain Ring gauges

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Taper Plug Gauges

- Used to check size of hole and taper accuracy
- Made with standard or special tapers
- Some have "go" and "no-go" rings scribed
  - gauge fits into hole between two rings means within required tolerance

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Taper Plug and Ring Gauges

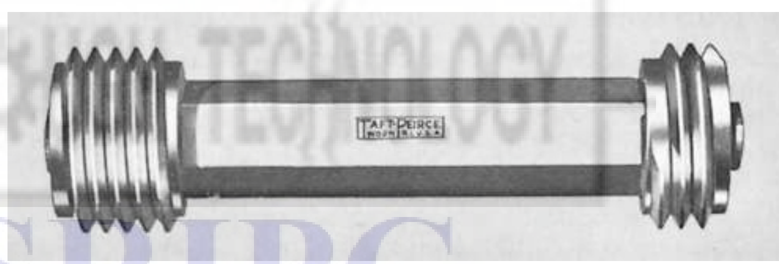
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Thread Plug Gauges

- Used for checking internal threads of the "go" and "no-go" variety
- Based on same principle as cylindrical plug gauges
- "go" end (longer end)
  - Should be turned in flush to bottom of hole
- "no-go" end
  - Should just start into hole and become snug before third thread enters

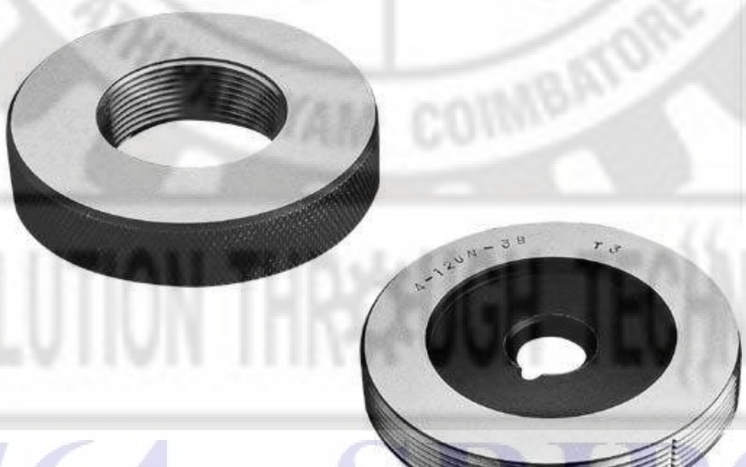
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Thread Plug Gauges



764 - SRIPC

Thread Ring Gauges



764 - SRIPC

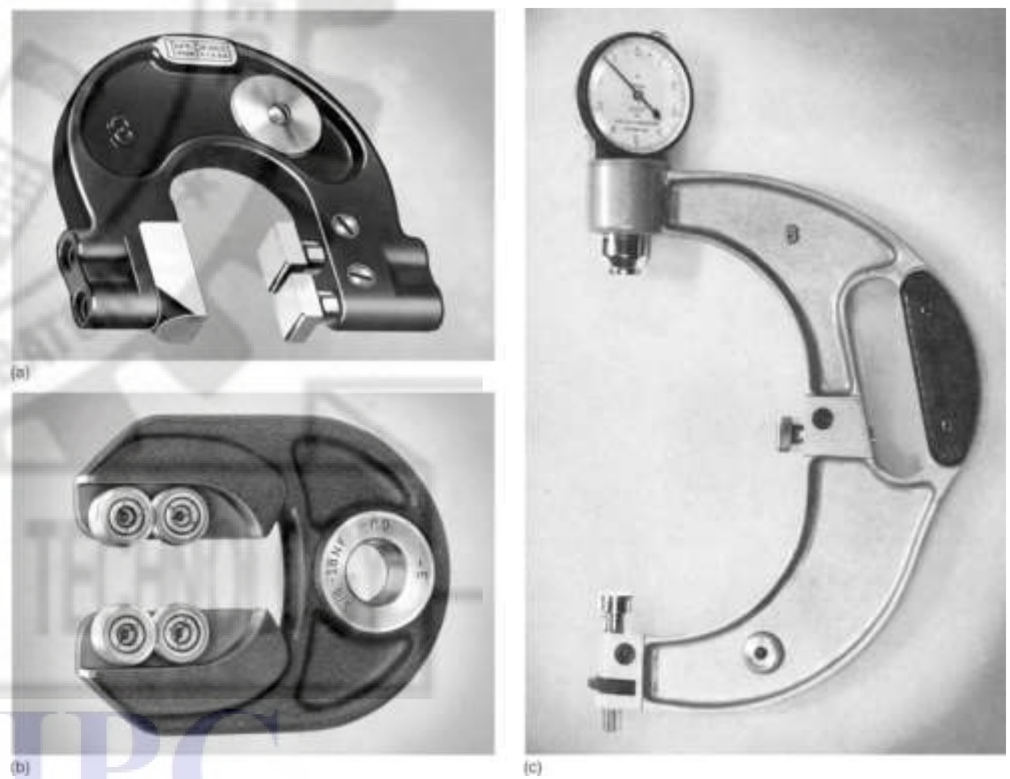
Snap Gauges

- One of most common types of comparative measuring instruments
- Faster to use than micrometers
- Limited in their application
- Used to check diameters within certain limits by comparing part size to preset dimension of snap gauge

764 - SRIPC

Snap Gauges

- Have C-shaped frame with adjustable gauging anvils or rolls set to "go" and "no-go" limits of the part
- Several styles



REVOLUTION THROUGH TECHN
764 - SRIPC

FEELER GAUGE

- A **feeler gauge** (also known as a **thickness gauge**) is an accurately manufactured strip of metal that is used to determine the gap or clearance between two components.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

FEELER GAUGE

- A feeler gauge can be used to check the following:
  - Piston ring gap
  - Piston ring side clearance
  - Connecting rod side clearance

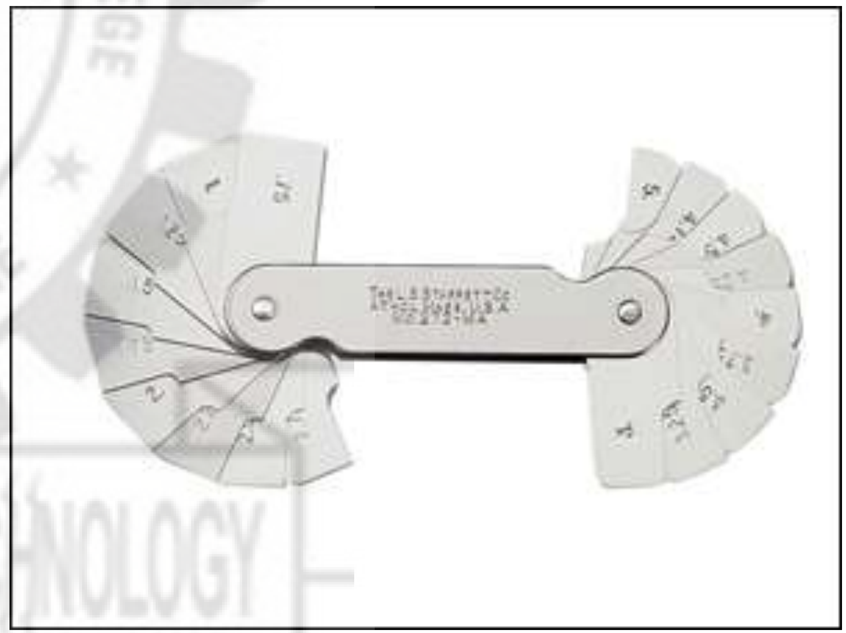
764 - SRIPC

- Feeler gauges are most commonly made of high-quality carbon steel, and are machined to a very smooth surface finish. Other blade materials are available, including stainless steel, brass, and plastic. Metal blades have better wear resistance and will maintain their accuracy after many uses

764 - SRIPC

Radius Gauge

- A **radius gauge** is a tool used to measure the radius of an object.



764 - SRIPC

Thread Pitch Gauge

- It used to quickly determine the pitch of various threads by matching the teeth on the leaves with teeth on the work.

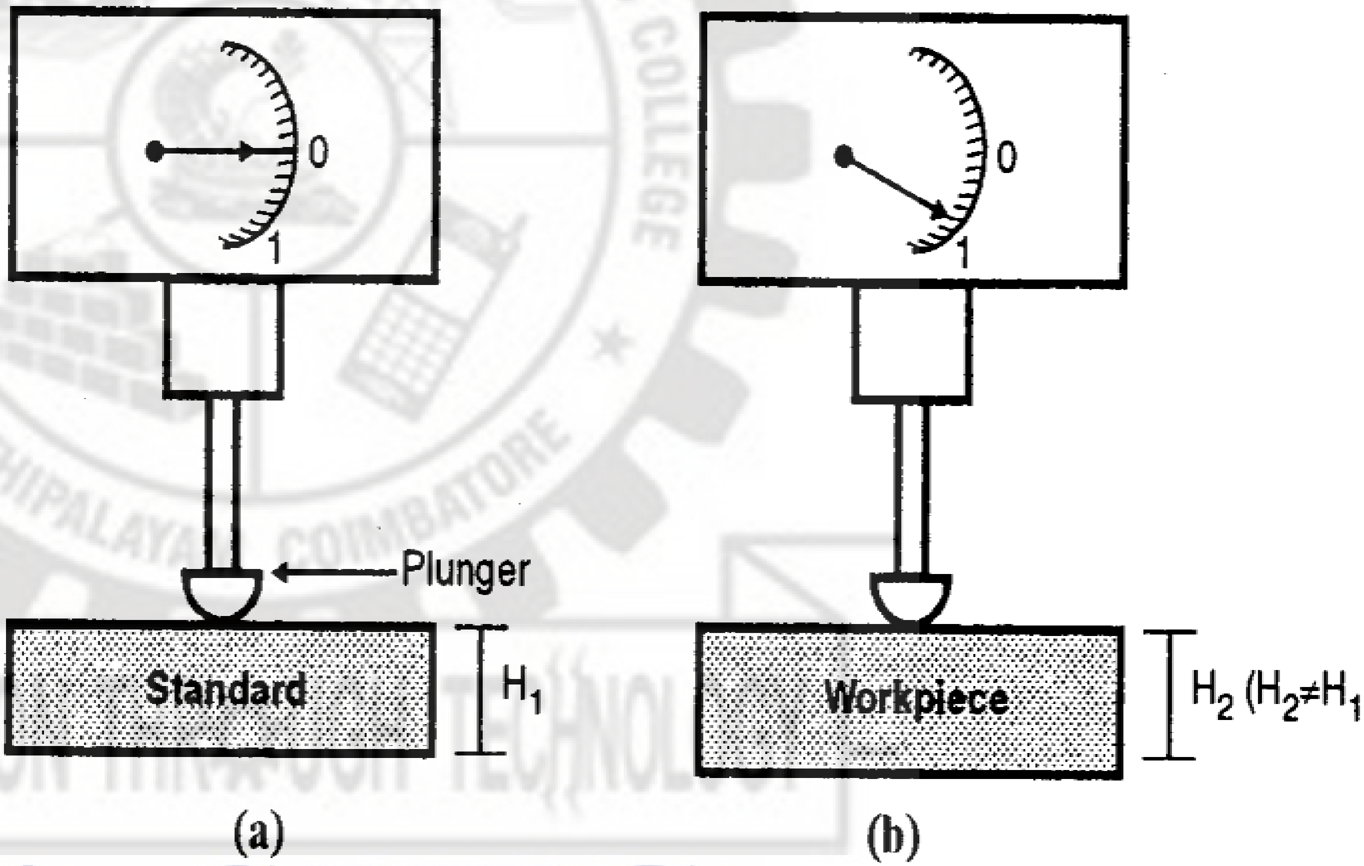
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Comparators

- Mechanical comparators
- Electrical comparators
- Optical comparators
- Pneumatic comparators

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Mechanical comparators

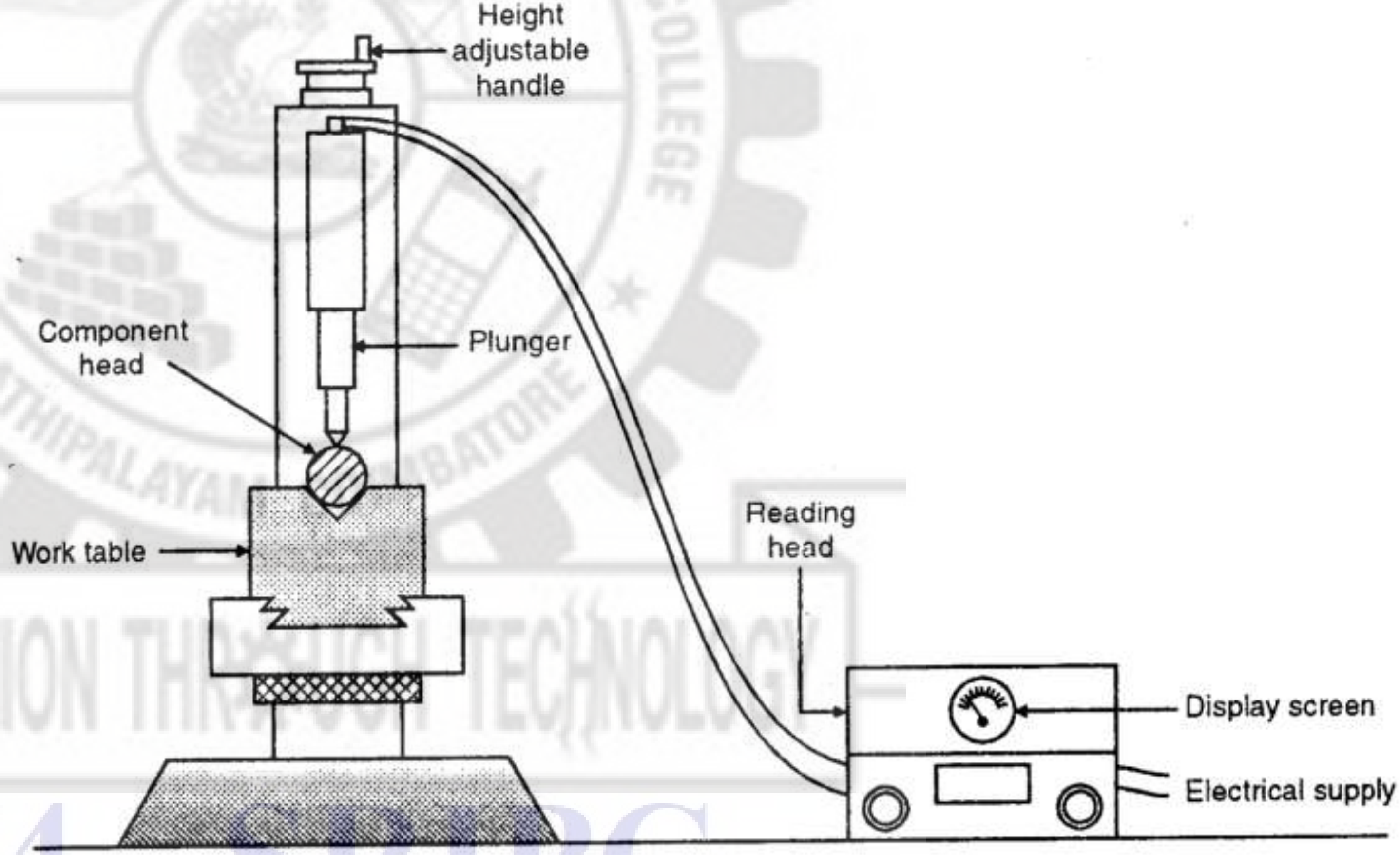


764 - SRIPC

- It is a precision instrument employed to compare the dimension of a given component with a working standard
- It does not measure the actual dimension but indicates how much it differs from the basic dimension

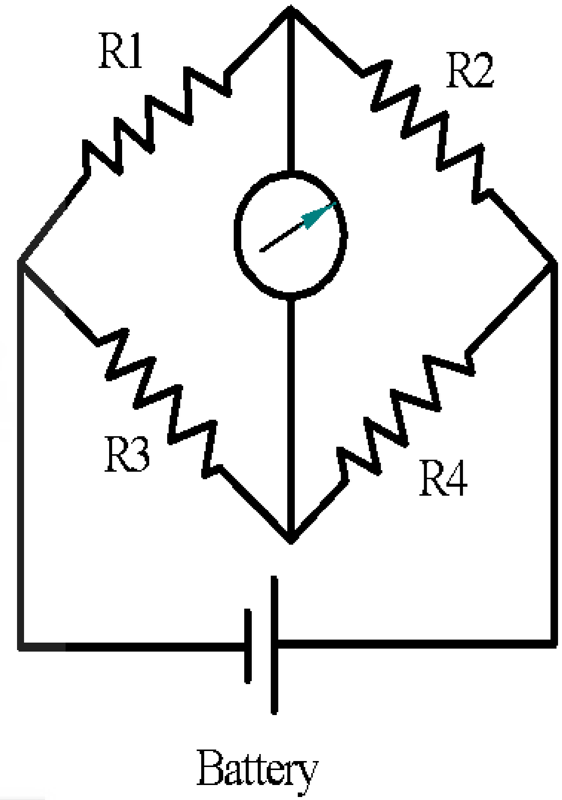
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

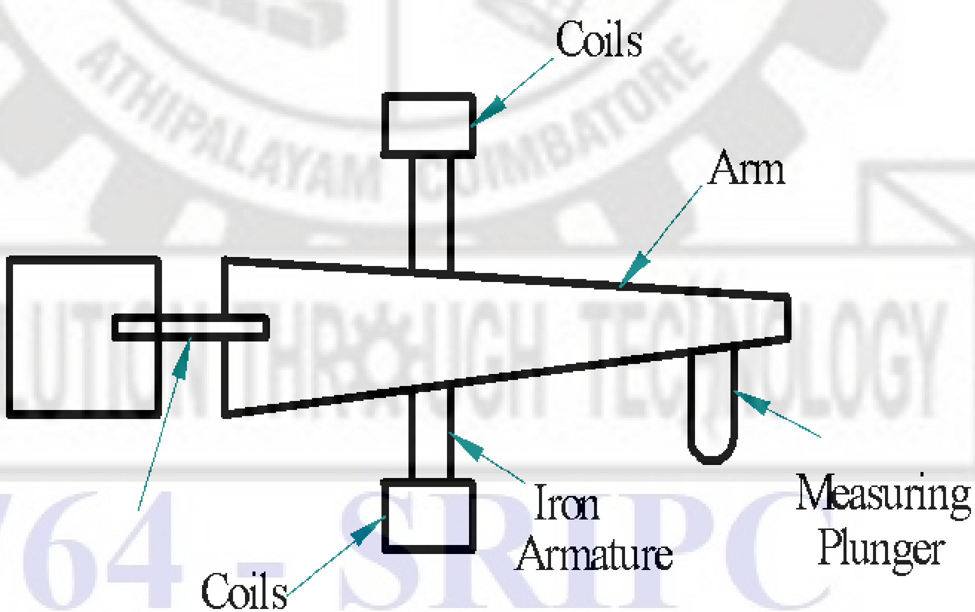
Electrical comparators



REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Electrical& Electronic Comparators

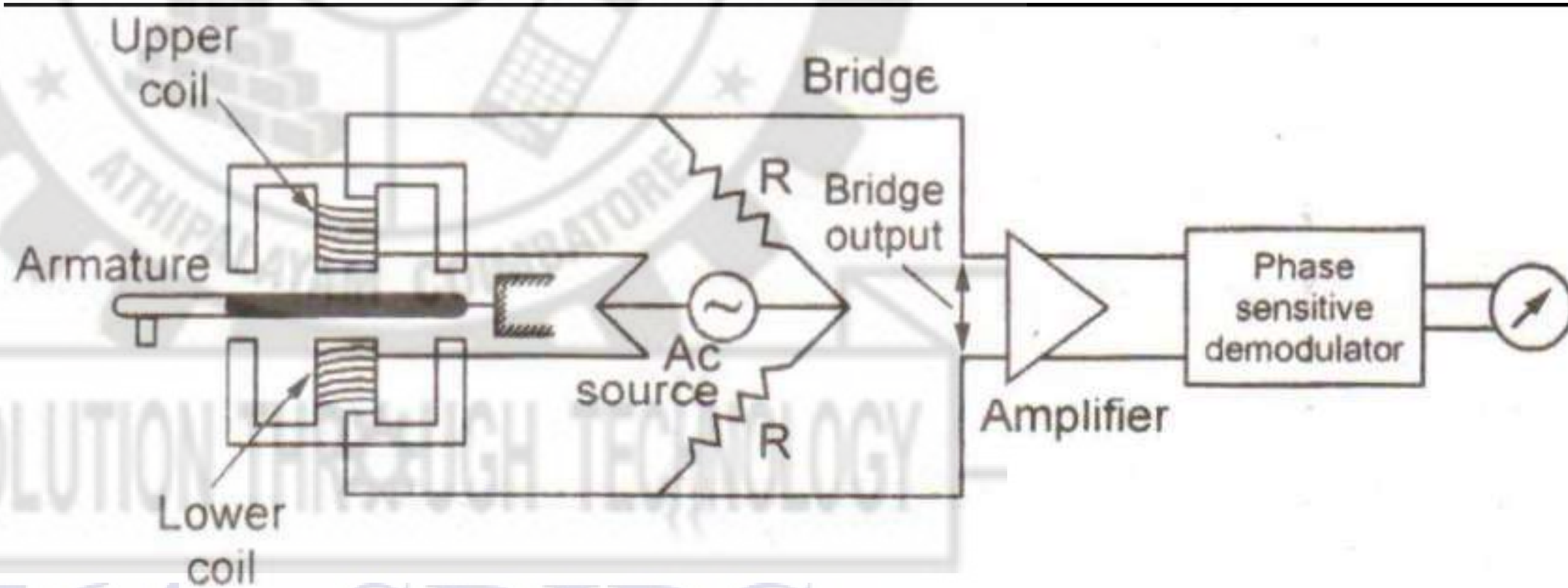




764 - SRIPC

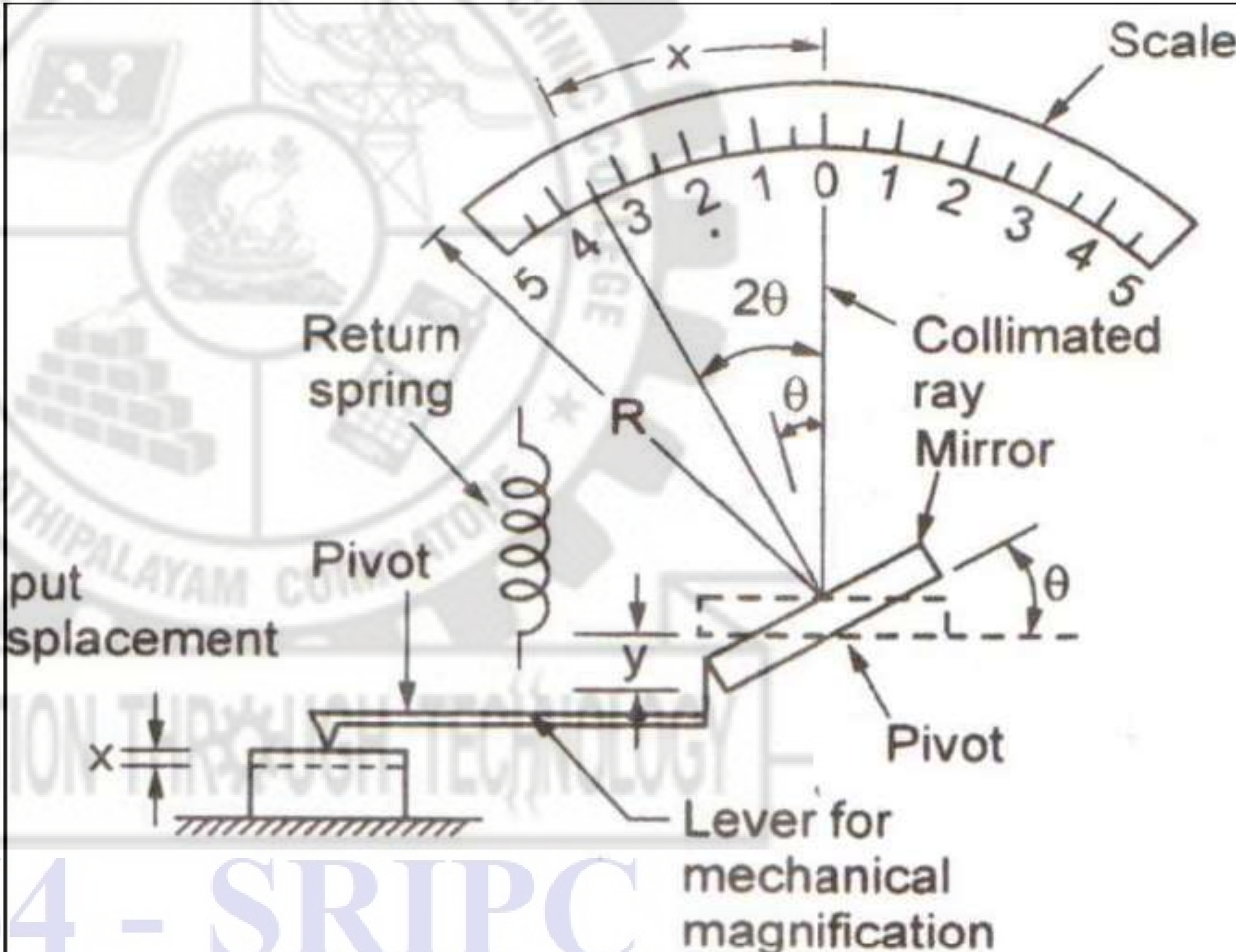
- These comparators depend on the principle of balancing the Wheatstone bridge,

  $(R_1/R_2) = (R_3/R_4)$ applicable for only to direct current obtained from a battery



764 - SRIPC

Optical comparator

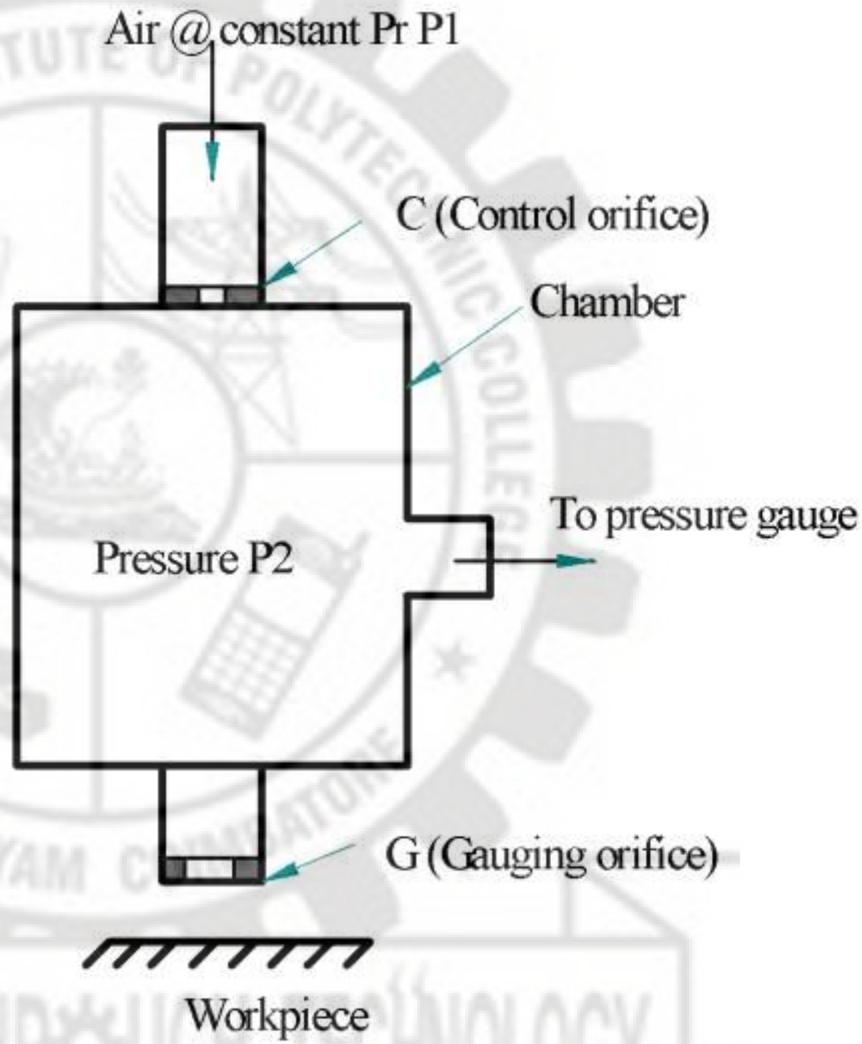


764 - SRIPC

Pneumatic comparators

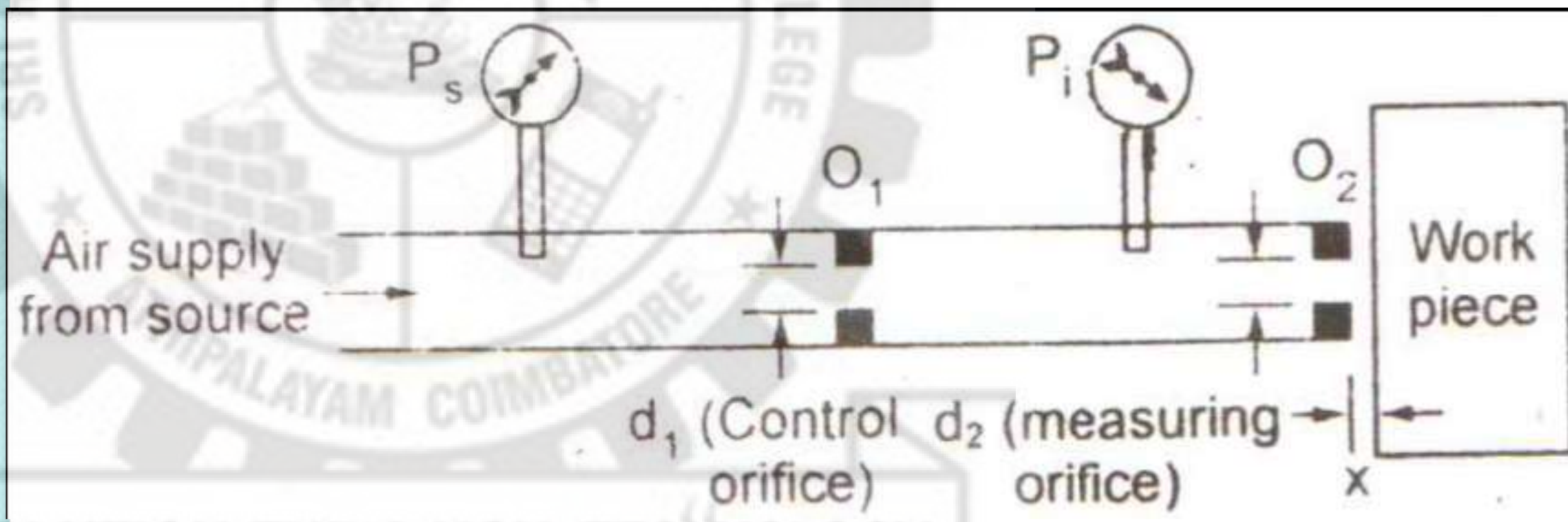
- In Pneumatic comparators air is used as a means of magnification and hence they use principle of air jet.
- A chamber is fitted with control orifice C and a gauging orifice G through which air flows from a supply at a constant pressure P_1.
- If the size of the control orifice C remains constant, any variation in size of G will cause alteration of pressure P_2 in the chamber.
- This variation is measured by a suitable pressure gauge graduated to read in linear units.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC



Principle of Pneumatic comparator

764 - SRIPC



P_s
P_i
O_1
O_2
Air supply from source
Work piece
d_1 (Control orifice)
d_2 (measuring orifice)
x

764 - SRIPC

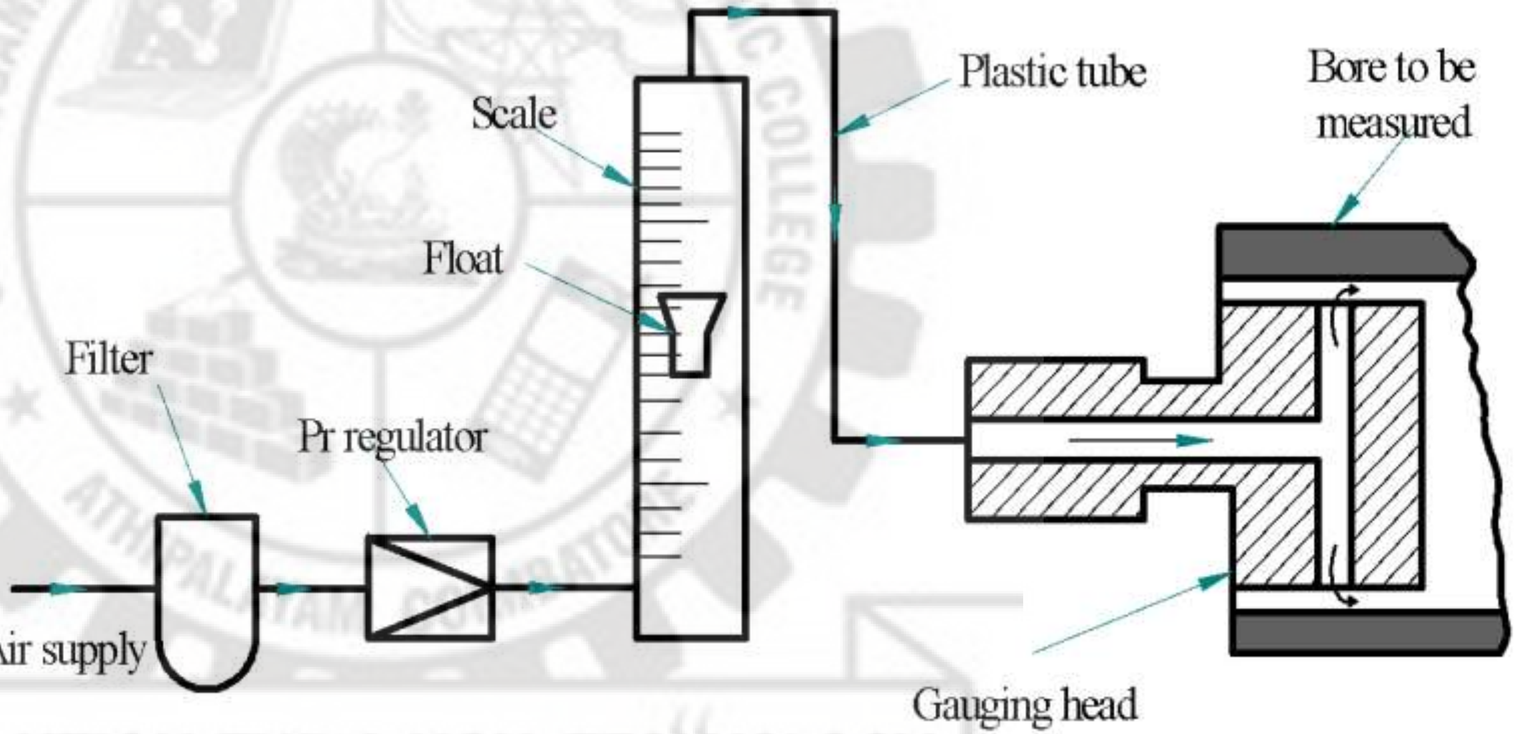
Systems of Pneumatic comparators

- Based on the physical phenomenon, Pneumatic comparators are classified as;

  (a) Flow or velocity type (b) Back pressure type
- Flow types operate by sensing & indicating the momentary rate of flow.
- Compressed air after filtering & pressure regulation flows through a glass tube with a small metal float.
- The air then passes through a plastic tube to the gauge head with two diametrically opposite orifices for the air to escape.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

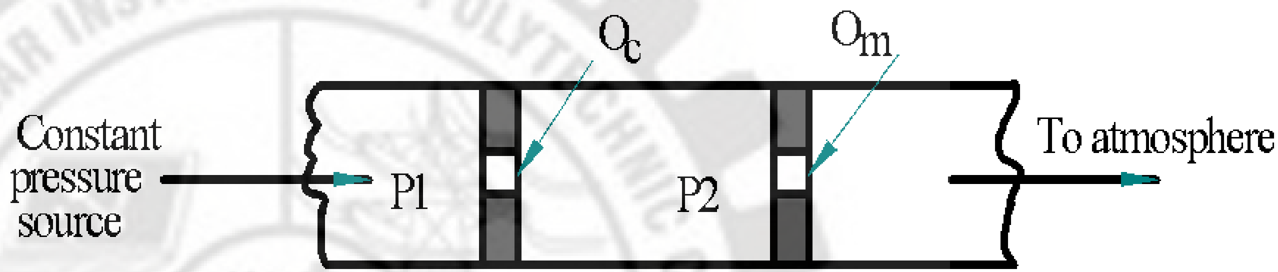
Pneumatic comparators (contd…)



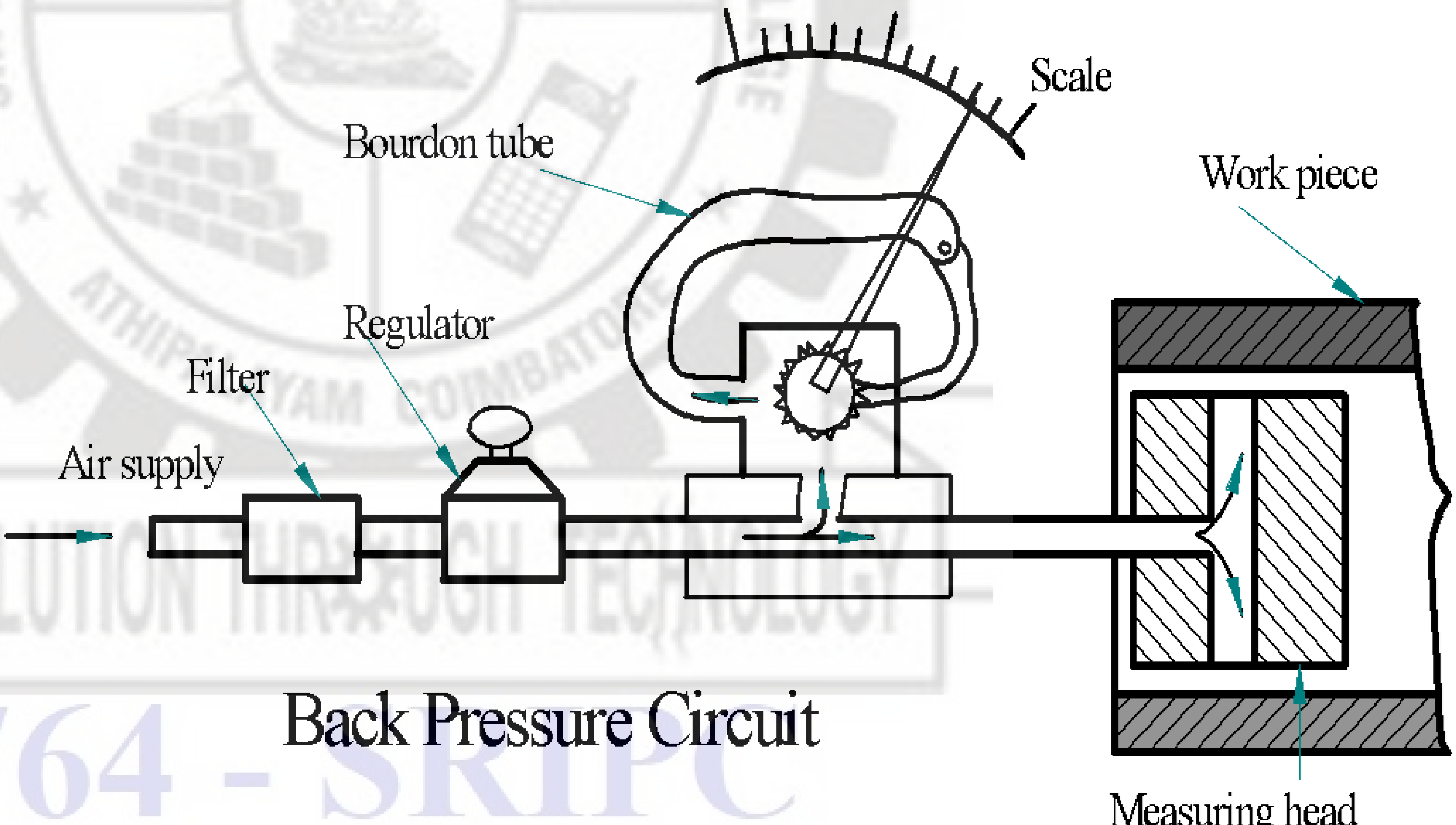
Flow or Velocity type Comparator

764 - SRIPC

Back pressure type Pneumatic Comparators

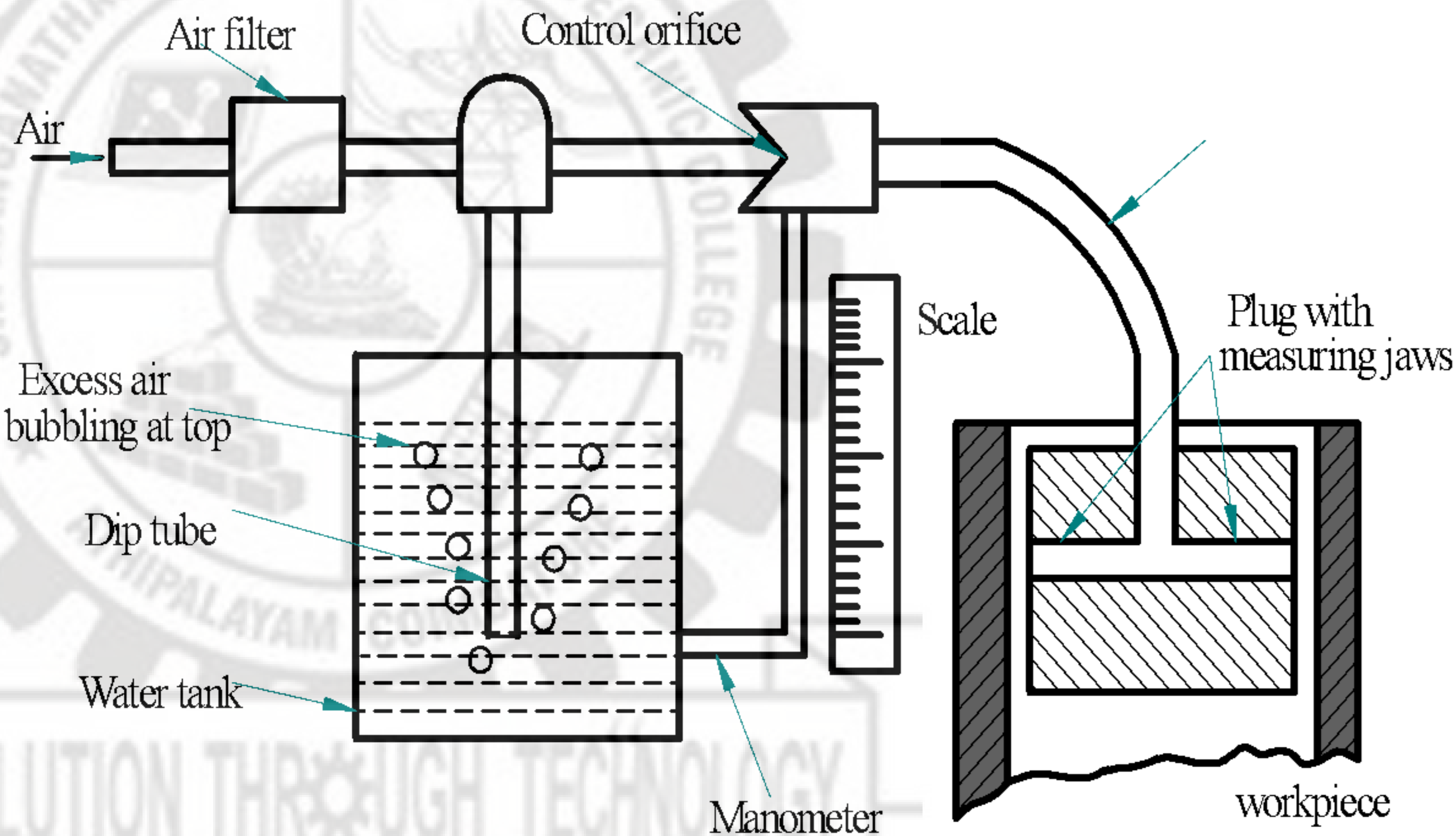


Principle of back pressure type Pneumatic comparator



Back Pressure Circuit

Solex Pneumatic gauge



Solex Pneumatic gauge

764 - SRIPC

ANGULAR MEASUREMENT

Sine bar, optical bevel protractor ,Taper measurements

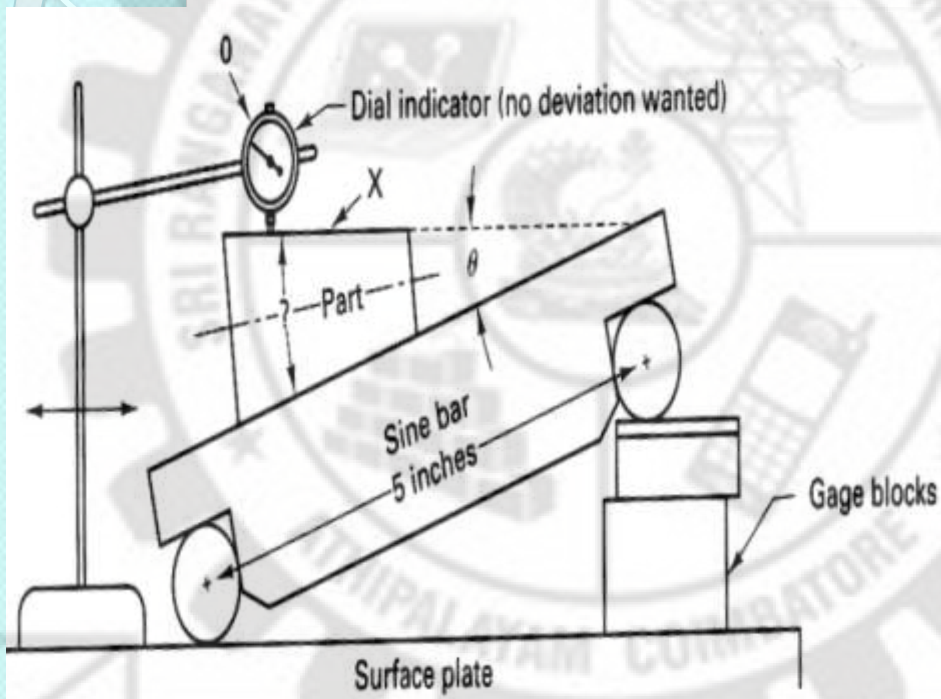
764 - SRIPC

Sine bars

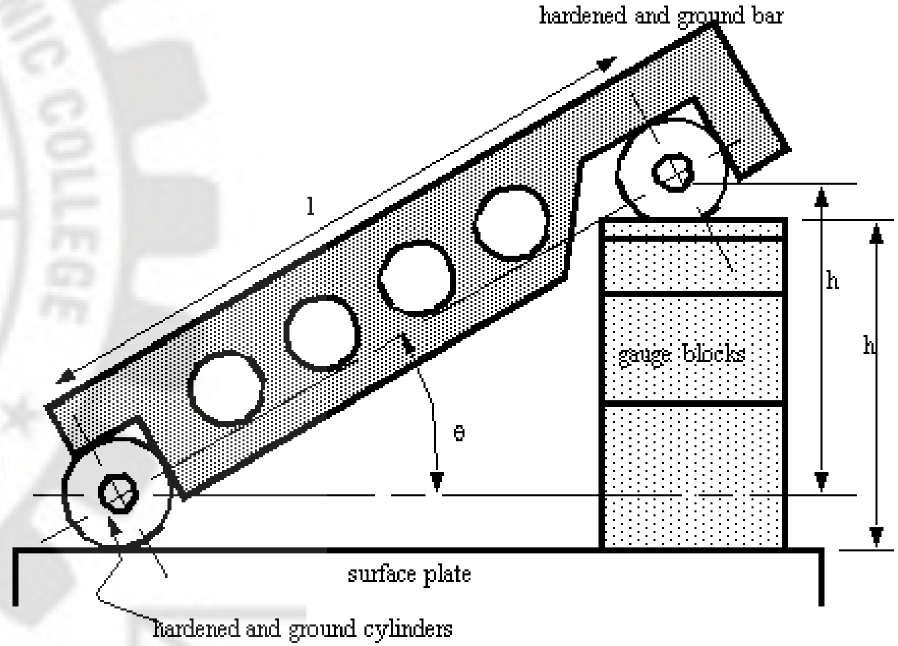
- A sine bar is a tool used to measure angles in metalworking.
- It consists of a hardened, precision ground body with two precision ground cylinders fixed at each end, the rollers are positioned at a precise distance and the top of the bar is parallel to the center line of the rollers.
- The dimension between the two rollers is chosen to be a whole number (for ease of later calculations)

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Sine bars



$$\sin(angle) = \frac{opposite}{hypotenuse}$$

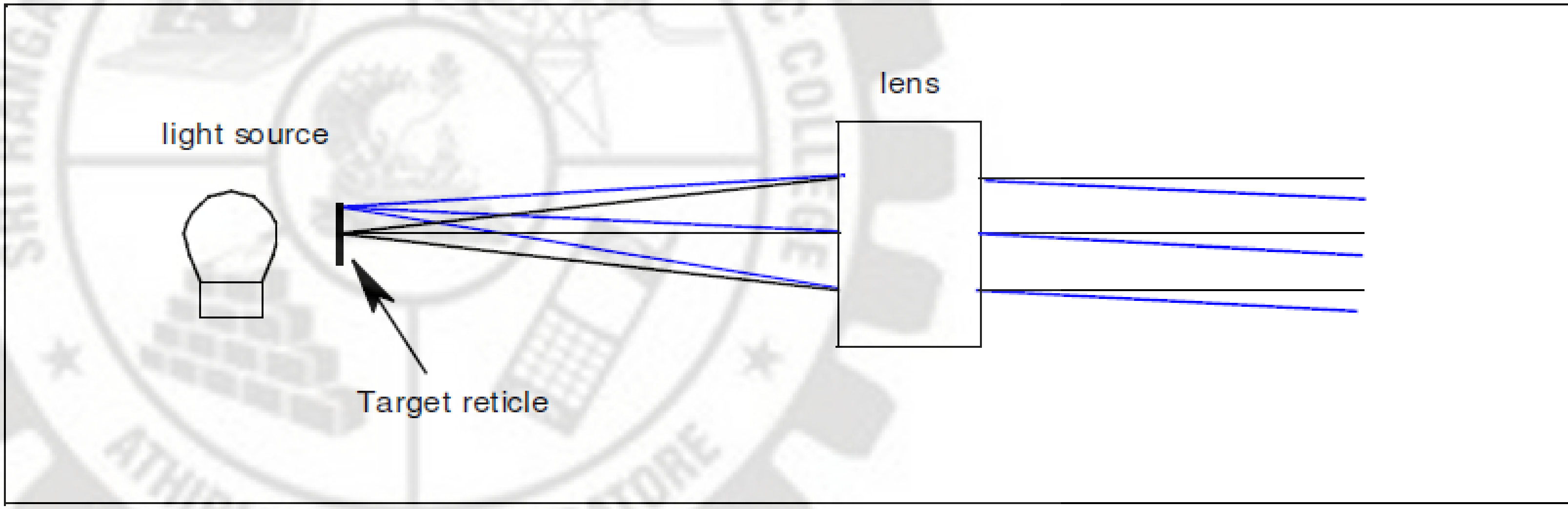


l = distance between centres of ground cylinders (typically 5" or 10")
h = height of the gauge blocks
θ = the angle of the plate

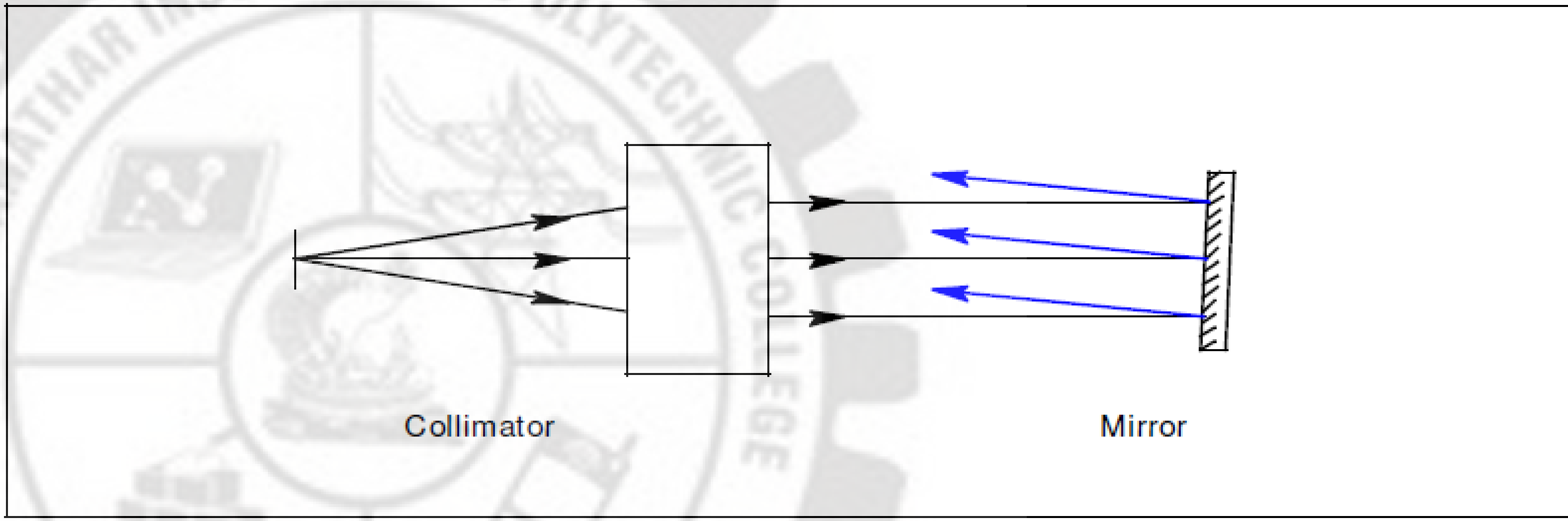
$$\theta = \operatorname{asin}\left(\frac{h}{l}\right)$$

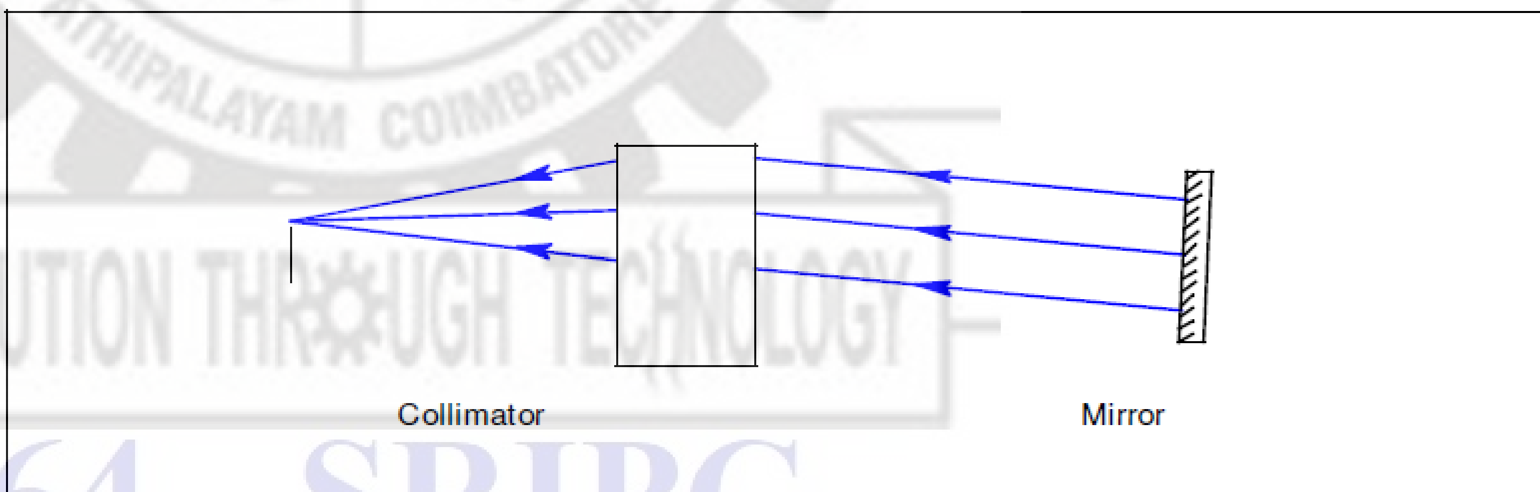
764 - SRIPC

Autocollimator

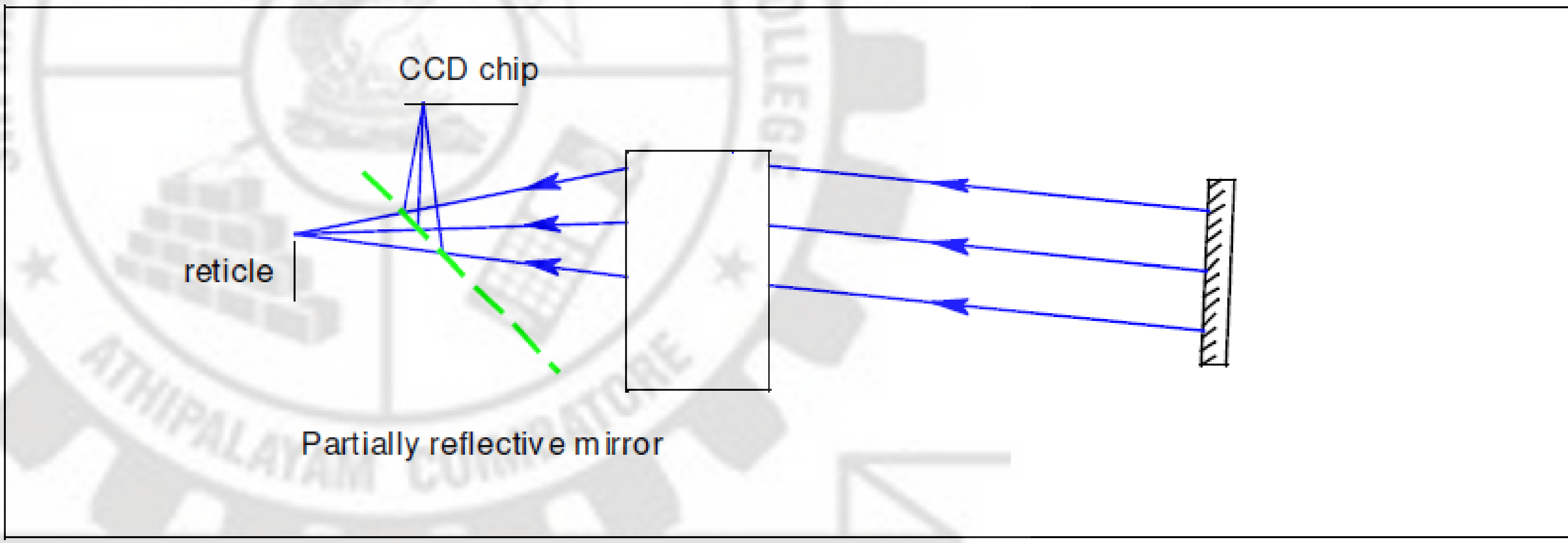


REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

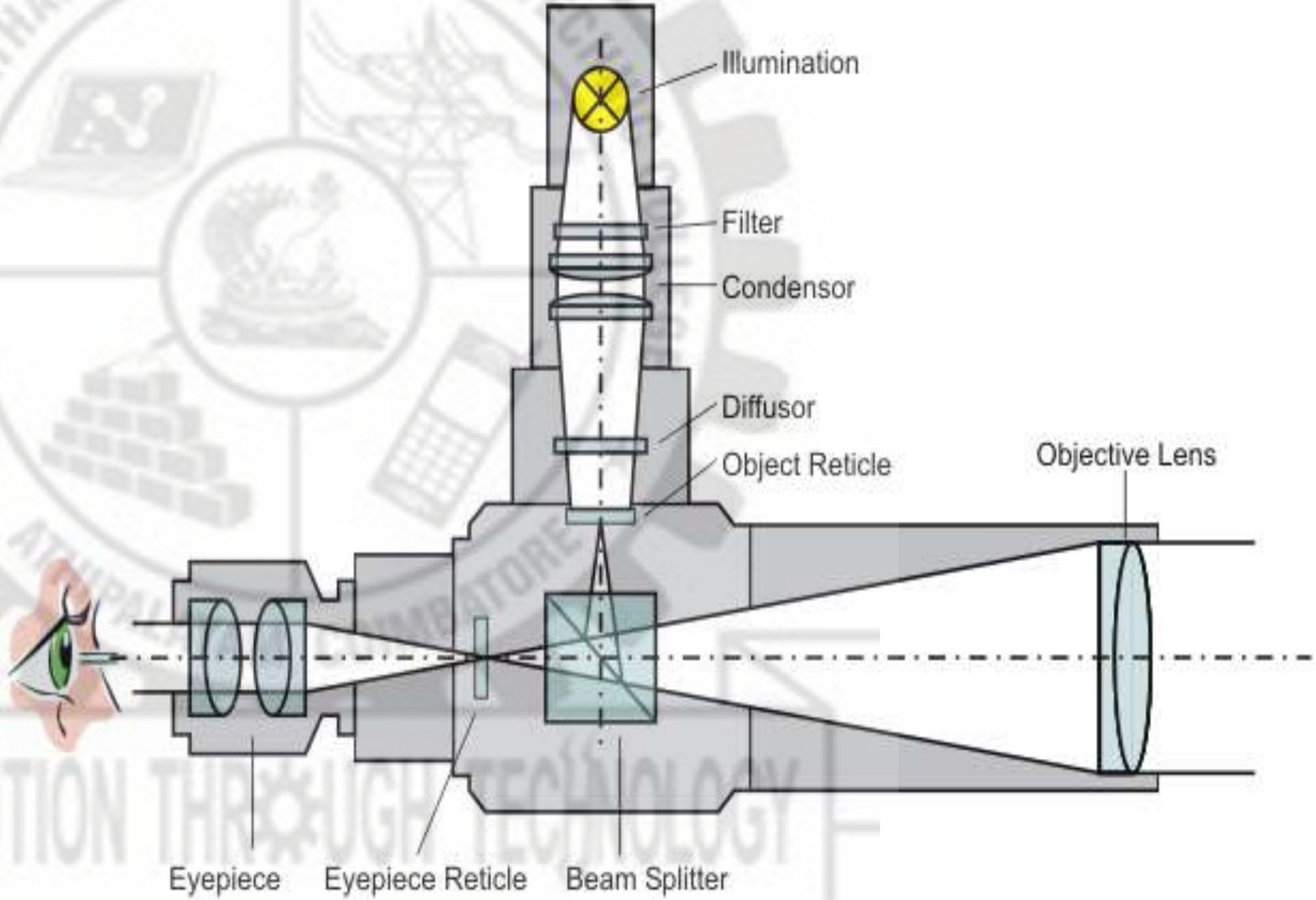




SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
ATHIPALAYAM COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC



764 - SRIPC


Illumination
Filter
Condensor
Diffusor
Object Reticle
Objective Lens
Eyepiece
Eyepiece Reticle
Beam Splitter

764 - SRIPC

Thank you

SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
ATHIPALAYAM COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

https://youtu.be/5YLvHXMr7f4 Optical Comparator

https://youtu.be/TyM28gmhJcc Pneumatic Comparator

https://youtu.be/S-KAt9trTiI Electrical Comparator

https://youtu.be/PkKOUOfrudw Thread errors

https://www.youtube.com/watch?v=kXIRCJ9nGlo gear tester

764 - SRIPC

ADVANCES IN METROLOGY

METROLOGY AND MEASUREMENTS

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

ADVANCES IN METROLOGY

Basic concept of lasers, advantages of lasers – laser interferometers – types – DC and AC lasers interferometer – Applications – Straightness – Alignment, Basic concept of CMM – Types of CMM – Constructional features – Probes – Accessories – Software – Applications – Basic concepts of Machine Vision System – Element – Applications.

LIGHT

- Light makes the world seem bright and colorful to our eyes.

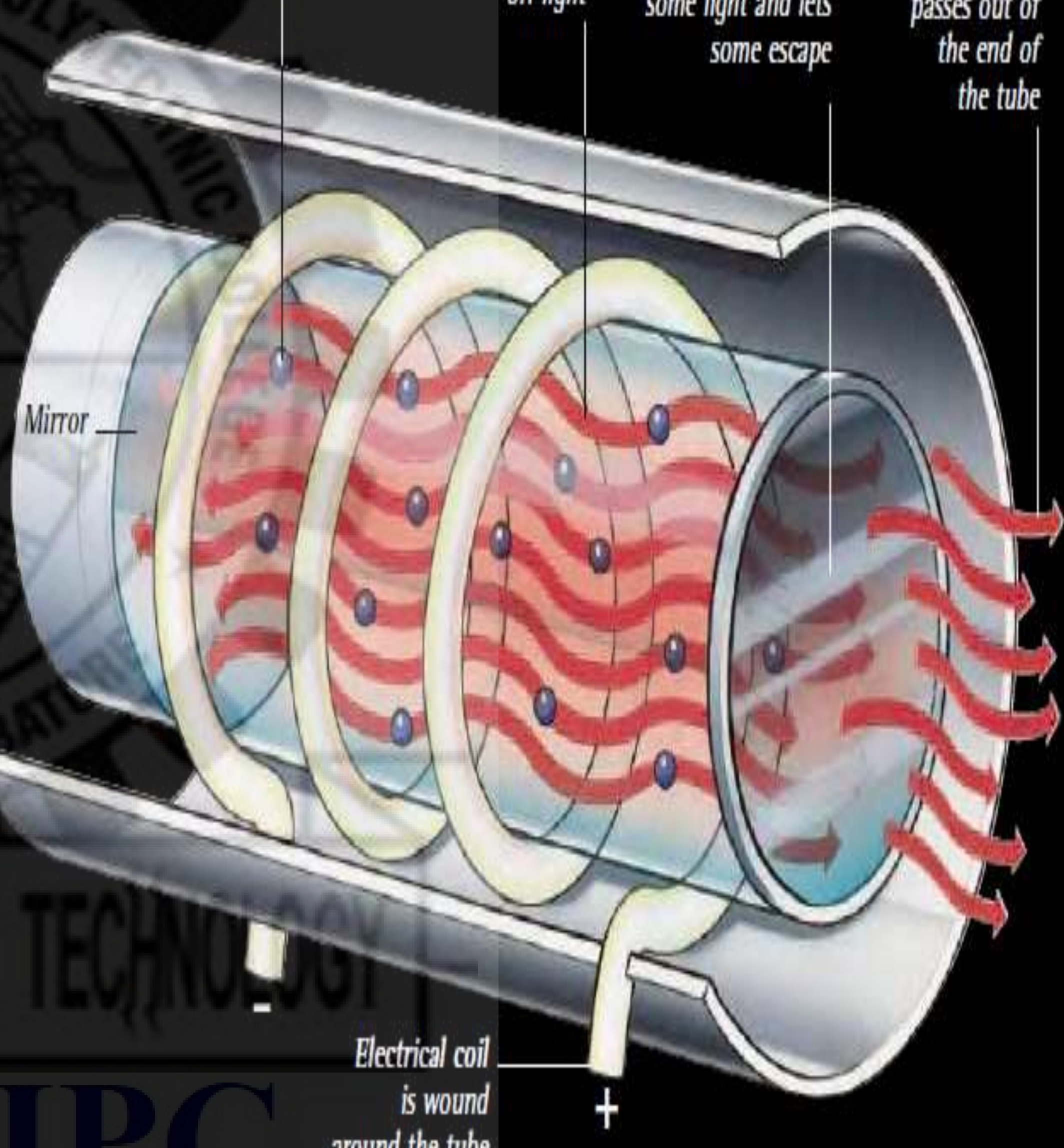
- Light is a type of electromagnetic radiation that carries energy from a **SOURCE (something that** makes light) at the very high speed of 186,000 miles per second (300,000 kps), or 670 million mph.

- Light rays travel from their source in straight lines. Although they can pass through some objects, they bounce off others or pass around them to make **SHADOWS.**

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

LASERS

Some beams of light are powerful enough to cut through metal. Others are precise enough to use for delicate surgery on people's bodies. These remarkable forms of light are made by lasers. Laser stands for Light Amplification by Stimulated Emission of Radiation. A laser is a device that concentrates light rays so they all travel exactly in step. Laser rays are much more powerful and precise than other light rays.



REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

PRECISION INSTRUMENTS BASED ON LASER

- Laser stands for "**Light Amplification by Stimulated Emission of Radiation**". Laser instruments are devices to produce powerful, **monochromatic** collimated beam of light in which the waves are coherent
- Properties of laser
  - **Monochromatic**
  - **Collimated beam**
  - **Coherent waves**
  - **Powerful**
- A typical helium-neon laser source produces a **1 to 2 mm** diameter beam of pure red light having power of **1MW.** So, this type of a beam is focused at a point. It means, beam has very high intensity. The laser is used extensively for interferometer. Upto a great distance beam has no divergence but then it begins to expand at a rate of about **1mm/m.**
- This is used for very accurate measurements in the order of **0.1 µm in 100m**.

764 - SRIPC

PRECISION INSTRUMENTS BASED ON LASER

- Laser are extensively used for interferometry
- Metrology laser are low power instrument that emit visible pr infrared light.
- Light at a wave length of 0.6μ m is produced by He-Ne lasers.
- Laser are used for dimensions measurements and surface inspection.

764 - SRIPC

LASER TELEMETRIC SYSTEM

- In general , telemetry means measurement made from distance.
- To detect change in dimension of the moving components. As the output of the system is in digital form.
- Laser telemetric system is a non contact gauge that measures with a collimated laser beam. It measures at the rate of 150 scans per second.

CONTRUCTION

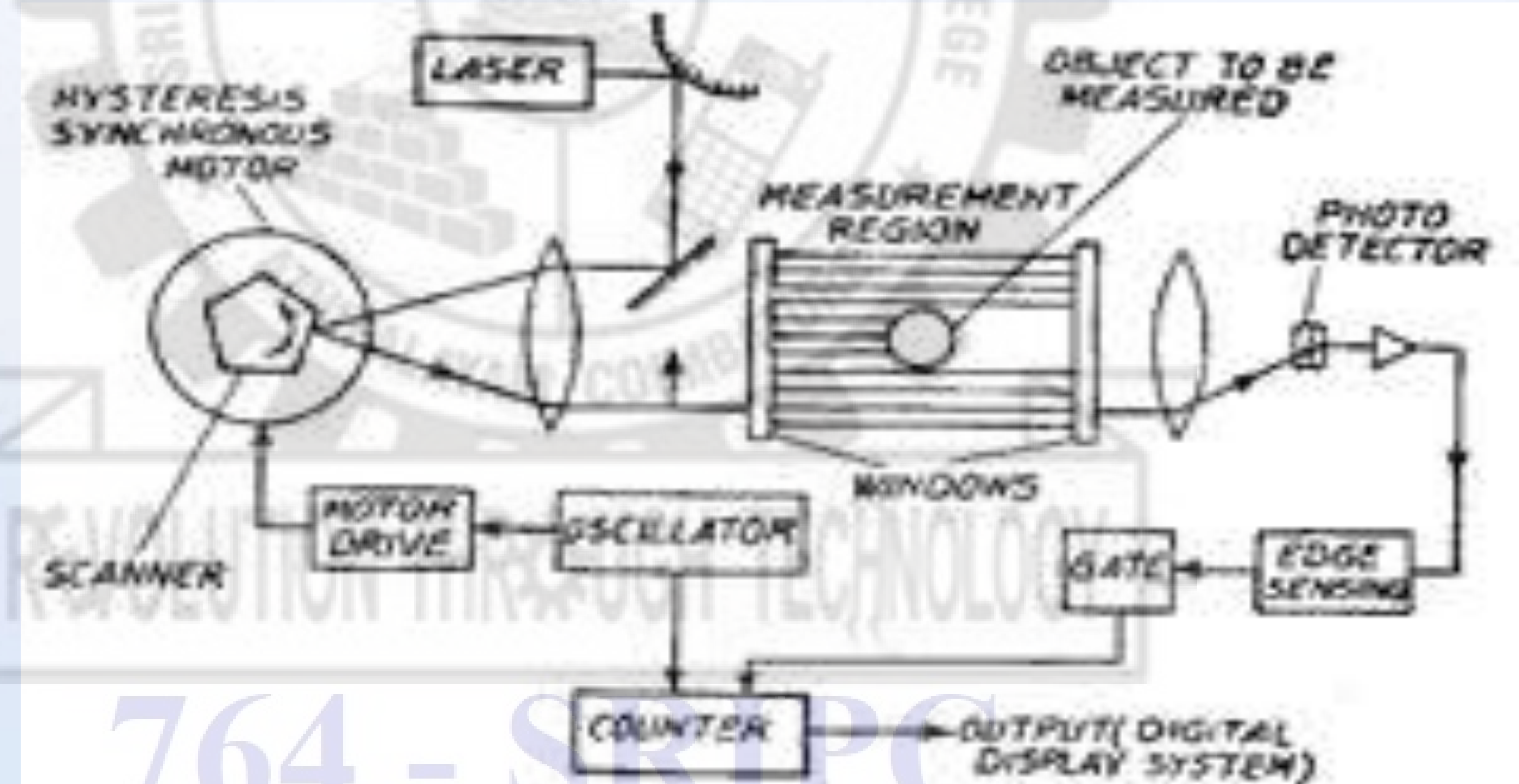
The laser telemetric system consists of mainly three components namely

1. Transmitter
2. Receiver
3. Processor electronics.

- The transmitter produces a collimated parallel scanning laser beam moving at a high constant linear speed. The beam appears as red line after scanning.
- The receiver collects the laser beam and photo electrically senses the laser light transmitted through the objects being measured. The processor receivers the signal and converts it into convenient from.

The transmitter has the following components.

1. Low power helium neon gas laser.
2. Synchronous motor.
3. Collimating lens.
4. Reflector prism
5. Synchronous pulse photo detector.
6. Replaceable window



764 - SRIPC

WORKING

- The object to be measured is placed in the measurement region. High constant and linear speed laser beams from transmitter which is focused on the object to be measured. The receiver module collects and senses the laser light transmitted past the object to be measured.
- After sensing, the processor electronics take the received signals and convert them into a convenient from and then display the dimensions being gauged.

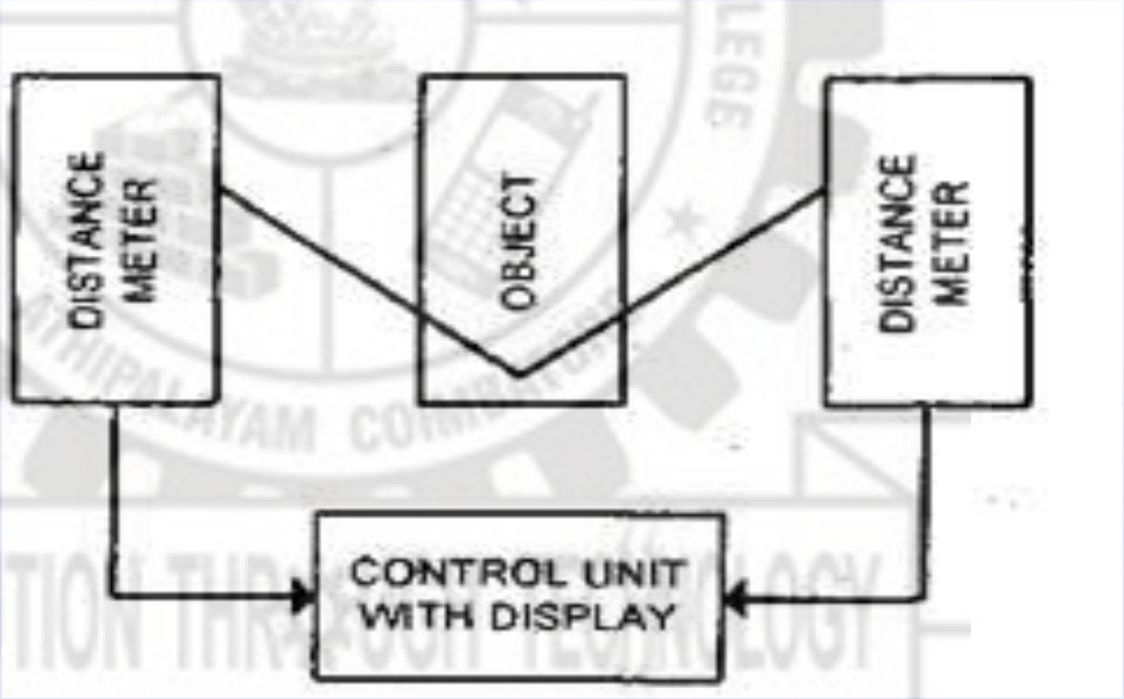
ADVANTAGES:

- It is possible to detect changes in dimensions when components are moving
- It is possible to detect changes in dimensions when product is in continuous processes.
- There is no need to wait for taking measurements when the product is in hot conditions
- It can be applied on production machines and controlled them with feedback loops
- It is possible to write programs for the microprocessor to take care of smoke, dust and other airborne interference around the work piece being measured.

764 - SRIPC

LASER AND LED BASED DISTANCE MEASURING INSTRUMENTS

- It can measure distance from 1to 2m with accuracy of the order of 0.1 to 1% of the measuring range. The measuring system uses two distance meter placed at equal distance on either side of the object and a control unit to measure the thickness of an object.



764 - SRIPC

WORKING

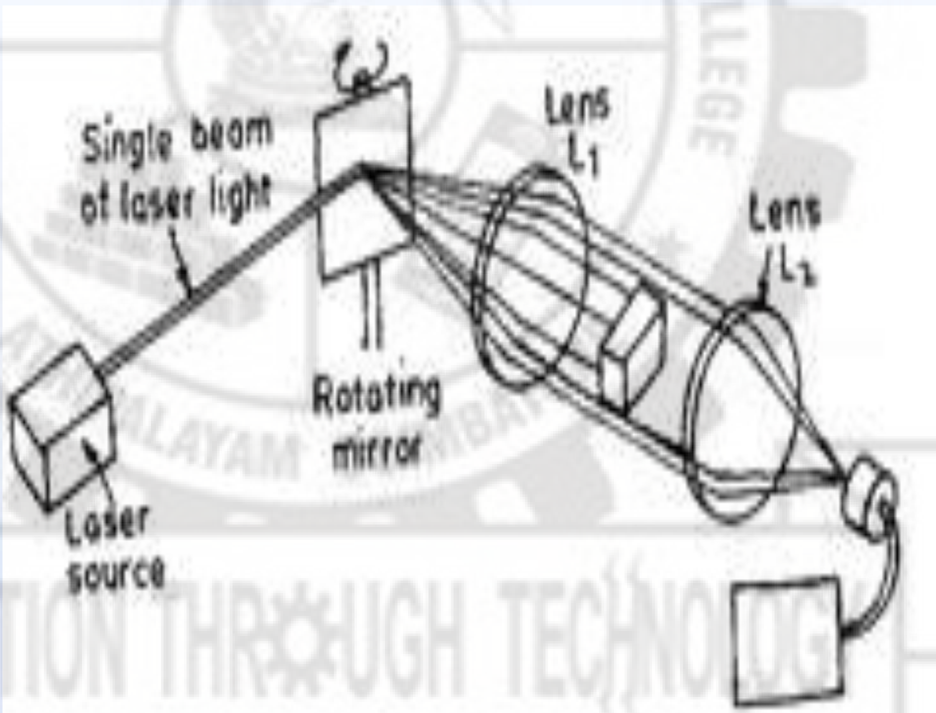
- When the light is emitted by laser or LED hits on object, it scatters and some of the scattered light is seen by a position sensitive detector or diode array.
- The angle at which the light enters the detector will change distance between the measuring head and object is changed. The change angle of deviation is measured and calibrated in terms of distance.

ADVANTAGE

- These types of instruments are very reliable because there is no moving part.
- Instrument response time is in milliseconds.
- The output is measured as 0-20mA.

SCANNING LASER GUAGE

- The scanning laser gauge is used for dimensional measurements. The figure shows a schematic diagram of a scanning laser gauge. It consists of transmitter, receiver and processor electronics.



764 - SRIPC

WORKING

- A scanning laser light is made to pass through a liner scanner lens as a parallel beam. The object is placed in a parallel beam, casts a dependent shadow. The signals from the light entering the photocell are processed by a microprocessor to provide display of the dimension represented by the time difference between the shadow edges.

ADVANTAGES

- Accuracy of ±0.25 μm for 10-50mm diameter objects.
- It is used to measure objects of 0.05mm to 450mm diameter.

764 - SRIPC

INTERFEROMETRY

INTRODUCTION

- The phenomenon of interaction of light is called interference.

- Under ordinary conditions, the wave nature of light is not apparent. But when the light waves interact with each other, the wave effect is visible and this is made use of for measuring purpose.

- A pattern of dark bands are produced when light is made to interfere. These bands correspond to accurate scale of division.

- The use of interferometric technique for measuring the interference, enables the size of slip gauges and end bars to be determined directly interms of the wavelength of the light source

MONOCHROMATIC LIGHT

- For length measurements by interferometry, monochromatic light source is used.
- A ray of light having a single frequency and wave length produces monochromatic light.

ADVANTAGES

- It is virtually independent by any ambient conditions.
- Its wavelength has precise value.
- It is reproducible.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

PRINCIPLES OF INTERFERENCE

- For interference to occur , the two light rays must be coherent. This is possible only when the two rays are originated from the same point of the light source at the same time.
- Mutual interference occurs when two rays with same wavelength meet at same point.
- The nature of interference will depend upon the phase of the two waves at their meeting point.
- The two waves are in same phase and they reinforce each other, then the resultant intensity is the sum of the two intensities.
- If these two waves that are in phase have the same amplitude, then the resultant amplitude become twice and a bright spot is resulted.
- The two waves are in out of phase, then the resultant intensity is the difference between the two intensities.
- If these two waves have same amplitude, the resultant amplitude is zero and a dark spot is resulted.

INTERFEROMETERS

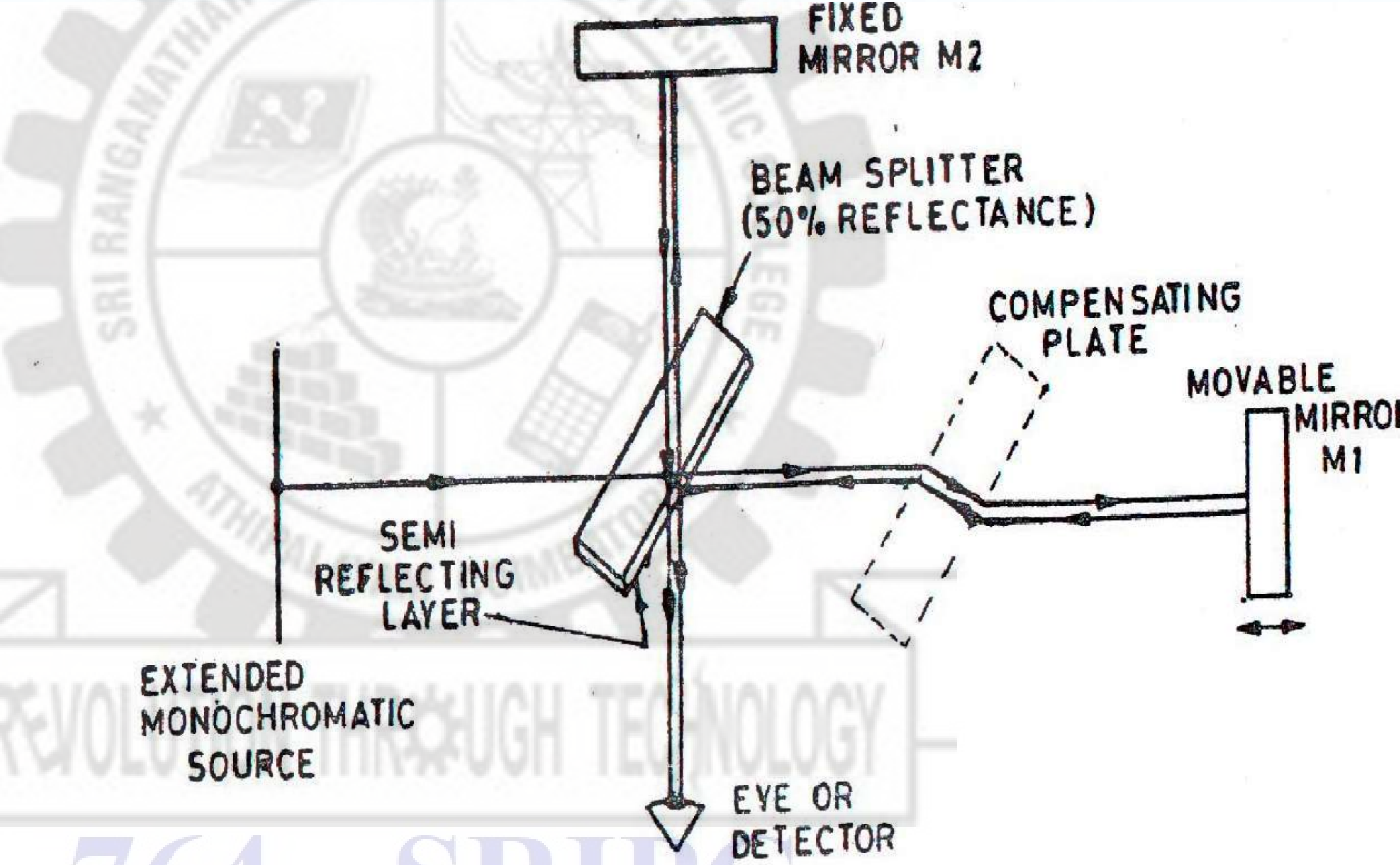
- Interferometers are optical instruments used for measuring flatness and determining the length of slip gauges.
  - The wavelength of lightwave is used for measuring unit.
  - It is based on the interference principle.
  - Interferometers are used to overcome the limitations of optical flat.

Types of interferometers.

1. Michelson interferometers
2. Twyman- green specialization of Michelson interferometer
3. Laser interferometer
4. N.P.L flatness interferometer

764 - SRIPC

MICHELSON INTERFEROMETER



764 - SRIPC

MICHELSON INTERFEROMETER

Construction and working:

- It is the oldest type of interferometer.
- The monochromatic light is made to fall on a beam divider. The beam divider splits the incoming light into two parts.
- It consists of two mirror M1 and M2 placed perpendicular to each other from the beam divider.
- The mirror M2 is fixed whereas M1 is movable. It is attached to the object whose dimension is to be measured.
- One part of the incoming light is transmitted through compensating plate P to the mirror M1.
- Other part is reflected through the beam divider to mirror M2.
- The rays are reflected back from the mirror and are reunited at the semi-reflecting surface where they are transmitted to the eye.

764 - SRIPC

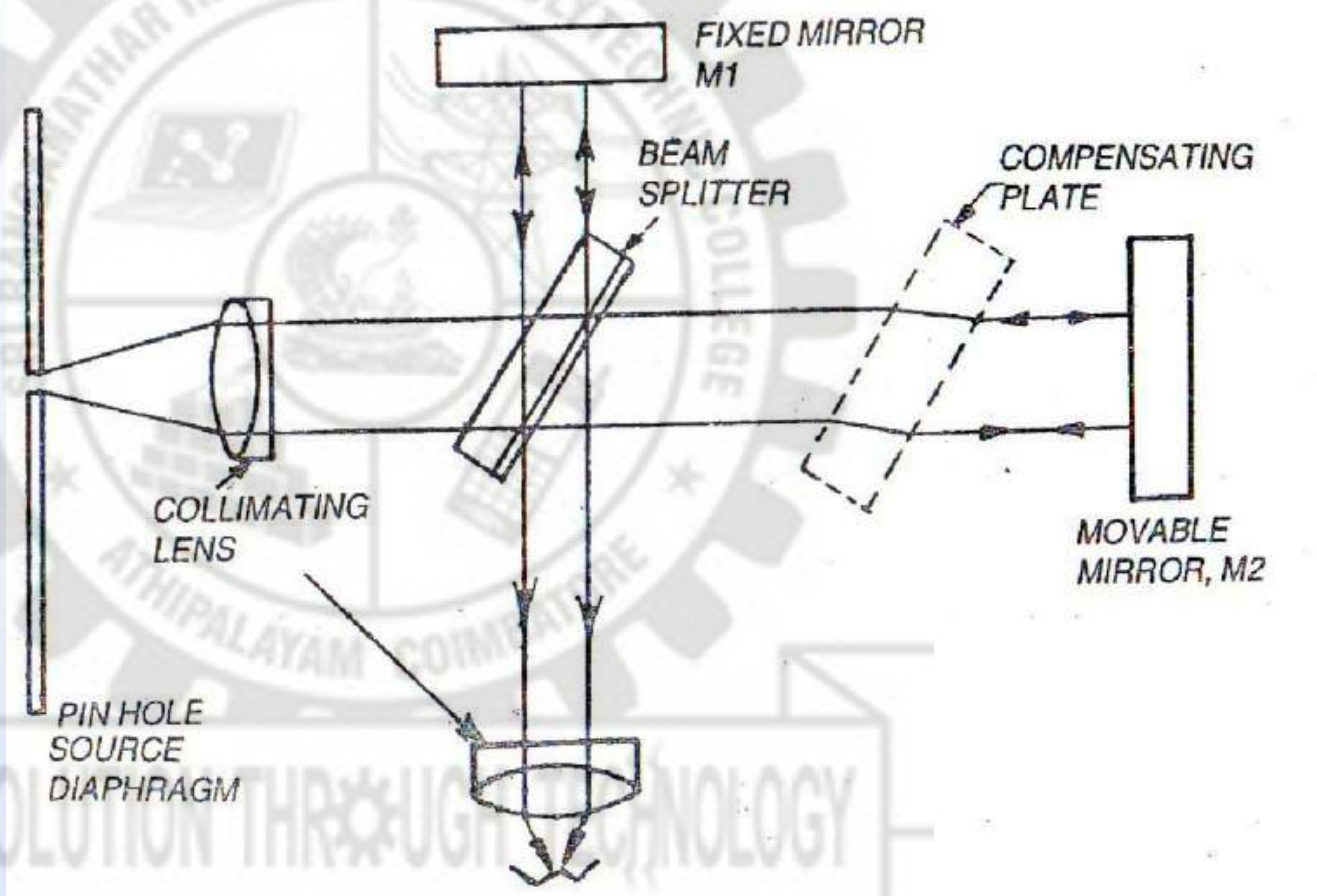
TWYMAN –GREEN SPECIALISATION OF MICHELSON INTERFEROMETER

Construction and working:

- In Michelson's interferometer, it is very difficult to interpret the fringe pattern.
- This was modified by Twyman -green. It utilises a pin –hole source diaphragm and collimating lenses.
- In this way , all rays are rendered parallel to the central rays and thus all rays describe the same path.
- It consists of two mirror M1 and M2 placed perpendicular to each other from the beam divider.
- The mirror M2 is fixed whereas M1 is movable. It is attached to the object whose dimension is to be measured.
- One part of the incoming light is transmitted through compensating plate P to the mirror M1.
- Other part is reflected through the beam divider to mirror M2.
- The rays are reflected back from the mirror and are reunited at the semi-reflecting surface where they are transmitted to the eye.
- Usually it is quite difficult to count such fringes by eye. However , photo detectors connected to high speed counters can do this job very accurately.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

TWYMAN-GREEN SPECIALISATION OF MICHELSON INTERFEROMETER



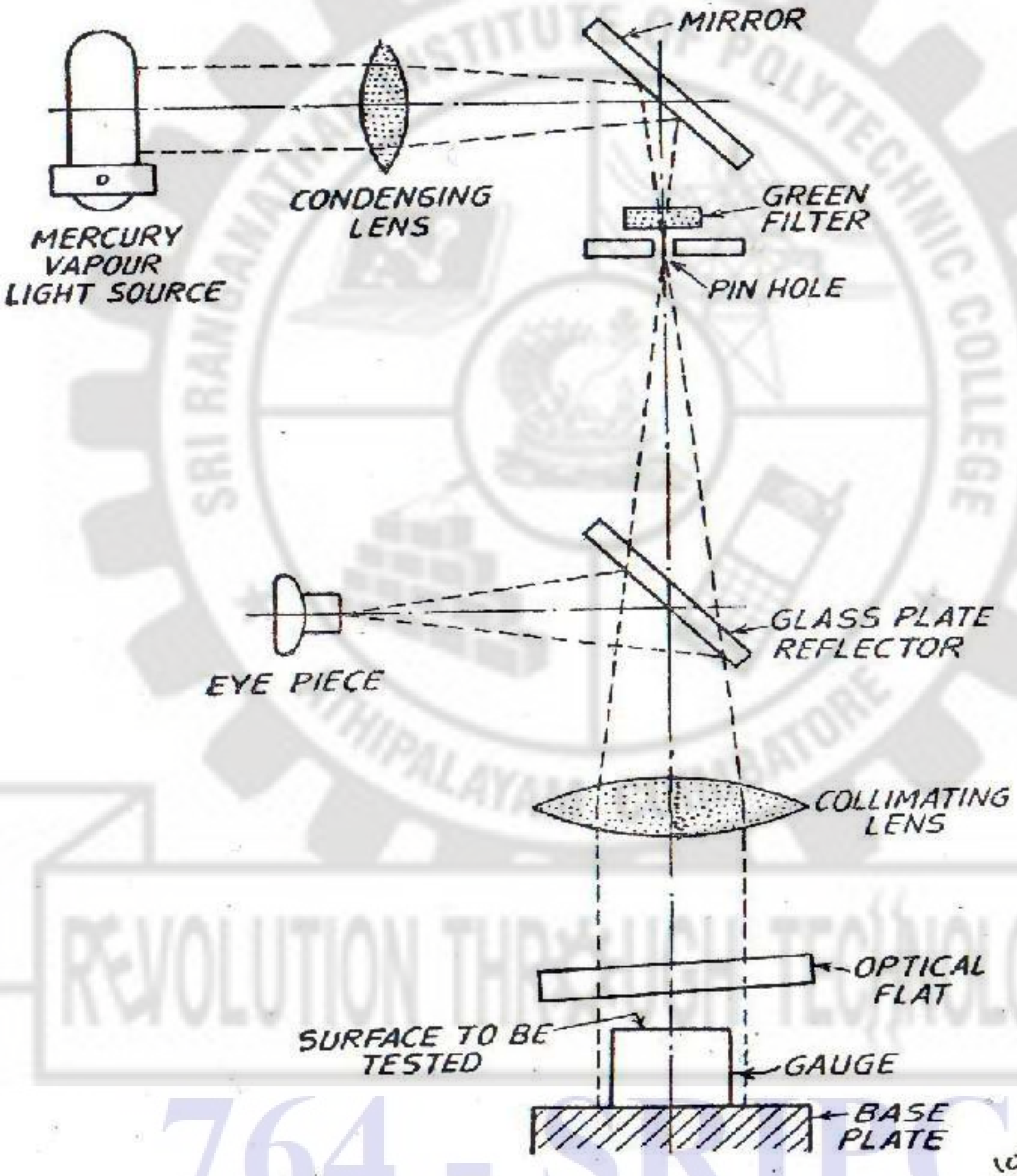
764 - SRIPC

N.P.L. FLATNESS INTERFEROMETER

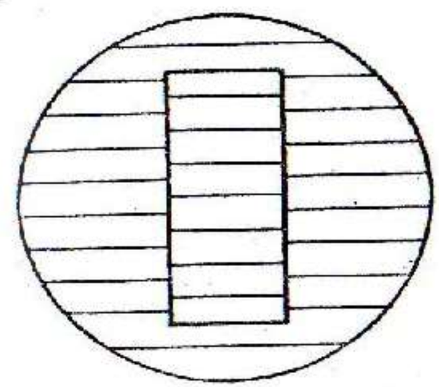
- This instrument is mainly used for checking the flatness of flat surfaces.
- This interferometer was designed by National Physical Laboratory and is commercially manufactured by Hilger and Watts Ltd.
- The flatness of any surface is judged by comparing with an optically flat surface which is generally the base plate of the instrument.
- This instrument essentially consists of a mercury vapour lamp as shown in the Fig. As we are interested in having single monochromatic source of light, the radiations of the mercury lamp are passed through a green filter. The wavelength of the resulting monochromatic radiation is of the order or 0.0005 mm.
- This radiation is then brought to focus on pinhole in order to obtain an intense point source of light. A mirror is used in order to deflect the light beam through 90°.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

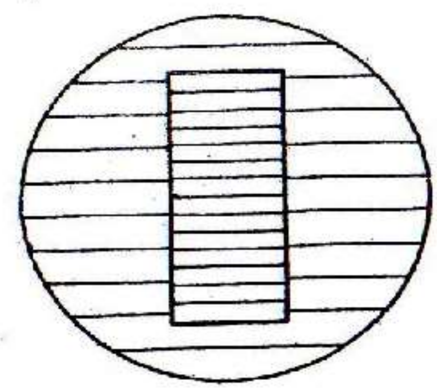
N.P.L. FLATNESS INTERFEROMETER



. NPL flatness interferometer.



(a) Gauge face flat and parallel to base plate.



(b) Gauge face flat but not parallel to base plate.

N.P.L. FLATNESS INTERFEROMETER

- The pinhole is placed in the focal plane of a collimating lens, thus the radiations out of the lens will be parallel beam of light. This beam is directed on the gauge to be tested via an optical flat. The fringes formed are viewed directly above by means of a thick glass plate semi-reflector set at 45° to the optical axis.
- The gauge to be tested is wrung on the base plate whose surface is finished to a degree comparable to that of the highest quality gauge face.
- If the gauge face is flat and parallel to the base plate, then the optical flat being equally inclined on both the surfaces the fringe pattern from both the gauge face and the base plate will consist of straight, parallel and equally spaced fringes as shown in Fig. 3. (a).
- When the gauge is flat but not parallel to the base plate, then straight and parallel fringes of different pitch above the gauge face as compared with those of the base plate are seen Fig. 3. (b)

LASER INTERFEROMETRY

The laser interferometry involves the following components,

1. Two frequency laser source.

2. Optical elements.

3. Laser heads measurement receiver.

4. Measurement display.

Two frequency laser source

- The two frequency laser source generally becomes He –Ne type that generates stable coherent light beams of two frequencies .In these two frequencies, one polarized horizontally relative to the plane of the mounting feet.
- Laser slightly oscillates at two frequencies by a cylindrical permanent magnet around the cavity.
- Beam containing both frequencies passes through a quarter wave and half wave plates which change the circular polarization, one vertical and other horizontal.
- The linear polarized beam is expanded in a collimating telescope, after which most of the beam is transmitted through a 45° beam splitter and one of laser head.

764 - SRIPC

Optical elements

The various optical elements are

1. Beam splitters.
2. Beam benders
3. Retro reflectors

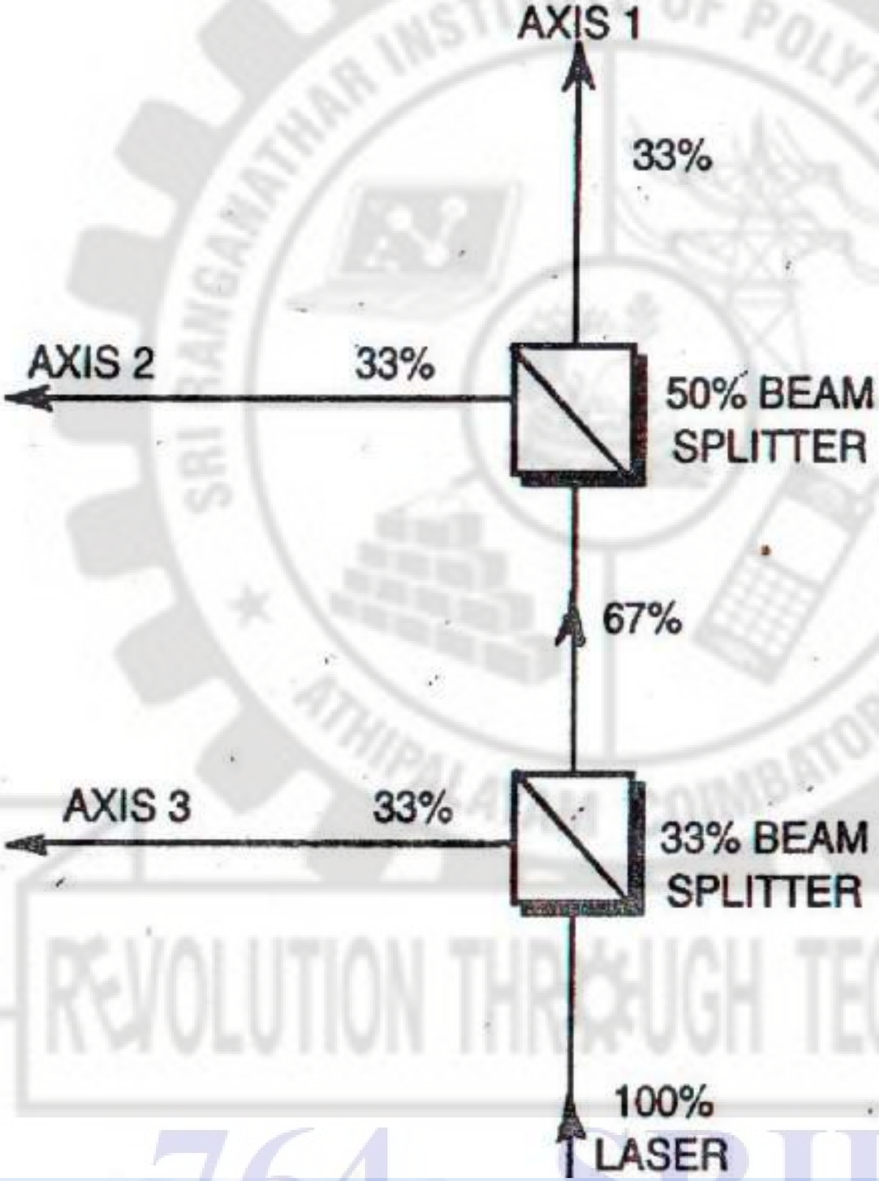
1. Beam splitters

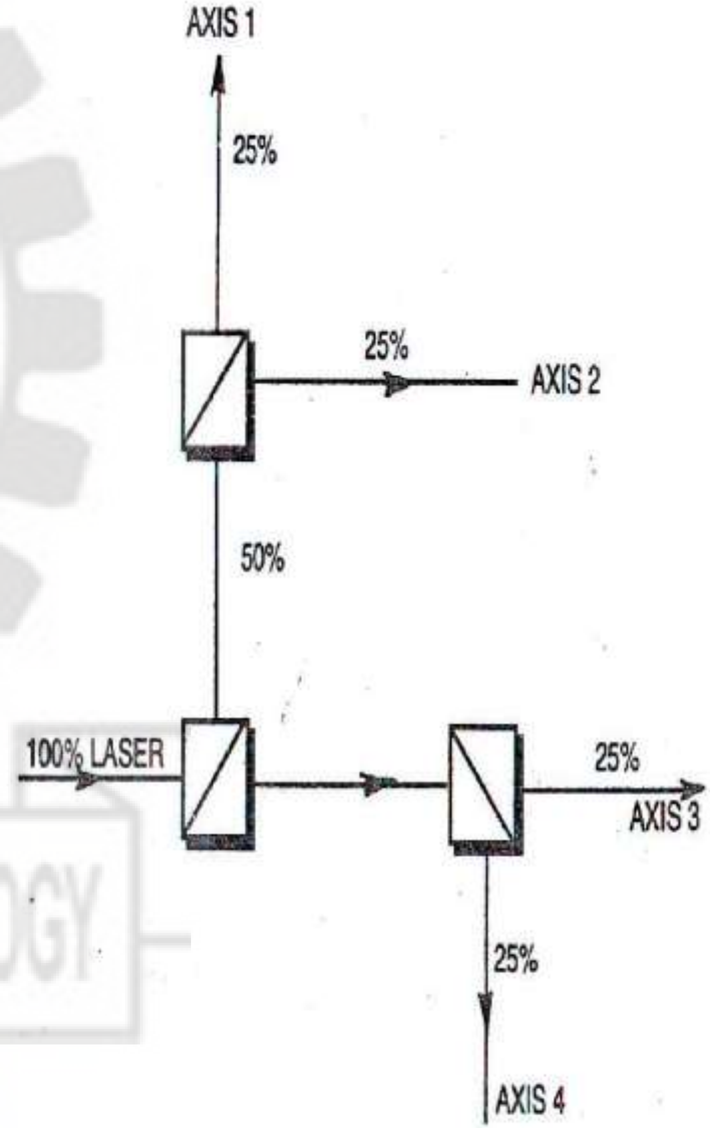
- It is used to divide the laser beam in to separate beams along different axes. It is possible to adjust the splitters laser's output intensity by having a choice of beam splitter reflectivities.
- The below fig shows the use of beam splitters to divide the laser output equally along the different axis. For example, tacking 100% laser beam is splitted equally in three axes.

2. Beam benders

- It is used to deflect the light beam around comers on it path from the laser to the axis .the beam benders are just flat mirrors ,but having absolute flat and very high reflectivity .normally .the 90° beam deflection is avoided for not to disturb the polarizing vectors.

764 - SRIPC


AXIS 1
33%
AXIS 2
33%
50% BEAM SPLITTER
67%
AXIS 3
33%
33% BEAM SPLITTER
100% LASER


AXIS 1
25%
25%
AXIS 2
50%
100% LASER
25%
AXIS 3
25%
AXIS 4

764 - SRIPC

3. Retro reflectors

- They are plane mirrors, roof prism or cubic corners. The cube corners are 3 mutually perpendicular plane mirrors, and the reflected beam is always parallel to the incident beam in these devices.
- In case of AC laser interferometer measurements, two retro reflectors are used. When plane mirror is used as retro reflector in plane mirror interferometer, it must be flat with in 0.06micron per cm

3. LASER HEAD'S MEASUREMENT RECEIVER:

- It is used to detect the part of the returning beam as $f1-f2$ and a Doppler shifted frequency component Δf.

4. MEASUREMENT DISPLAY:

- The measurement display has a microcomputer to compute and display results. The signals from reference receiver and measurement receiver located in the laser head are counted in two separate pulse counter and subtract. Other input signals for correction are temperature co-efficient of expansions. Air velocity is also displayed.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

A.C LASER INTERFEROMETER

Introduction

Laser interferometer uses A.C laser as the light source and thus it enables the measurements to be made over longer distance. Laser represents a source of intensively monochromatic optical energy, which can be collimated into a directional beam. The laser beam wavelength is exact and pure for highly accurate measurements. The laser interferometers utilize the principles of both optical techniques and digital electronics.

Construction

The AC laser interferometer has the following components.

1. Two frequency Zeeman laser
2. Beam splitters.
3. Fixed internal cube corners.

764 - SRIPC

4. External cube corners.
5. Photo detectors.
6. Amplifiers.
7. Pulse converter.

1. Two frequency Zeeman laser.

It is generally He-Ne type that generates stable coherent light beams of two frequencies, one is polarized vertically and the other one is polarized horizontally relative to the plane of the mounting.

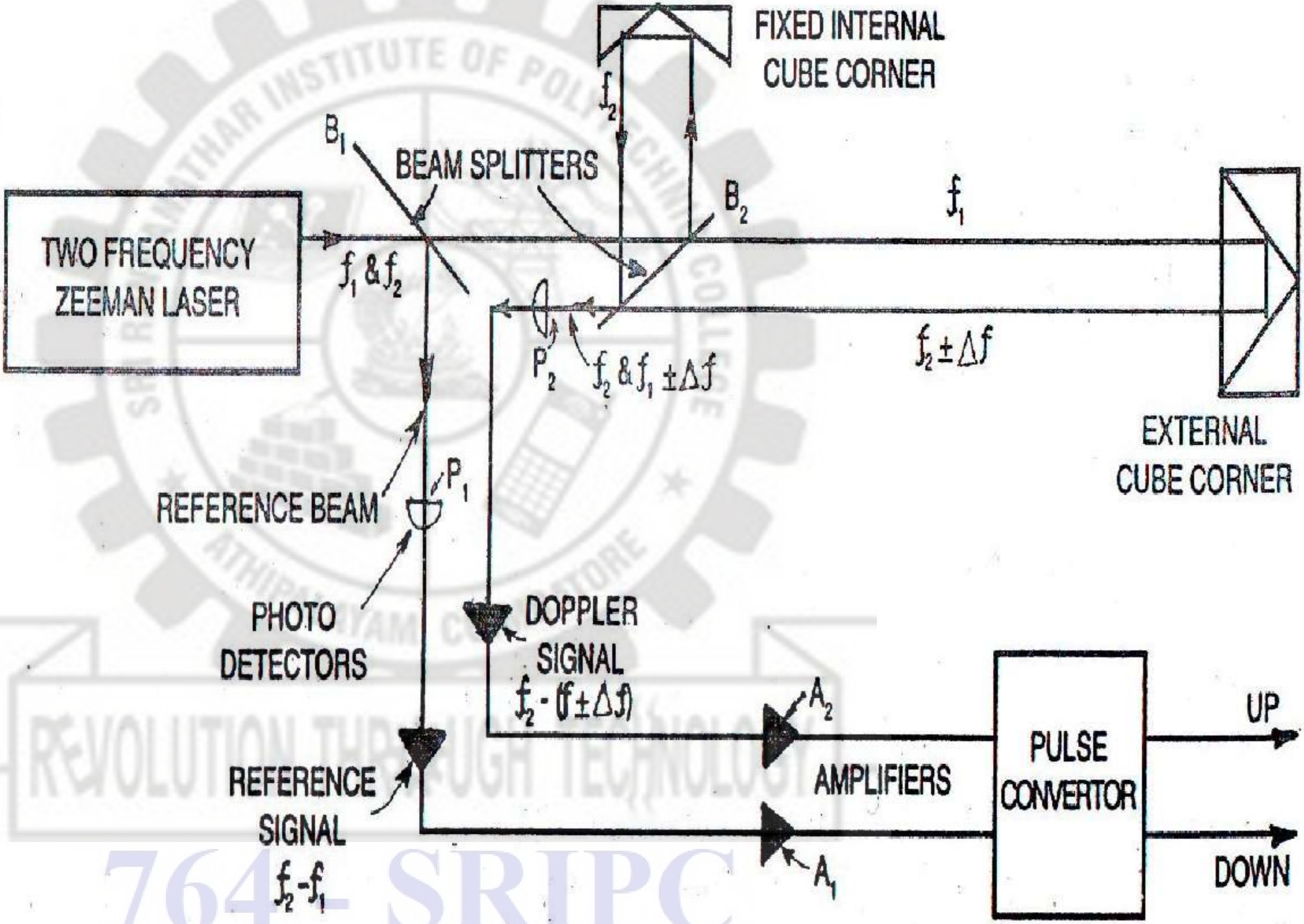
2. Beam splitters

It divides the laser beam into separate beams along different axis. It is possible to adjust the splitted laser's output intensity by having a choice of beam splitter reflectivities.

3. Cube corners

The cube corners can be plane mirrors roof prisms. Each AC laser interferometers are required at least two retro frequencies. One is fixed external cube corner and another one is external cube corner. Both the cube corners are used to reflect the laser beam.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC



FIXED INTERNAL CUBE CORNER
f_2
B_1
BEAM SPLITTERS
B_2
f_1
TWO FREQUENCY ZEEMAN LASER
f_1 & f_2
P_2
f_2 & $f_1 \pm \Delta f$
$f_2 \pm \Delta f$
EXTERNAL CUBE CORNER
REFERENCE BEAM
P_1
PHOTO DETECTORS
DOPPLER SIGNAL
$f_2 - (f \pm \Delta f)$
A_2
PULSE CONVERTOR
UP
AMPLIFIERS
REFERENCE SIGNAL
$f_2 - f_1$
A_1
DOWN

764- SRIPC

4. Photo detectors

Photo detectors receive the signal from the beam splitters and changers into electrical signal.

5. Amplifiers

There are two amplifiers used in AC laser interferometer. It is used to separate the frequency difference.

6. Pulse converter

The pulse converter is used to extracts change in frequency Δf.

Working

The two frequencies Zeeman laser generate light of two slightly different frequencies with opposite circular polarizations. The beams are splitted by the beam splitters B1. In this, one part travels towards B2 and from B2 to external cube corners, where the displacement is measured.

Beams splitter B2 optically separates the frequencies f1 which is sent to a fixed reflector and then rejoins f1 at the beam splitter B2 to produce alternate light and dark interference. Now, the external cube corner moves which it will produce a change in f1(i.e.,Δf1) in the returning beam frequency. So, the light beams move towards photo detectors p2 having frequencies f2(i.e.,f1 to Δti) and p2 will be changed into electrical signal.

The photo detector p1 receives signal from beam splitter B1 and changes the references beam f1 and f2 into electrical signal. The two amplifiers A1 and A2 separate frequency difference signals f2-f1 andf2-(f1+Δf). The pulse converter extracts Δf and displays in the form of pulses in analog or digital form in the output.

Basic Principles of Coordinate Measuring machines

A coordinate measuring machine (CMM) is a device for measuring the physical geometrical characteristics of an object.

This machine may be manually controlled by an operator or it may be computer controlled.

Measurements are defined by a probe attached to the third moving axis of this machine. Probes may be mechanical, optical, laser, or white light, among others.

764 - SRIPC

DESCRIPTION

CMM is composed of three axes, an X, Y and Z. These axes are orthogonal to each other in a typical three dimensional coordinate system.

- Each axis has a scale system that indicates the location of that axis. The machine will read the input from the touch probe, as directed by the operator or programmer.
- The machine then uses the X,Y,Z coordinates of each of these points to determine size and position. Typical precision of a coordinate measuring machine is measured in Microns, or Micrometers, which is 1/1,000,000 of a meter.
- A coordinate measuring machine (CMM) is also a device used in manufacturing and assembly processes to test a part or assembly against the design intent. By precisely recording the X, Y, and Z coordinates of the target, points are generated which can then be analyzed via regression algorithms for the construction of features.
- These points are collected by using a probe that is positioned manually by an operator or automatically via Direct Computer Control (DCC). DCC CMMs can be programmed to repeatedly measure identical parts, thus a CMM is a specialized form of industrial robot.

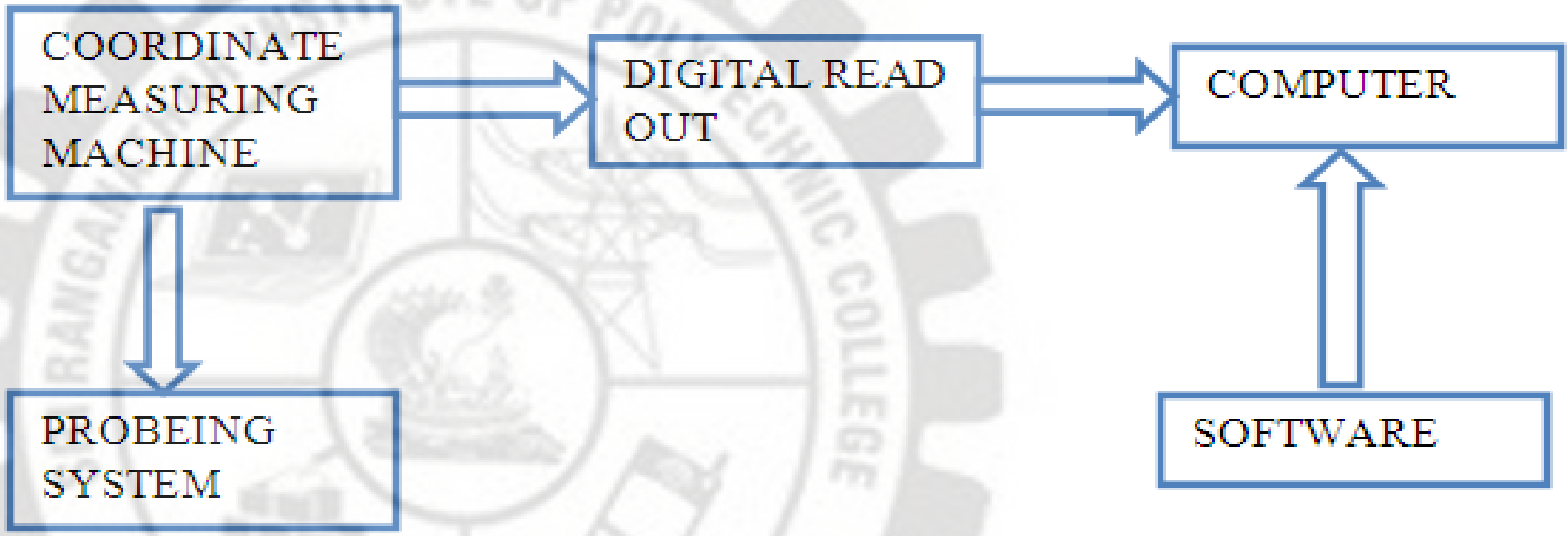
764 - SRIPC

Parts

- Coordinate-measuring machines include four main components:
  1. The main structure which include three axes of motion
  2. Probing system
  3. Data collection and Reduction system - typically includes a machine controller, desktop computer.
  4. Application software

764 - SRIPC

BLOCK DIAGRAM OF THE ELEMENTS OF A CMM



A basic Co-ordinate Measuring Machine consists of four elements.

1) The machine structure which is basically an X-Y-Z positioning device.

2) The Probing system use to collect raw data on the part and provide input to the control system.

3) Machine Control and Computer hardware.

4) The Software for three dimensional analyses.

764 - SRIPC

Uses

They are often used for:

- Dimensional measurement
- Profile measurement
- Angularity or orientation measurement
- Depth mapping
- Digitizing or imaging
- Shaft measurement

764 - SRIPC

Feature Based Measurement

- **Form**
  - straightness, flatness, roundness, cylindricity, sphericity
- **Orientation**
  - parallelism, perpendicularity, concentricity, angularity
- **Profile**
  - profile (scanning), surface (manual), output (graphics)

764 - SRIPC

ADVANTAGES OF USING CMM

FLEXIBILITY:

- Co-ordinate measuring machines are essentially universal measuring machines and do not need to be dedicated to any single or particular measuring task.
- They can measure practically any dimensional characteristic of virtually any part configuration, including cams, gears, and contoured surfaces.
- No special fixtures or gages are required; because electronic probe contact is light, most parts can be inspected without being clamped to a surface plate.

REDUCED SETUP TIME:

- Establishing part alignment and appropriate reference points are very time consuming with conventional surface-plate inspection techniques.
- These procedures are greatly simplified or virtually eliminated through software available on computer-assisted or computer-controlled CMMs.

764 - SRIPC

IMPROVED ACCURACY:

- All measurements on a CMM are taken from a common geometrically fixed measuring system, eliminating the introduction and accumulation of errors that can result with hard gage inspection methods and transfer techniques.

- Moreover, measuring all significant features of a part in one setup prevents the introduction of errors due to setup changes.

- In the part-program-assisted mode, the operator positions the machine; once the initial position has been set, the machine is under the control of a program that eliminates operator choice.

- In the Computer Numerically Controlled (CNC) mode, motor-driven machines run totally unattended by operators.

- Also, automatic data recording, available on most machines, prevents errors in transcribing readings to the inspection report.

- This all adds up to the fact that less skilled operators can be readily instructed to perform relatively complex inspection procedures.

IMPROVED PRODUCTIVITY:

- All the factors previously mentioned help to make CMMs more productive than conventional inspection techniques.

- Further dramatic productivity improvements are realized through the computational and analytical capabilities of associated data handling systems, including calculators and all levels of computers.

- All CMMs will have three moving elements of which one is capable of moving in x-axis, another in y-axis and another in z-axis with respect to each other.

- Each moving element is also fitted with a linear measurement transducer for positional feedback, with the help of which we can have the co-ordinate of a particular position with respect to a reference.

- The moving elements can be moved by means of frictionless air bearings or mechanical bearings.

- The Job to be measured will be mounted over a table made of granite because of its stability in various temperatures.

- The work table of the machine generally consists of tapped holes to facilitate clamping and locating of parts.

- A total of 11 different machine configurations exist; however, some of these configurations are modifications of one of the five primary configurations:

MACHINE CONFIGURATIONS

- A variety of machine configurations is available from the manufacturers of CMMs.
- Each configuration has advantages that make it suitable for particular applications.
- A total of 11 different machine configurations exist; however, some of these configurations are modifications of one of the four primary configurations: bridge, column, gantry, and horizontal arm.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

TYPES OF CMM

1. Cantilever type
2. Bridge type
3. Column type
4. Gantry type
5. Horizontal type.

CANTILEVER TYPE

- The probe is attached to the vertical quill that moves in a Z-axis direction relative to a horizontal arm that over hangs the work table.
- The quill can be moved along the length of the arm to achieve y-axis motion, and the arm can be moved to the work table to achieve x-axis motion.

Advantages

- Convenient access to the work table and its relatively small floor space requirements

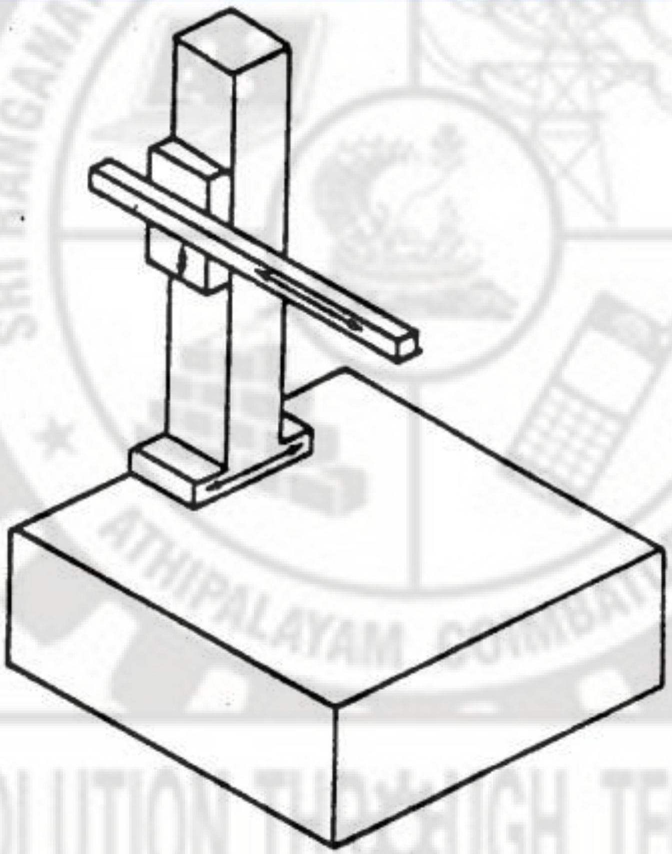
Disadvantages

- Lower rigidity than some of the other CMM construction

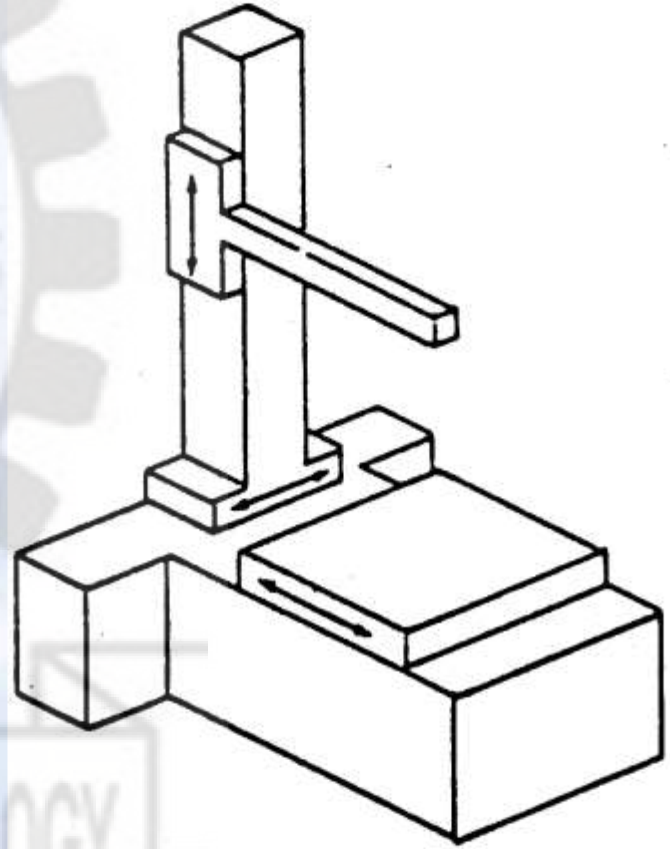
Types of cantilever

1. Moving Table Horizontal Arm CMM
2. Moving Arm Horizontal Arm CMM
3. Column CMM
4. Fixed Table Horizontal Arm CMM

Types of CMM

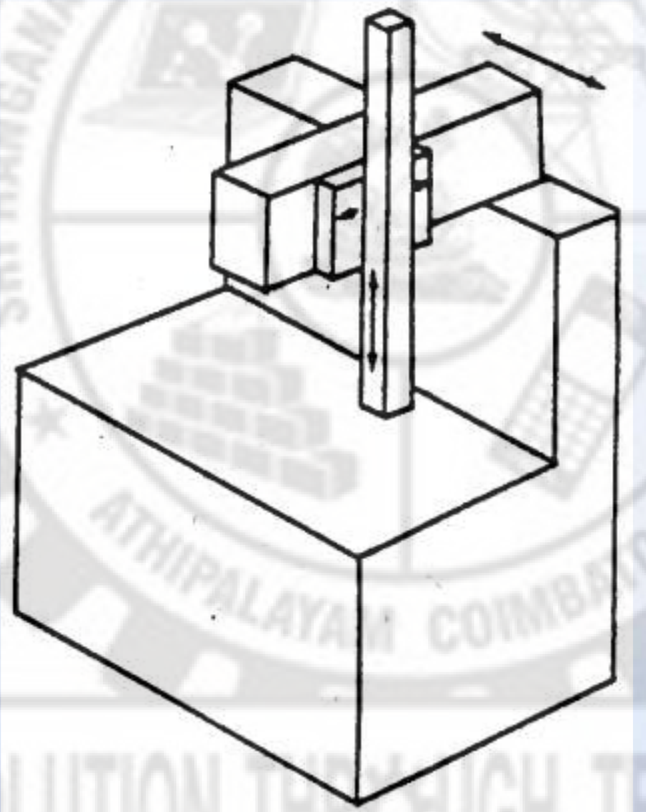


Moving Arm Horizontal Arm Coordinate Measuring Machine

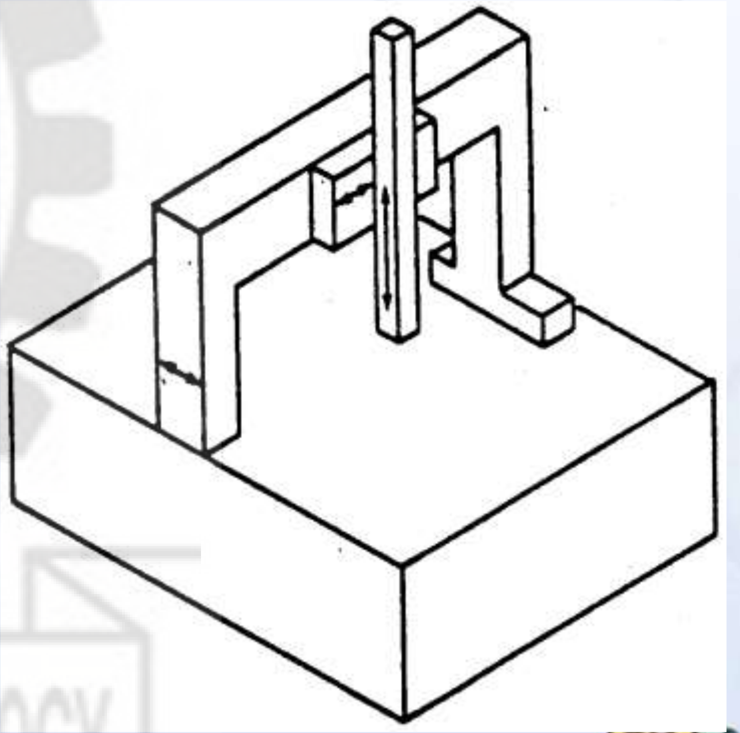


Moving Table Horizontal Arm Coordinate Measuring Machine

Types of CMM



Fixed Table Cantilever Coordinate Measuring Machine



Moving Bridge Coordinate Measuring Machine

764 - SRIPC

BRIDGE:

- It is difficult to load but less sensitive to mechanical errors.
- Bridge-type coordinate measuring machines employ three movable components moving along mutually perpendicular guide ways.
- This eliminates pitching and yawing moments on the bridge assembly, allowing higher acceleration and deceleration rates.
- The bridge-type CMM is the most popular configuration.
- The double-sided support of this type of CMM provides more support for large and medium-sized machines.
- The bridge can slide back on the base to give complete accessibility to the working area for safe, easy loading and unloading of parts.

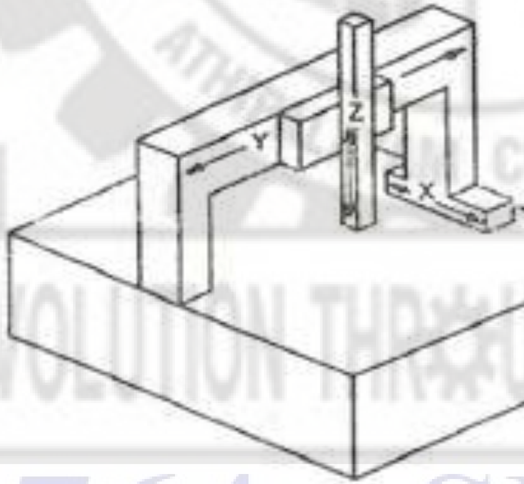
764 - SRIPC

- Traveling-bridge CMMs have longer Y strokes for less cost than do cantilever-type CMMs.

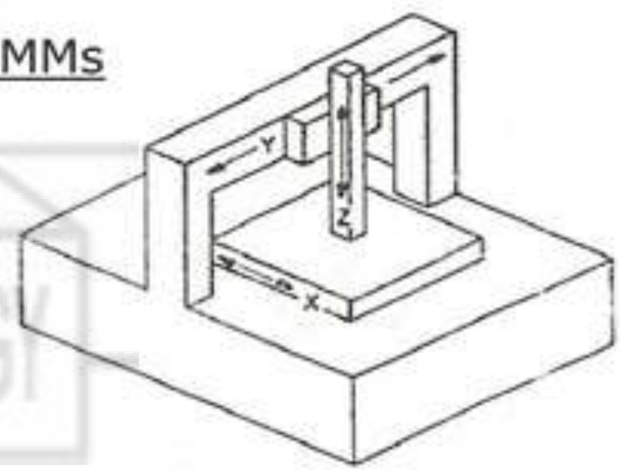
- However, because of the weight of the extra support, the inertia of the moving mass is greater than in the cantilever configuration.

- In addition, the parts being measured with this type of CMM cannot be wider than the clearance between the two sides of the bridges.

<u>Bridge type CMMs</u>



(a)
Moving bridge

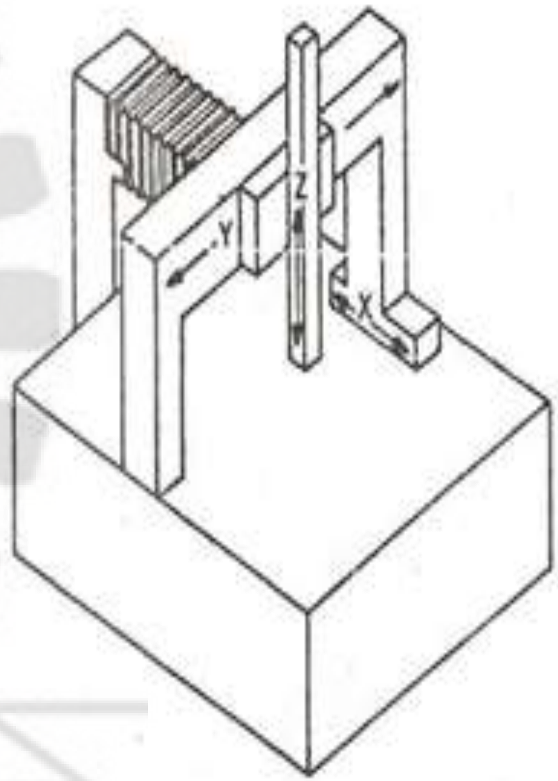


(b)
Fixed bridge

764 - SRIPC

(c)

L-shaped bridge



(d)

Central drive bridge

SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE
COIMBATORE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

COLUMN:

- Column-type CMMs are similar in construction to accurate jig boring machines.
- The column moves in a vertical (Z) direction only, and a two-axis saddle permits movement in the horizontal (X and Y) direction.
- Column-type CMMs are often referred to as universal measuring machines rather than CMMs by manufacturers and are considered gage-room instruments rather than production-floor m/c.

764 - SRIPC

GANTRY:

- Gantry-type CMMs employ three movable components moving along mutually perpendicular guide ways.
- The probe is attached to the probe quill, which moves vertically (Z direction) relative to a cross beam.
- The probe quill is mounted in a carriage that moves horizontally (Y direction) along the cross beam.
- The cross beam is supported and moves in the X direction along two elevated rails, which are supported by columns attached to the floor.
- The gantry-type configuration was initially introduced in the early 1960s to inspect large parts such as airplane fuselages, automobile bodies, ship propellers, and diesel engine blocks.
- The open design permits the operator to remain close to the part being inspected while minimizing the inertia of the moving machine parts and maintaining structural stiffness.

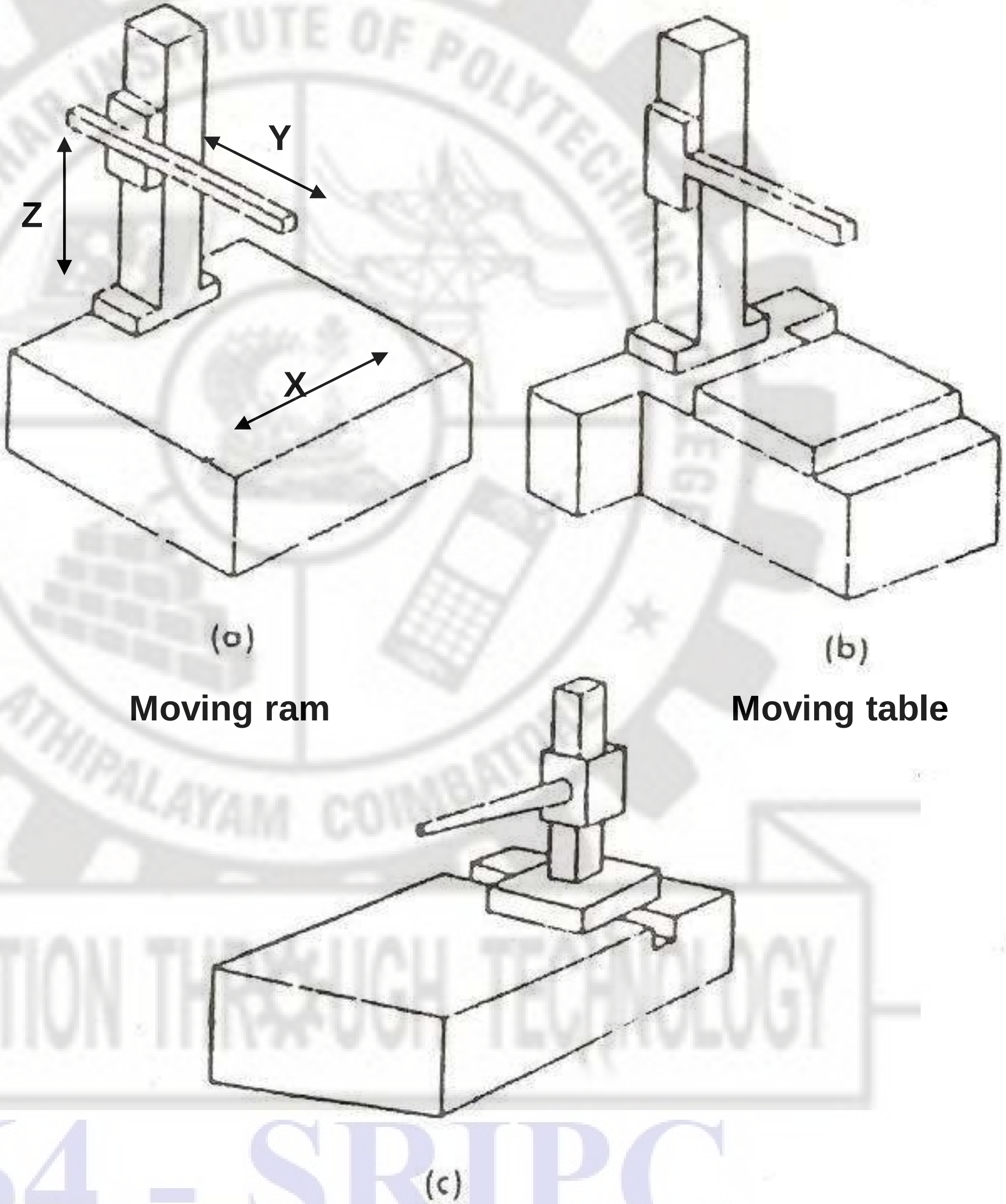
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

HORIZONTAL ARM:

- Several different types of horizontal arm CMMs are available.
- As is typical of all CMMs, the horizontal arm CMMs employ three movable components moving along mutually perpendicular guideways.
- The probe is attached to the first component, which moves vertically (Z direction) relative to the second.
- The second component moves horizontally (Y direction) relative to the third. The third component is supported on two legs that reach down to opposite sides of the machine base and moves horizontally (X direction) relative to the base.
- Another modification of the bridge configuration has two bridge-shaped components.
- One of these bridges is fixed at each end to the machine base. The other bridge, which is an inverted L-shape, moves horizontally (X direction) on guideways in the fixed bridge and machine base.
- A third modification of moving-bridge configuration is the central-bridge drive. The drive forces are applied to the center of mass of the bridge assembly.
- This configuration employs three movable components moving along mutually perpendicular guideways. In the moving-arm design, the probe is attached to the horizontal ram, which moves in a horizontal Y direction.

764 - SRIPC

Horizontal arm CMMs



Fixed table

- The ram is encased in a carriage that moves in a vertical (Z) direction and is supported on a column that moves horizontally (X direction) relative to the base.

- In the moving-table design, the probe is attached to the horizontal arm, which is permanently attached at one end only to a carriage that moves in a vertical (Z) direction on the column.

- The arm support and table move horizontally (X and Y directions) relative to the machine base.

- In the fixed-table design, the probe is attached to the horizontal arm, which is supported cantilever style at the arm support and moves in a vertical (Z) direction.

- The arm support moves horizontally (X and Y directions) relative to the machine base.Horizontal arm CMMs are used to inspect the dimensional and geometric accuracy of a broad spectrum of machines or fabricated workpieces.

- Utilizing an electronic probe, these machines check parts in a mode similar to the way they are machined on horizontal machine tools.

- They are especially suited for measuring large gear cases and engine blocks, where high-precision bore alignment and geometry measurements are required.By incorporating a rotary table, four-axis capability is obtainable.

PROBES

- The utility of a Coordinate measuring machine depends largely on the nature of the probing device.
- Three types of probes are commonly used:
  1. Hard
  2. Electronic
  3. Noncontact
- A probe is selected according to the dimensional and geometrical requirements of the inspection process.

HARD PROBES:

- Hard probes consist of a shaft and a probe tip mounted in various ways to the probe arm.
- A variety of probe tip shapes and sizes are available: the shape of the probe determines its application.
- Conical probes are used for locating holes. Ball probes for establishing surface locations. Cylindrical probes for checking slots and holes in sheet metal parts.
- Hard probes can only be used in small, manually operated CMMs when inspecting simple parts of a short production run.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

ELECTRONIC PROBES:

- Electronic probes are the most popular probes in use.
- This electronic probe, also called a touch probe, is an omni-directional triggering device consisting of a probe body and a stylus; multiple stylus arrangements are also available.
- When the stylus is brought into contact with the workpiece, a signal is sent to the computer interface, indicating the instantaneous three-dimensional location of the stylus.
- There are two types of probes.

    1. Trigger type probe system
    2. Measuring type probe system

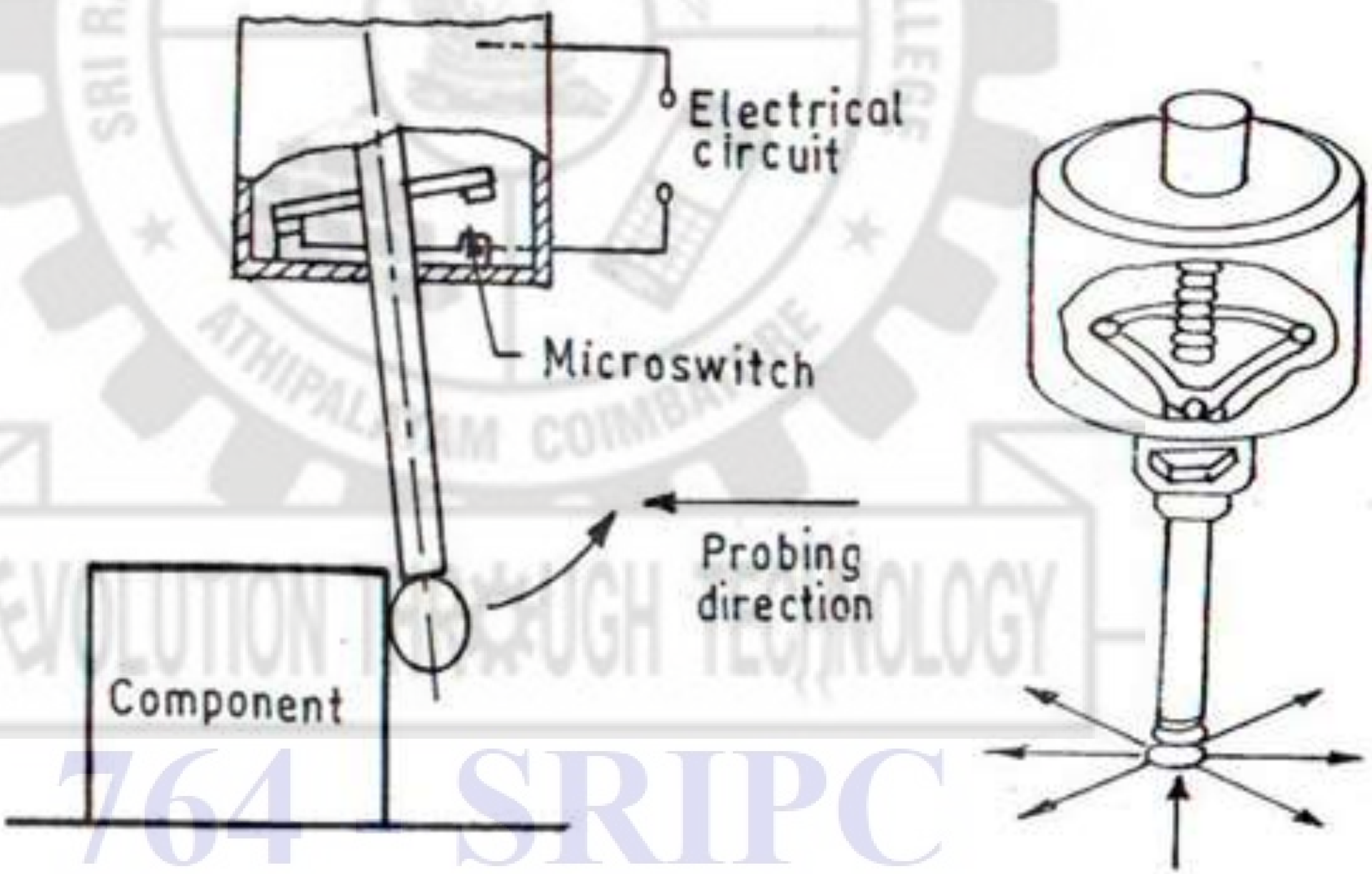
1. Trigger type probe system:

The "buckling mechanism" is a three point bearing, the contacts of which are arranged at 120° around the circumference. These contacts act as electrical micro switches. When being touched in any probing direction, one or more contacts are lifted off and the current is broken, thus it generates a pulse. If the circuit is opened, the current

764 SRIPC

co-ordinate positions are read and stored. After probing, a prestressed spring ensures the perfect Zero position of the three point bearing.

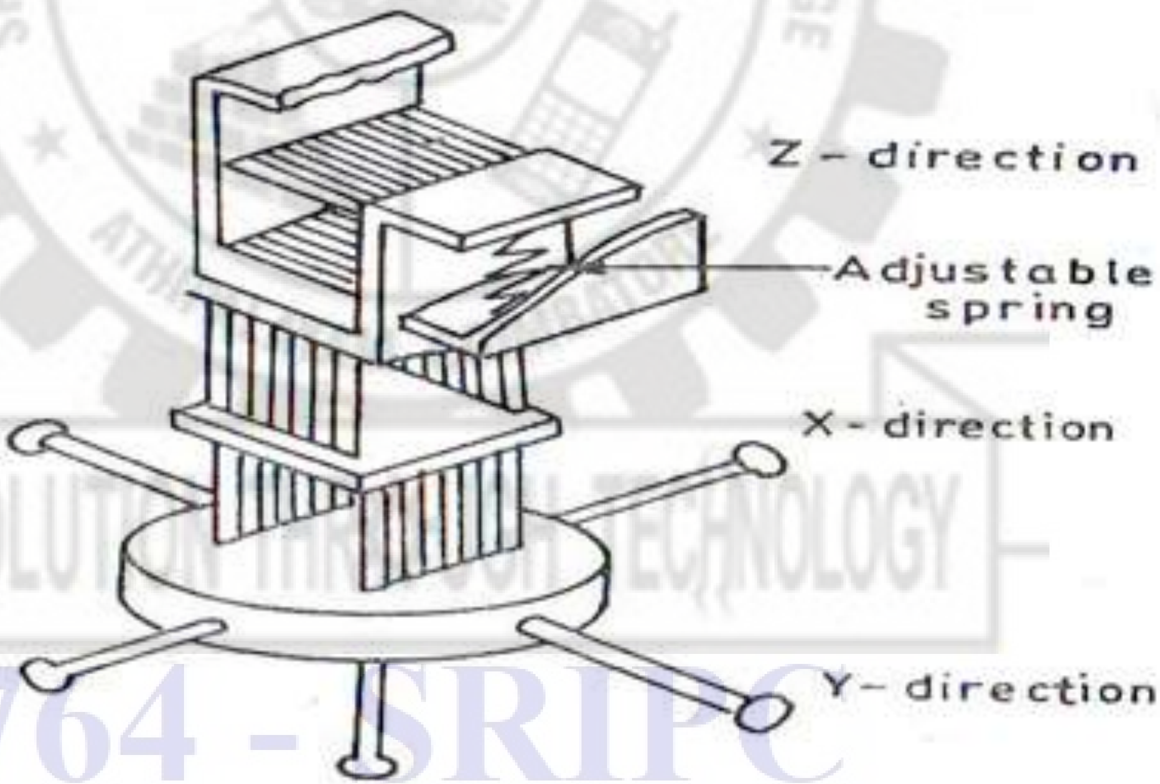
The probing force is determined by the prestressed force of the spring. The measuring time is shorter than in static principle; because of the probe system with data acquisition is always dynamic in nature.



764 SRIPC

2. Measuring type probe system:

- Measuring type probe mechanism is a small co-ordinate measuring machine in itself.The "buckling mechanism" of this system consists of parallel guide. At the moment of probing, the spring parallelograms are deflected from their initial position.
- The measurements can be made easily because the entire system is free from torsion, play and friction. A defined parallel displacement of probes as compared to their original arrangements can be measured.



764 - SRIPC

NONCONTACT PROBES:

- Noncontact probes are used when fast, accurate measurements are required with no physical contact with the part. Several types of noncontact probes are used.

- Optical probes are used when inspecting drawings, printed circuit boards, and small, fragile workpieces. When these probes are used, the basic measuring programs can still be used.

    1. TOUCH SCANNERS
    2. LASER PROBES
    3. VISION PROBES

ADVANTAGES OF CMM

1. Faster rate of inspection
2. Improved accuracy
3. Minimisation of operator error
4. Reduced operator skill requirements
5. Reduced need of fixtures and maintenance costs
6. Uniform inspection quality
7. Reduction of scrap
8. Reduction in setup time
9. Simplification of inspection procedures.
10. Reduction in calculating and recording time and errors

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

FORM MEASUREMENTS

764 - SRIPC

Screw Threads

Screw threads are used;

- To hold parts together (eg: V-threads)
- To transmit motion & power (Square, Acme threads)

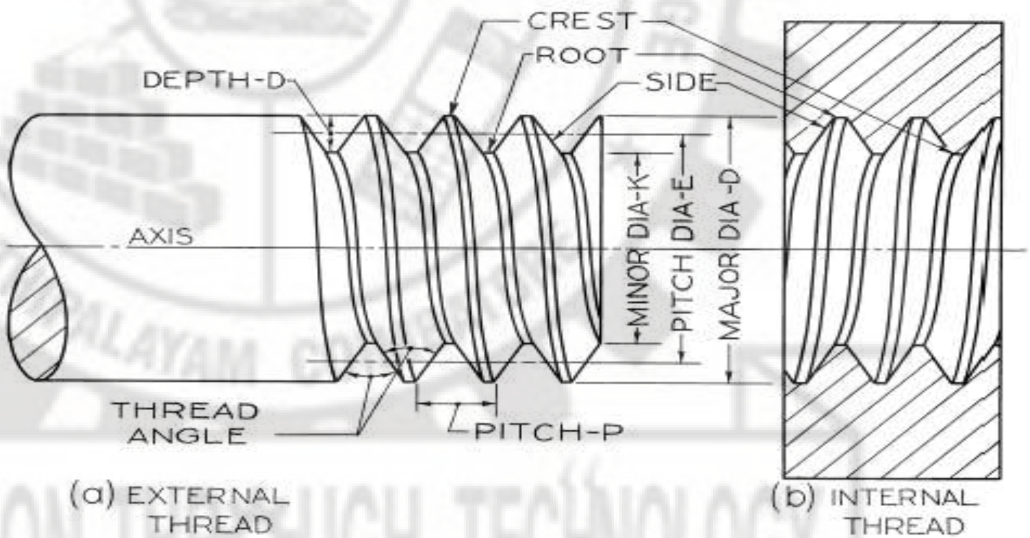


Figure 13-1

Screw Thread Nomenclature.

764 - SRIPC

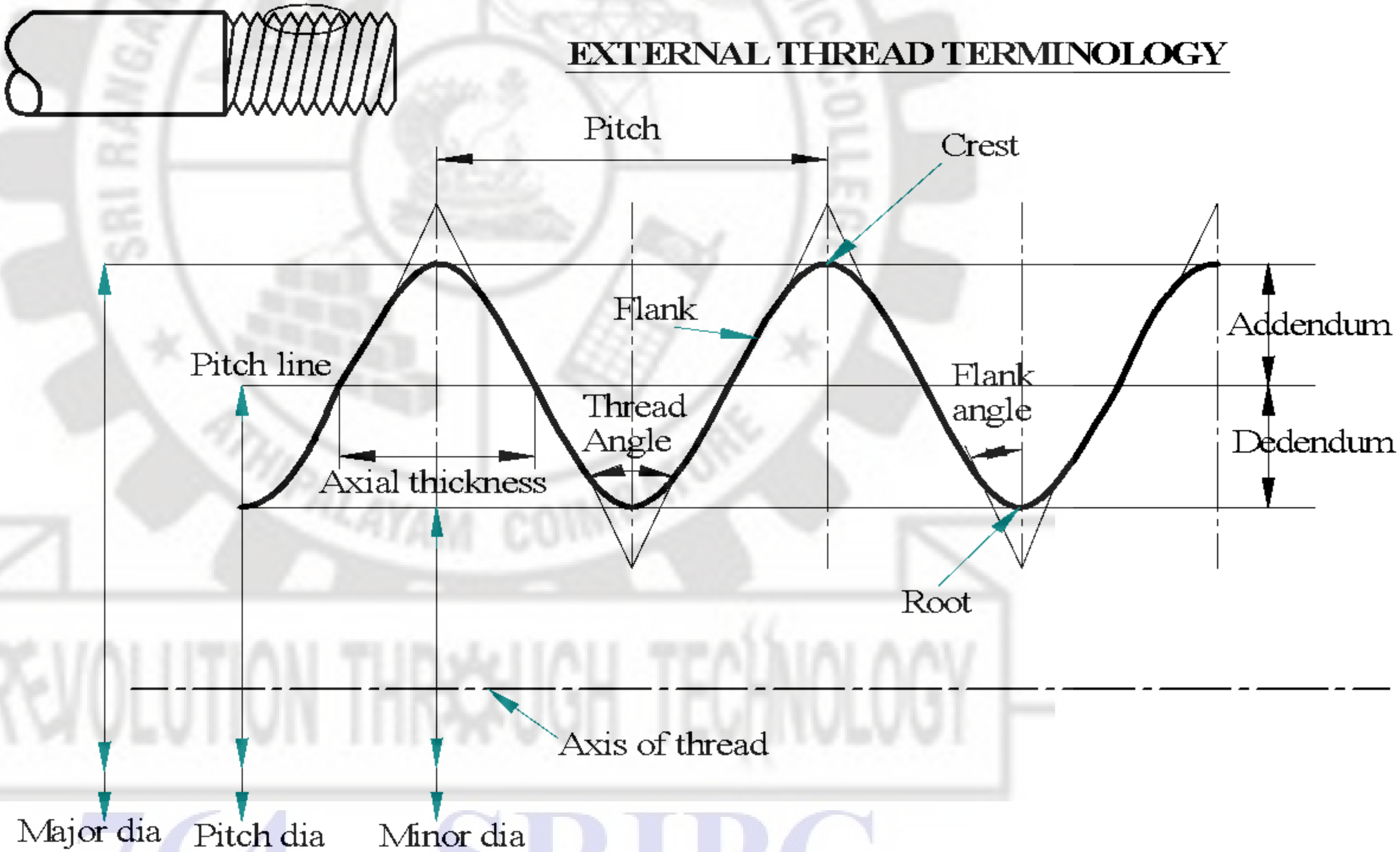
Screw threads Terminology

- PITCH: The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis.
- LEAD: The distance a screw thread advances in one turn. For a single start threads, lead=pitch,

  For double start, lead=2xpitch, & so on.
- THREAD FORM: The cross section of thread cut by a plane containing the axis.
- MAJOR DIAMETER: This is the diameter of an imaginary cylinder, co-axial with the screw, which just touches the crests of an external thread or roots of an internal threads. It is also called as ‘Nominal diameter’.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

SCREW THREAD TEMINOLOGY



764 - SRIPC

Screw threads Terminology

- Minor diameter: This is the diameter of an imaginary cylinder, co-axial with the screw which just touches the roots of an external thread or the crest of an internal thread. This is also referred to as 'root' or 'core diameter'.
- Effective diameter or Pitch diameter: It is the diameter of an imaginary cylinder coaxial with the axis of the thread and intersects the flanks of the thread such that width of the threads & width of spaces between threads are equal.
- Flank: It is the Thread surface that connects crest with root.

Depth of thread: It is the distance between crest and root measured perpendicular to axis of screw.

764 - SRIPC

Screw threads Terminology

Angle of thread: Included angle between sides of thread measured in axial plane.

Helix angle: Angle that thread makes with plane perpendicular to thread axis.

Flank angle: It is half the included angle of the thread.

Addendum: It is the distance between the crest and the pitch line measured perpendicular to axis of the screw.

Dedendum: It is the distance between the pitch line & the root measured perpendicular to axis of the screw.

764 - SRIPC

Errors in screw threads

- There are six important elements in a thread, errors in any one of which may lead to rejection.
- They are Major diameter, Minor diameter, effective diameter, Pitch, Flank angle and the profile at root & crest.
- Errors in screw threads may cause interference with mating threads or slackness due to improper flank contact.
- Errors in pitch of screw thread may be classified into three types;

  (i) Periodic errors (ii) Progressive errors (iii) Erratic errors

764 - SRIPC

(i) Periodic errors

- Periodic errors are those which vary in magnitude along the length of the thread and occurs at regular intervals as shown in fig (a).
- A ‘drunken thread’ is a particular case of periodic error where the error repeats once per turn.
- For a true thread, if the thread is imagined to be unwound from the pitch cylinder, the helix will be a straight line. For a drunken thread, it will be a curve as shown in fig (b).
- In a drunken thread, the advance of the helix is irregular in one complete revolution. This is due to thread being not cut to true helix.

764 - SRIPC

(i) Periodic errors

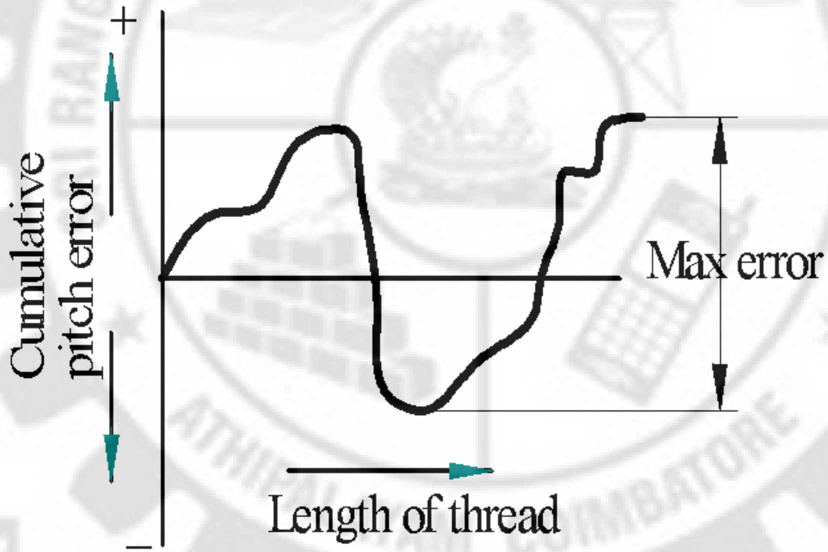


Fig (a)

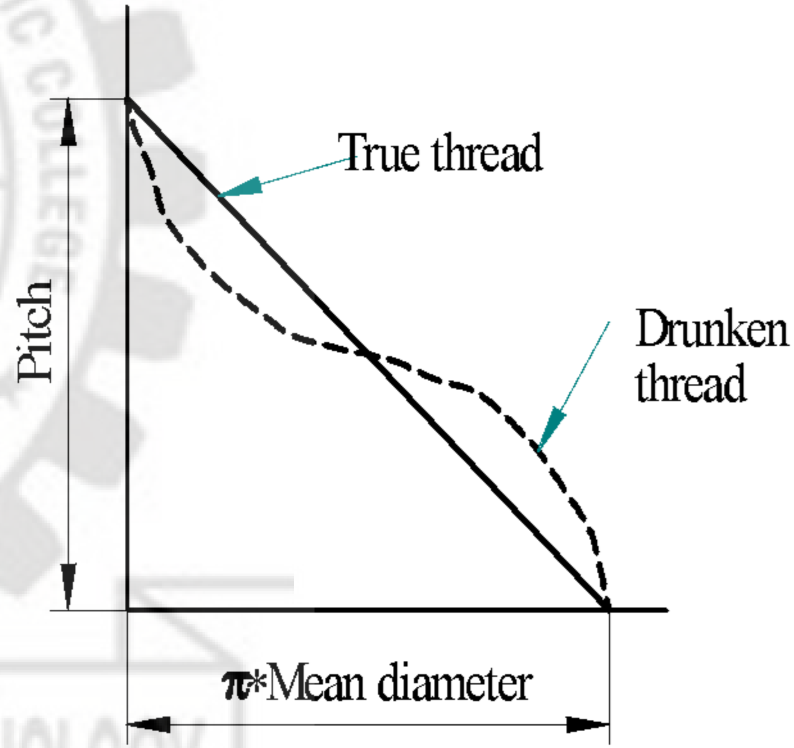


Fig (b)

PERIODIC ERRORS

DRUNKEN THREAD

764 - SRIPC

- Progressive pitch error: If the pitch of the thread is uniform but is longer or shorter than its nominal value, then the error is called progressive as shown in fig (c). These errors may be caused by a change in length due to hardening, or by the errors in the pitch of the lead screw, or by the faults in the saddle guide ways.

- Erratic errors: These errors vary in irregular manner along the length of the thread as shown in fig (d). Their causes are difficult to identify. Possible sources are faults in the machine and irregular cutting action resulting from material non uniformity.

764 - SRIPC

(ii) Progressive & (iii) Erratic errors

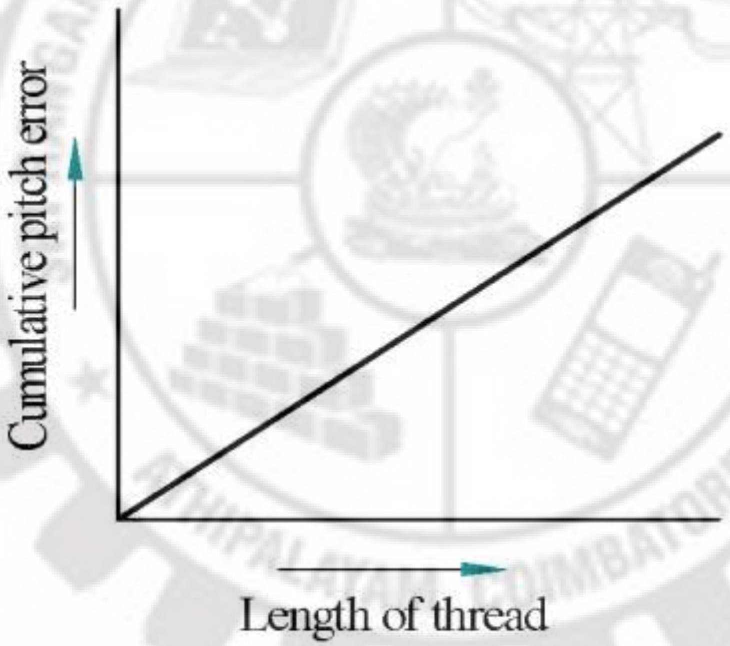


Fig (c)
PROGRESSIVE ERROR

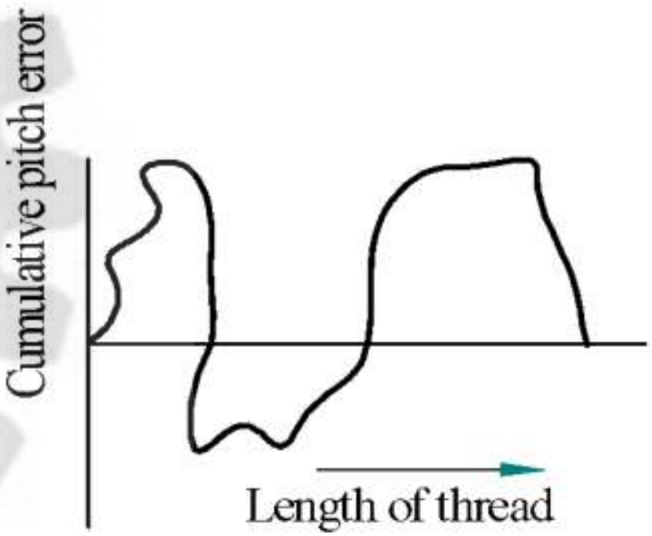
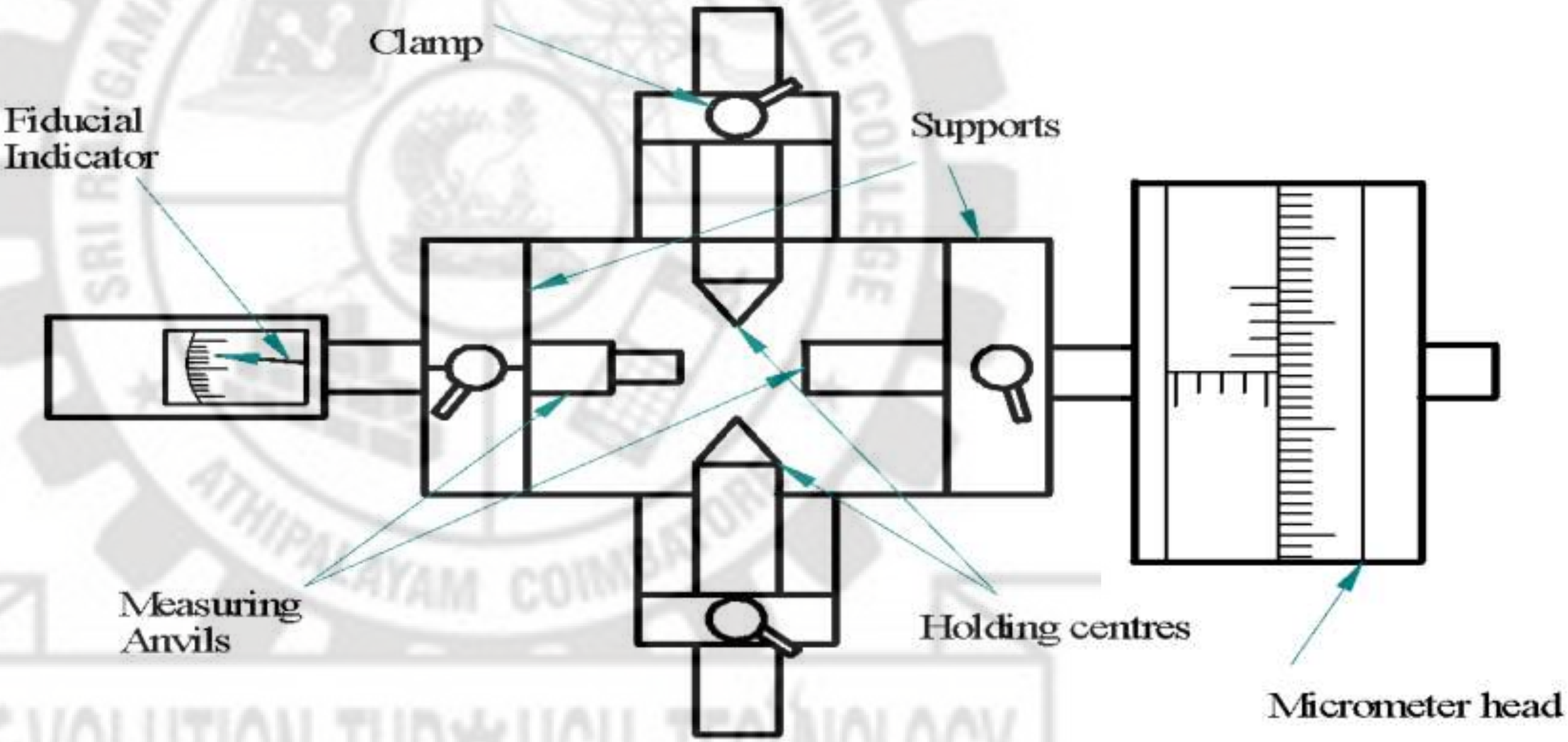


Fig (d)
ERRATIC ERRORS

764 - SRIPC

Measurement of major diameter



BENCH MICROMETER

764 - SRIPC

Bench Micrometer

764 - SRIPC

BENCH MICROMETER

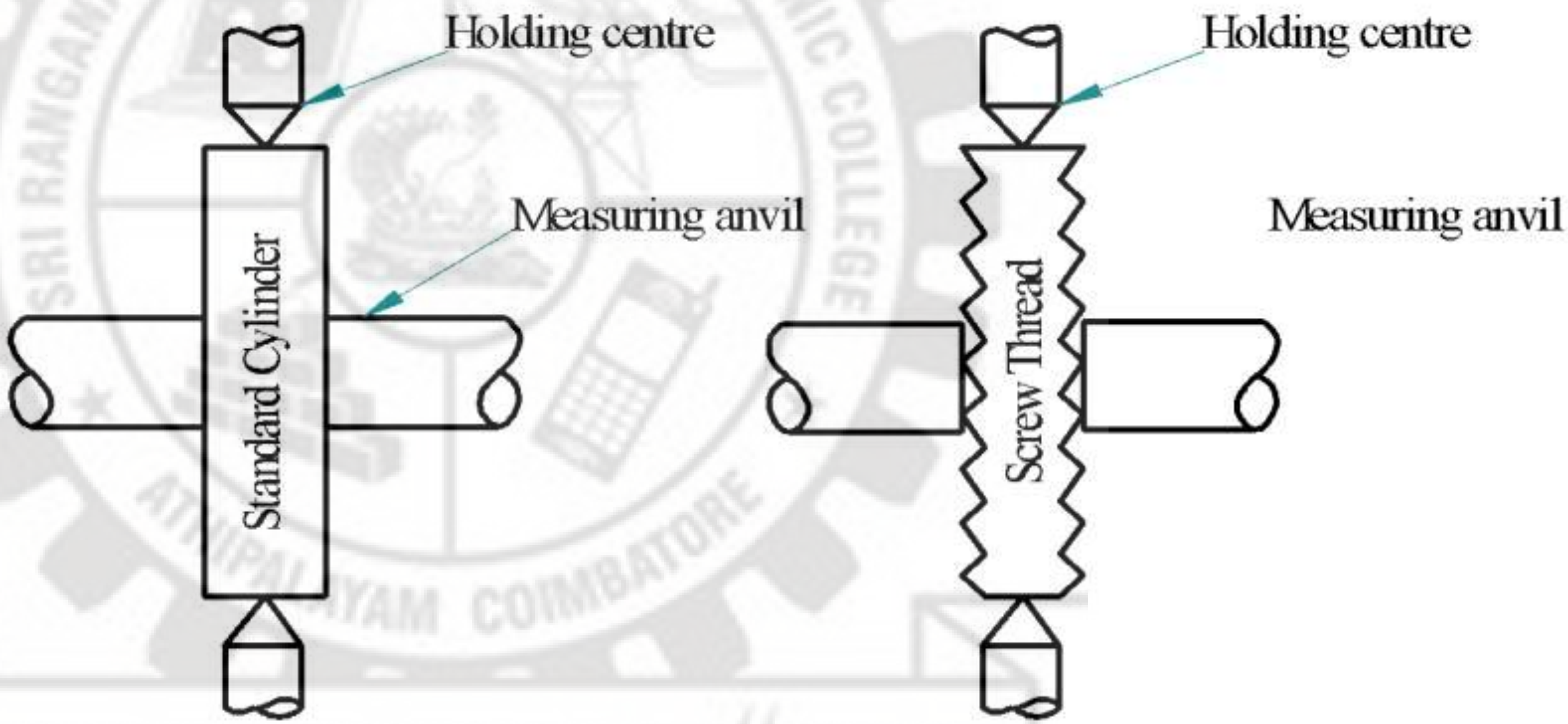
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Bench Micrometer

- A good quality hand held micrometer is quite suitable for measuring external thread, but only light pressure has to be applied on the anvils to make only contact on the screw threads.
- Excessive pressure may lead to elastic deformation of screw threads leading to errors.
- A bench micrometer may be used for greater accuracy which give direct readings of 0.0002 mm.
- A standard cylinder of known diameter ‘S’ (which is nearly equal to thread diameter) is held between centers & a reading R_1 between the fiducial indicator anvil & micrometer anvil is taken. The cylinder is then removed.
- Then the screw thread to be measured is held between centers & a second micrometer reading R_2 is taken.
- Then,

$$D_1 = S \pm (R_1 \sim R_2)$$

764 - SRIPC



Measurement of Major diameter

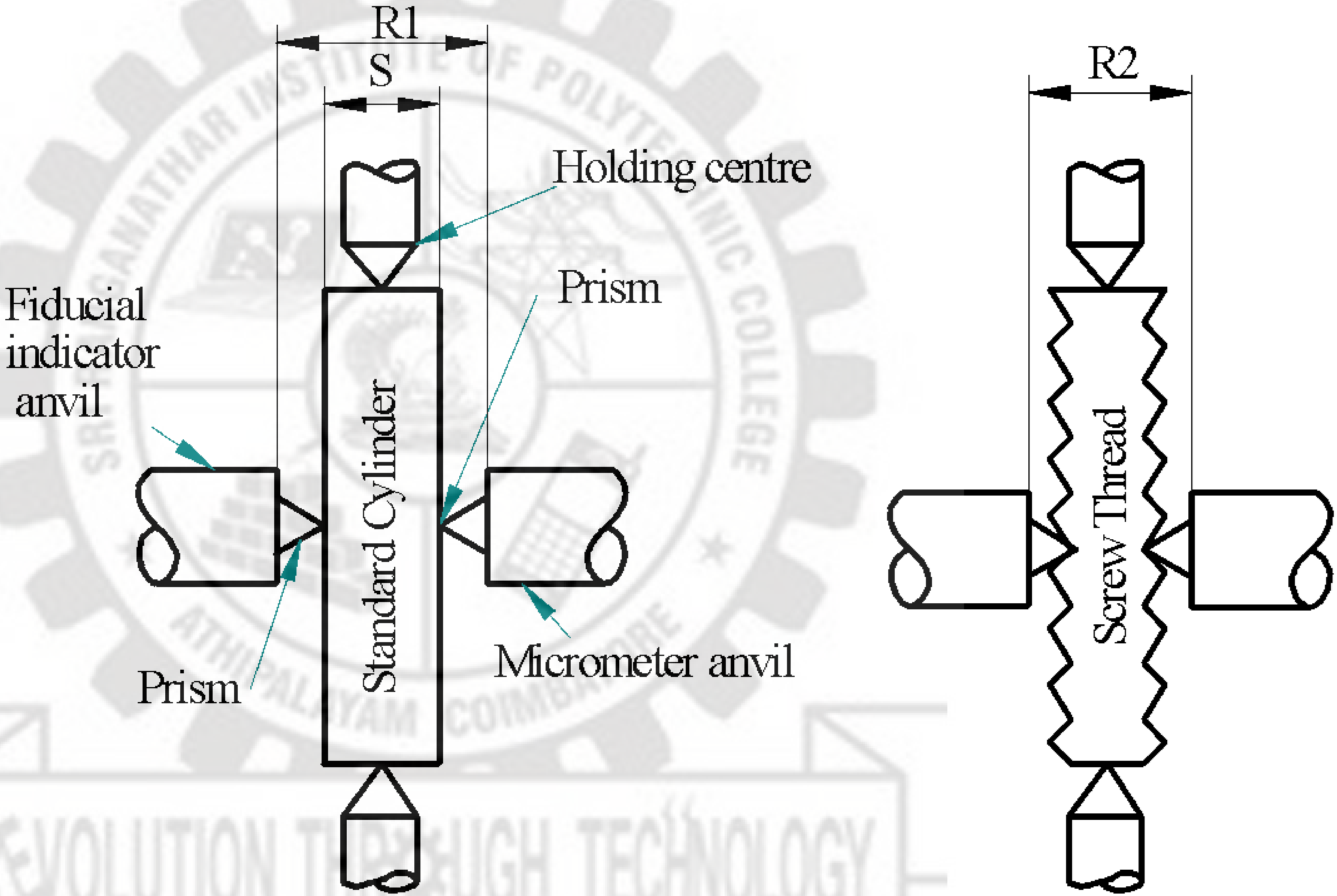
764 - SRIPC

Measurement of minor diameter

- The principle of minor diameter is same as that of measuring major diameter except that v -shaped prisms are used.
- Prisms of suitable sizes are placed between the standard cylinder and the instrument anvils in order to take a reading first micrometer reading R_1.
- The standard cylinder is then replaced by the screw thread and a second reading R_2 is taken as shown in fig.
- Then the minor diameter,

$$D_2 = S \pm (R_1 \sim R_2)$$

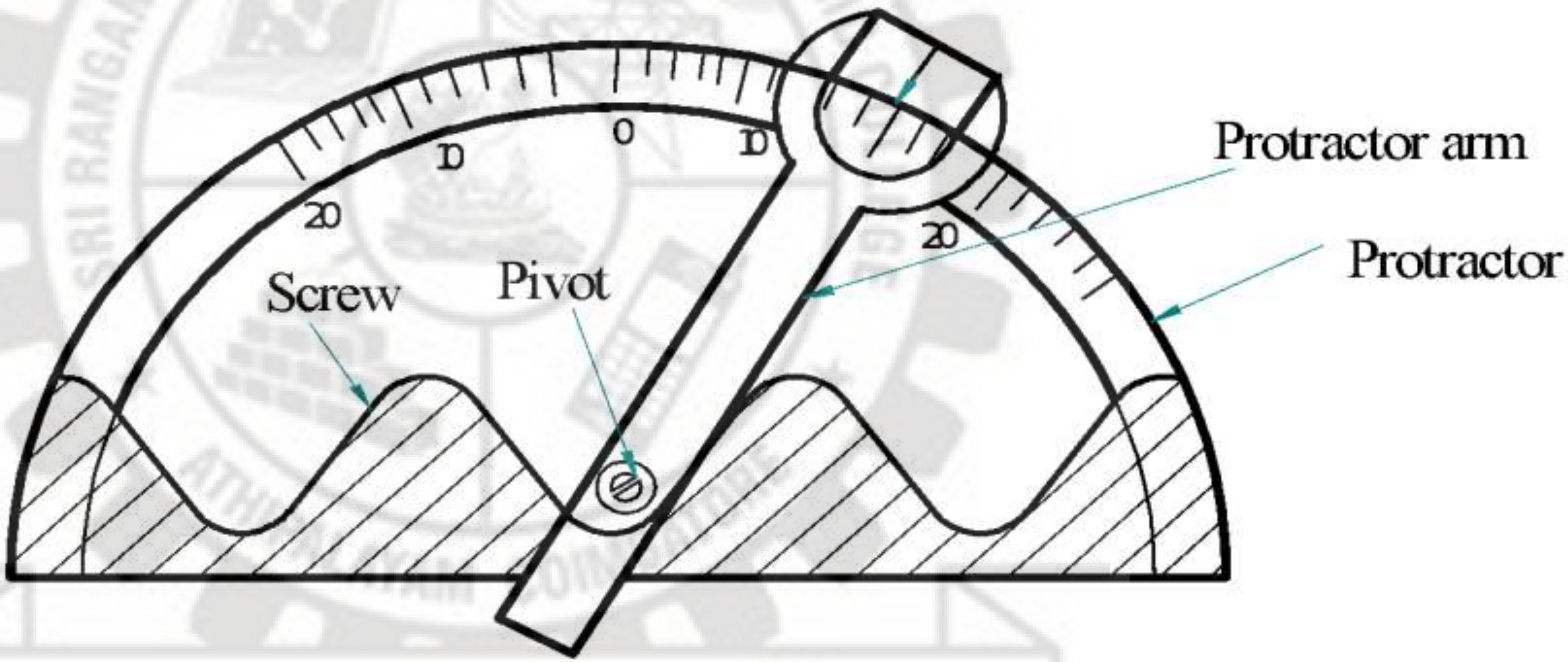
764 - SRIPC



Measurement of Minor diameter

764 - SRIPC

Measurement of Flank angle



Shadow Protractor

764 - SRIPC

Shadow protractor

- Shadow protractor is most convenient method for measurement of flank angles using optical projection.
- The shadow of the thread is viewed on a screen and the angles are measured by means of a protractor.
- For clear definition of a thread form on the screen it is necessary to project the light beam along the thread helix angle by using a lamp & collimating unit.
- The protractor is supported at the screen on a straight edge. The pivoted arm of the protractor is rotated until its shadow is parallel to the flank & the first reading is taken.
- The screw is then rotated 90º to its axis and the protractor is swung about its pivot and adjusted to measure the angle of the same flank and a second reading is taken.
- The mean of the two readings is then the angle between the flank & normal to the screw axis.

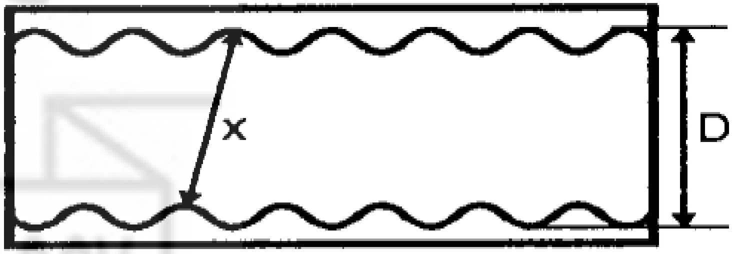
764 - SRIPC

Measurement of Internal Threads(Major Diameter)

- A comparator consists of special anvils which can be placed in the groove and measure the distance x.
- The major diameter D can be calculated by knowing value of x as,

where p = Pitch of the screw

$$D = \sqrt{x^2 - \left(\frac{p}{2}\right)^2}$$



764 - SRIPC

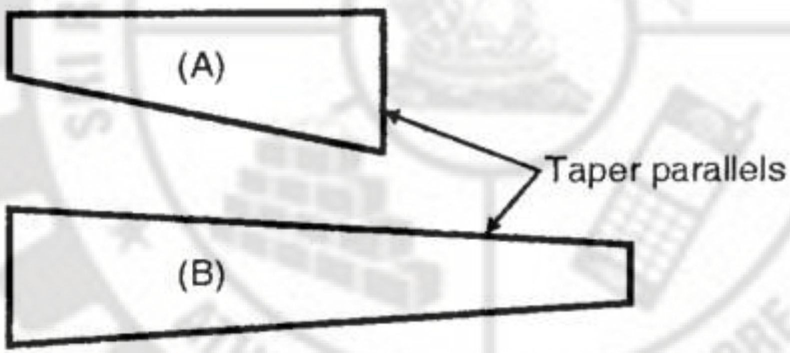
Measurement of Internal Threads (Minor Diameter)

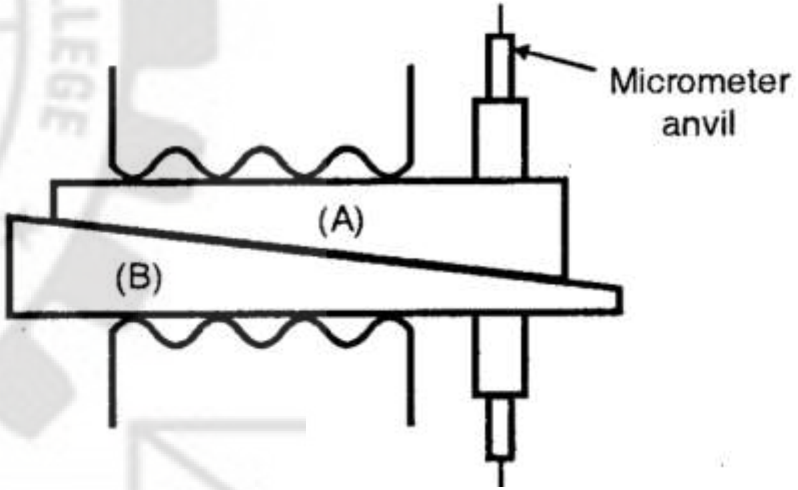
1. Using Taper Parallels:

- The minor diameter can be easily measured by using taper parallels. These taper parallels are inserted inside the thread and adjusted until they are perfectly aligned with each other.
- Micrometer anvil will read the height of taper parallels in contact, thus indicating the internal diameter of the thread.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

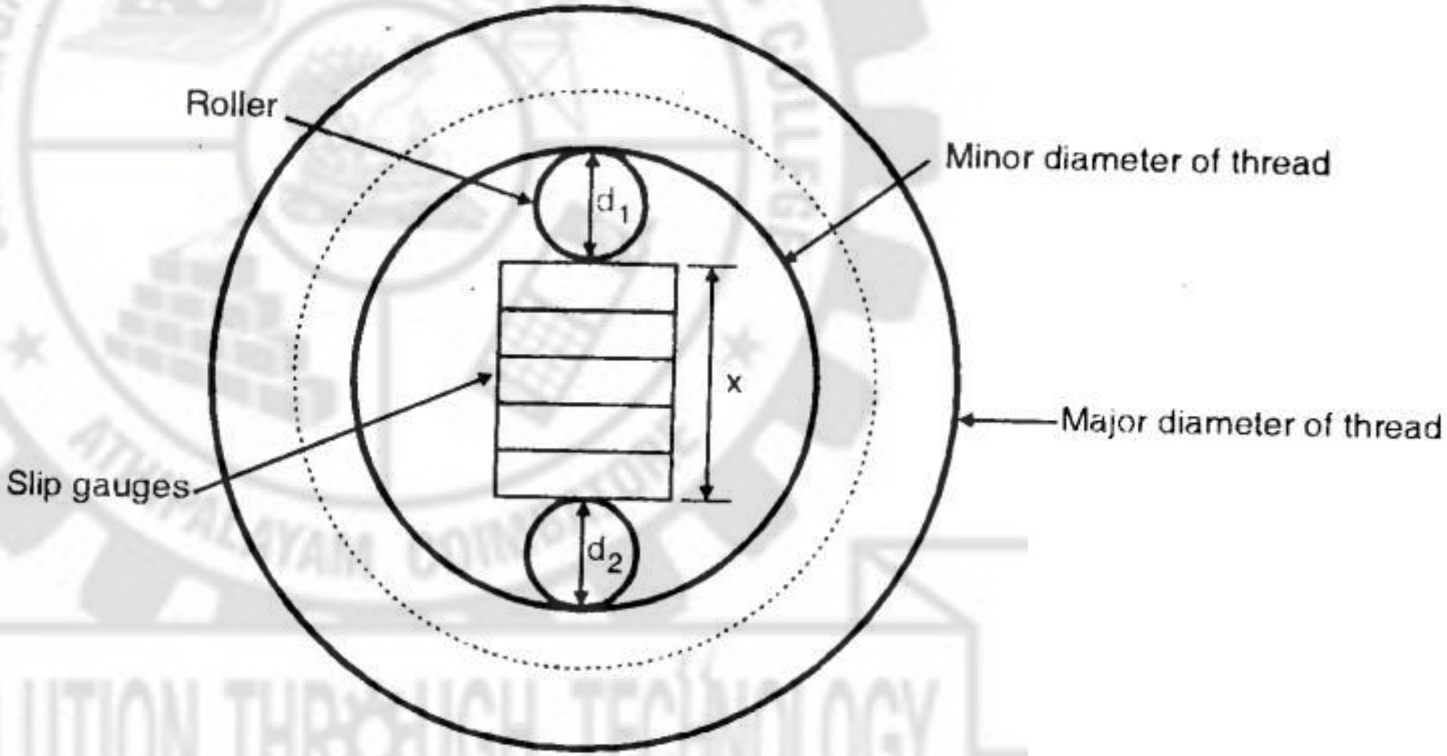
Measurement of Internal Threads (Minor Diameter)- Using Taper Parallels





764 - SRIPC

Measurement of Internal Threads (Minor Diameter)- Using Slip Gauge and Rollers



764 - SRIPC

Measurement of Internal Threads (Minor Diameter)

2. Using Slip Gauge and Rollers

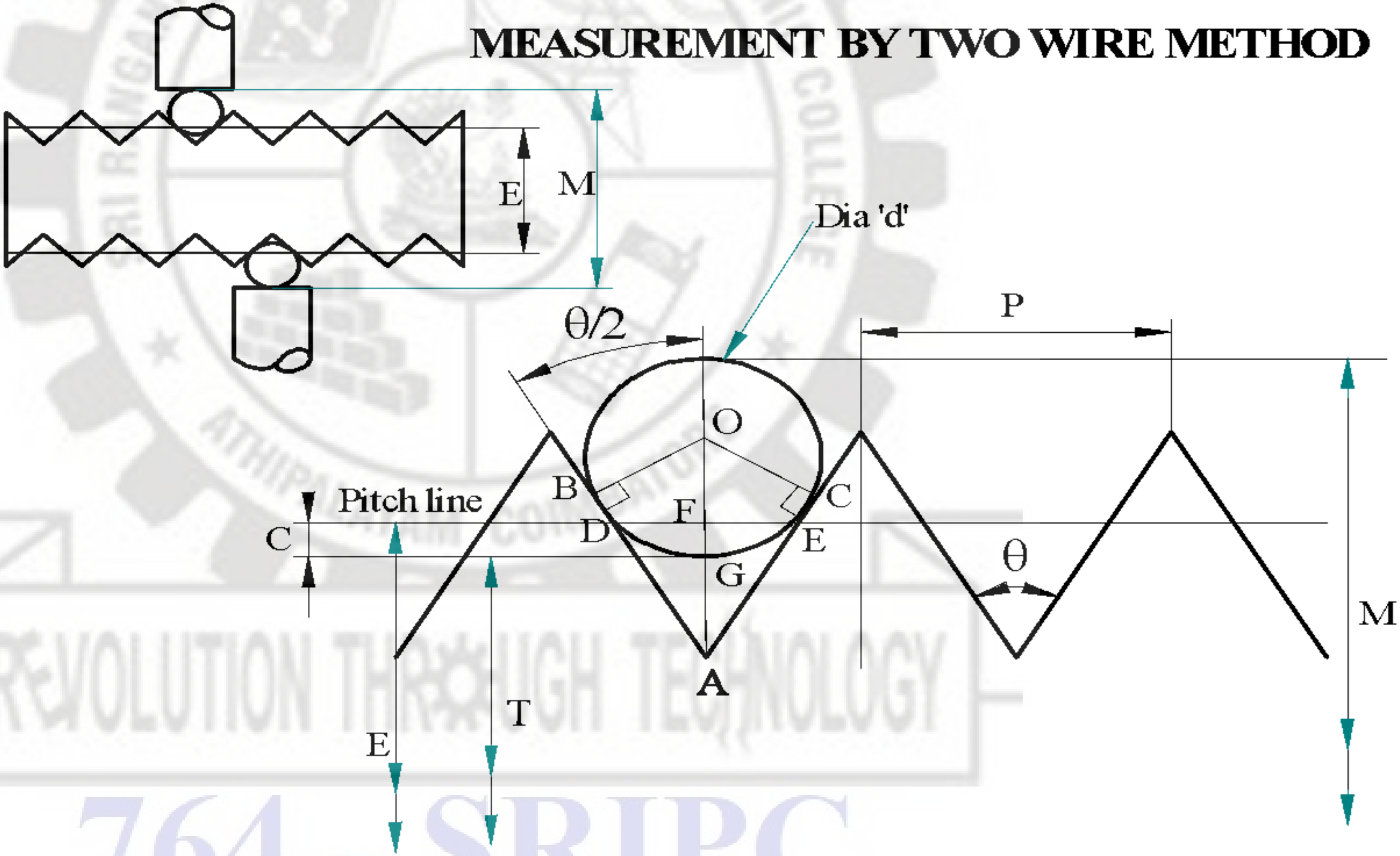
- For large thread diameter precision rollers are used. They are inserted in the internal thread of known diameter say d1 and d2.
- The gap between them is filled by slip gauges.
- Then the internal diameter of thread d, can be calculated as.

$$d = d1 + d2 + x$$

Where d1 and d2 is the roller diameter and x is the slip gauge distance

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Measurement of effective diameter by Two wire method



764 - SRIPC

Measurement of effective diameter using two wire method

- The effective diameter can not be measured directly but can be calculated from the measurements made.
- Wires of exactly known diameters are chosen such that they contact the flanks at their straight portions.
- If the size of the wire is such it contacts the flanks at the pitch line, it is called the 'best size' of wire which can be determined by geometry of screw thread.
- The screw thread is mounted between the centers & wires are placed in the grooves and reading M is taken.
- Then the effective diameter E =T+C

  where T =M-2d, & C is a value which depends on diameter of wire, pitch & angle of the screw thread.

764 - SRIPC

Measurement of effective diameter using two wire method

From the triangle OAB, $OA = OB.\text{cosec}\frac{\theta}{2} = \frac{d}{2}.\cos ec\frac{\theta}{2}$

$$AG = (OA - OG) = \frac{d}{2}\left(\cos ec\frac{\theta}{2} - 1\right) \qquad \left[\because OG = OB = \frac{d}{2}\right]$$

In the triangle AFD, $AF = DF.\cot\frac{\theta}{2}$. But $DF = \frac{P}{4}$

and $FG = (AF - AG) = \frac{P}{4}.\cot\frac{\theta}{2} - \frac{d}{2}\left(\cos ec\frac{\theta}{2} - 1\right)$

Effective diameter $E = T + (2\times C)$ where $C = 2\times FG$

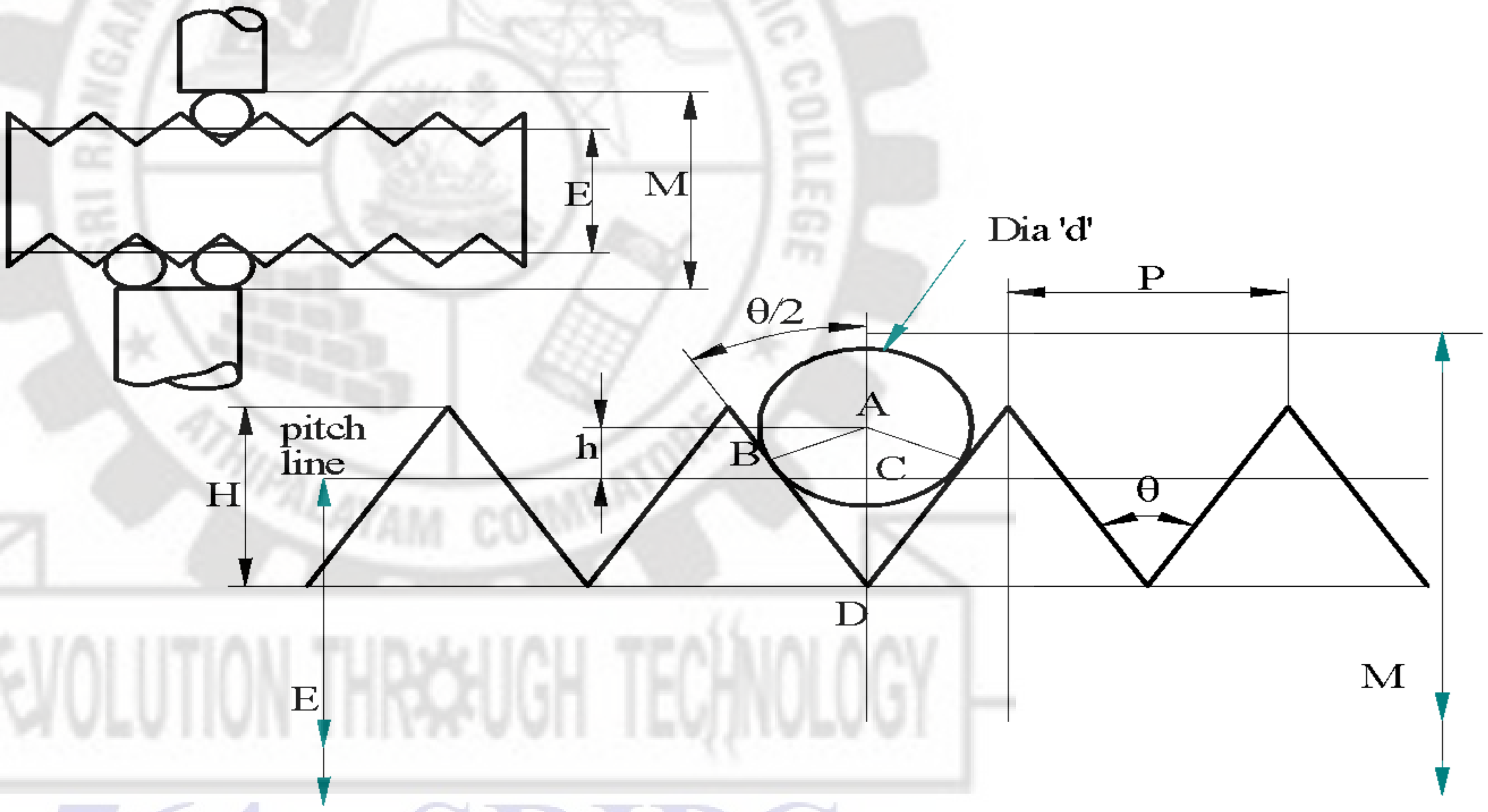
$$\therefore \text{Effective diameter } E = T + (2\times FG) = T + 2\left\{\frac{P}{4}.\cot\frac{\theta}{2} - \frac{d}{2}\left(\cos ec\frac{\theta}{2} - 1\right)\right\}$$

$$\therefore E = T + 2\left\{\frac{P}{2}.\cot\frac{\theta}{2} - d\left(\cos ec\frac{\theta}{2} - 1\right)\right\}$$

For whitworth thread, $\theta = 55^\circ \therefore C = 0.9605P - 1.1657d$

For metric thread $\theta = 60^\circ \therefore C = 0.866P - d$

Effective diameter by three wire method



764 - SRIPC

Effective diameter by three wire method

- This method is more accurate than two wire method as it ensures alignment of micrometer faces parallel to the thread axis.
- Here, three wires of exactly known diameters are used, one on one side & the two on the other side. The wires may be held in hand or hung from a stand.
- From the fig, M=diameter over the wires

  E= effective diameter (to be found)

  d= diameter of wires, h=height of wire center above the pitch line, r=radius of wire, H=depth of thread, D=major diameter of the thread.

764 - SRIPC

Effective diameter by three wire method

$$\textit{From the} \ \text{triangle ABD, AD} = \text{AB cosec}\frac{\theta}{2} = \frac{d}{2}\text{cosec}\frac{\theta}{2}$$

$$H = DE\cot\frac{\theta}{2} = \frac{P}{2}\cot\frac{\theta}{2} \quad \text{and CD} = \frac{\text{H}}{2} = \frac{P}{4}\cot\frac{\theta}{2}$$

$$\textit{Further} \ h = (AD - CD) = \left[\frac{d}{2}\text{cosec}\frac{\theta}{2}\right] - \left[\frac{P}{4}\cot\frac{\theta}{2}\right]$$

$$\text{Distance over the wires, M} = \text{E} + 2\text{h} + 2\text{r}$$

$$\text{i.e. M} = \text{E} + 2\left\{\text{rcosec}\frac{\theta}{2} - \frac{P}{4}\cot\frac{\theta}{2}\right\} + 2r = E + 2r\left\{1 + \text{cosec}\frac{\theta}{2}\right\} - \frac{P}{2}\cot\frac{\theta}{2}$$

$$\text{Or M} = \text{E} + \text{d}\left\{1 + \text{cosec}\frac{\theta}{2}\right\} - \frac{P}{2}\cot\frac{\theta}{2}$$

764 - SRIPC

$$\text{For Whitworth thread, } \theta = 55^\circ \text{, depth of thread} = 0.64P$$

$$\therefore E = D - 0.64P,\ \operatorname{cosec}\frac{\theta}{2} = 2.1657, \text{ and } \cot\frac{\theta}{2} = 1.921$$

$$M = D + 3.1657d - 1.605P \text{ where D is the major diameter of the thread.}$$

$$\text{For Metric threads, Depth of thread} = 0.6495P$$

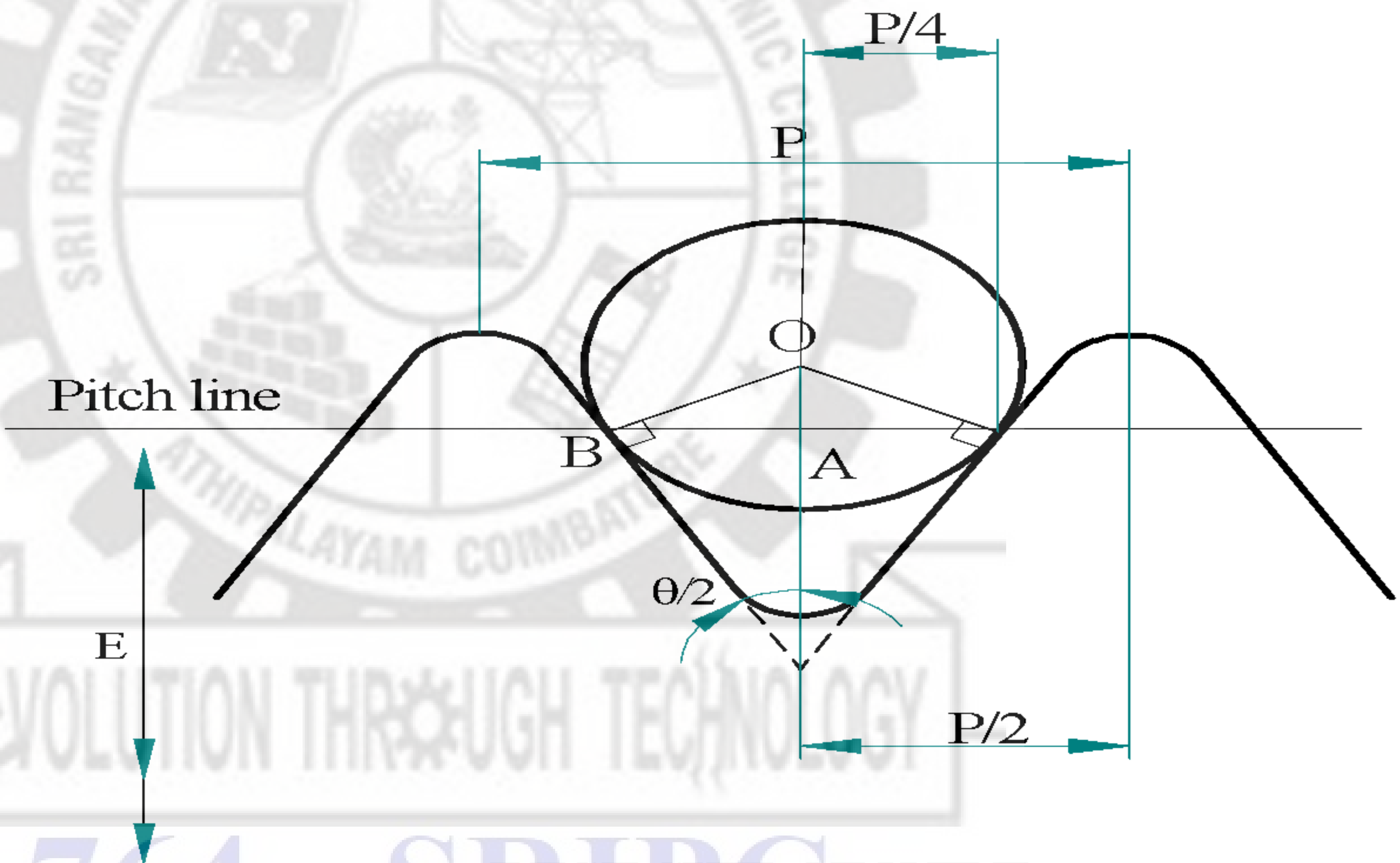
$$\therefore E = D - 0.6495P,\ \theta = 60^\circ,\ \operatorname{cosec}\frac{\theta}{2} = 2,\ \cot\frac{\theta}{2} = 1.732$$

$$\therefore M = D + 3d - 1.5155P$$

We can measure the value of M practically & then compare with the theoretical values using formulae derived above.

After finding the correct value of M, as d is known, E can be found out.

Expression for Best size Wire



BEST SIZE OF WIRE

764 - SRIPC

Expression for Best size Wire

The best size wire is the one which makes contact at the pitch line or effective diameter of the screw thread. In other words, as shown in fig OB is perpendicular to flank portion of the thread at the pitch line.

In the triangle OAB, $\sin\left(B\hat{O}A\right) = \frac{AB}{OB}$, or $\sin\left(90 - \frac{\theta}{2}\right) = \frac{AB}{OB}$

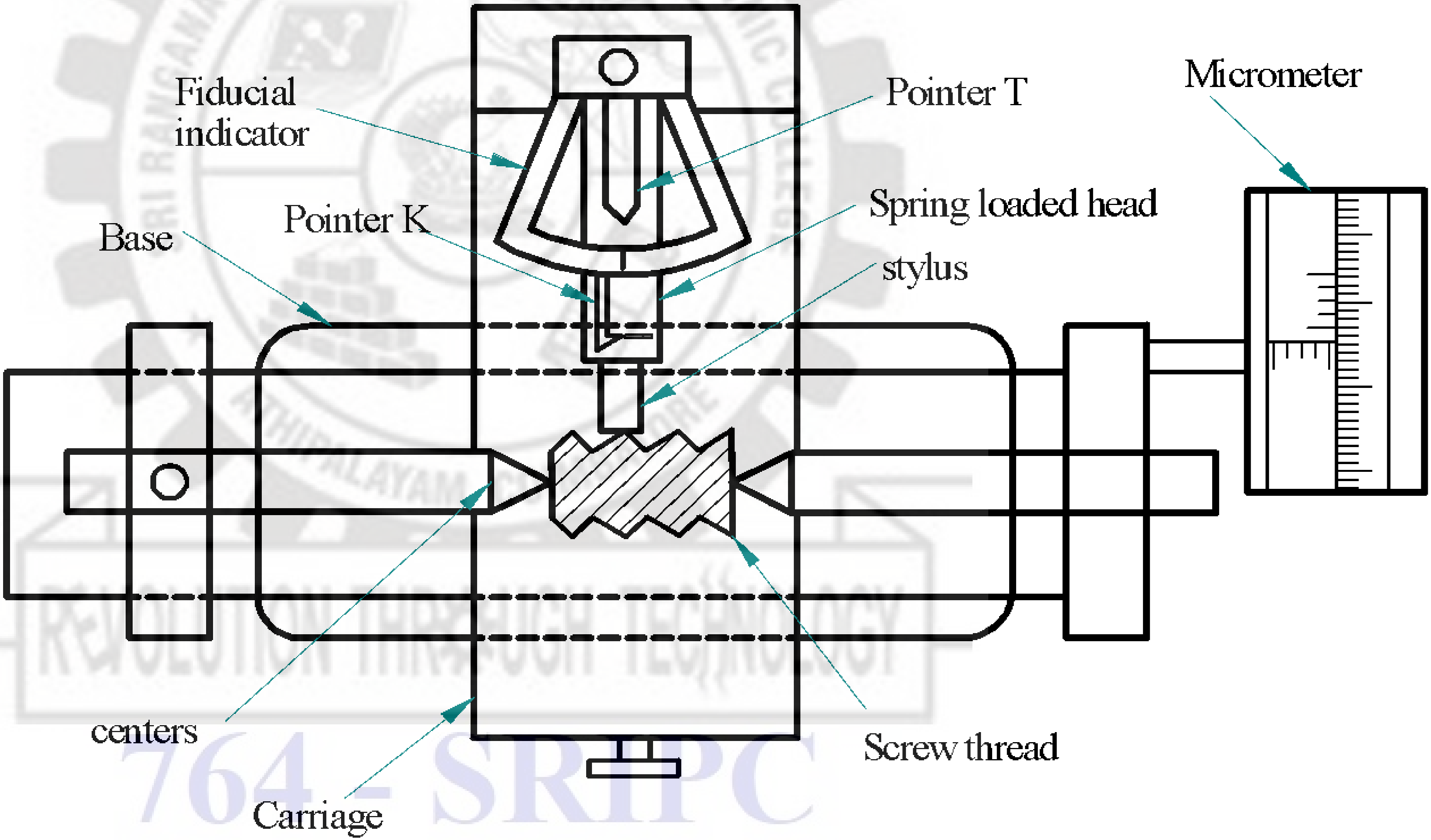
$$\therefore OB = \frac{AB}{\sin\left(90 - \frac{\theta}{2}\right)} = \frac{AB}{\cos\frac{\theta}{2}} = AB\sec\frac{\theta}{2}.$$

But $OB = \text{radius of wire} = \frac{1}{2} \times \text{dia of best size wire } (D_b)$

i.e. $D_b = 2 \times OB = 2 \times AB\sec\frac{\theta}{2}$. Also since AB lies on the pitch line, $AB = \frac{P}{4}$ where P is the pitch of the thread.

$$\therefore D_b = 2\frac{P}{4}\sec\frac{\theta}{2} = \frac{P}{2}\sec\frac{\theta}{2}$$

Pitch Measuring machine



764 - SRIPC

Pitch Measuring machine

- For measuring pitch, two methods are commonly employed as follows;

  (a) Using pitch measuring machine

  (b) Using Toolmaker's microscope
- In a pitch measuring machine, the screw thread is mounted between the centers of the machine. A stylus inserted into a spring loaded head makes contact at the thread flanks near the pitch line.
- The spring loaded head permits the stylus to move up the flank of the thread & down into the next space as it is moved parallel to the axis.
- Accurate positioning of the stylus between the two flanks is ensured by keeping the pointer T is always opposite to its index mark while taking readings.

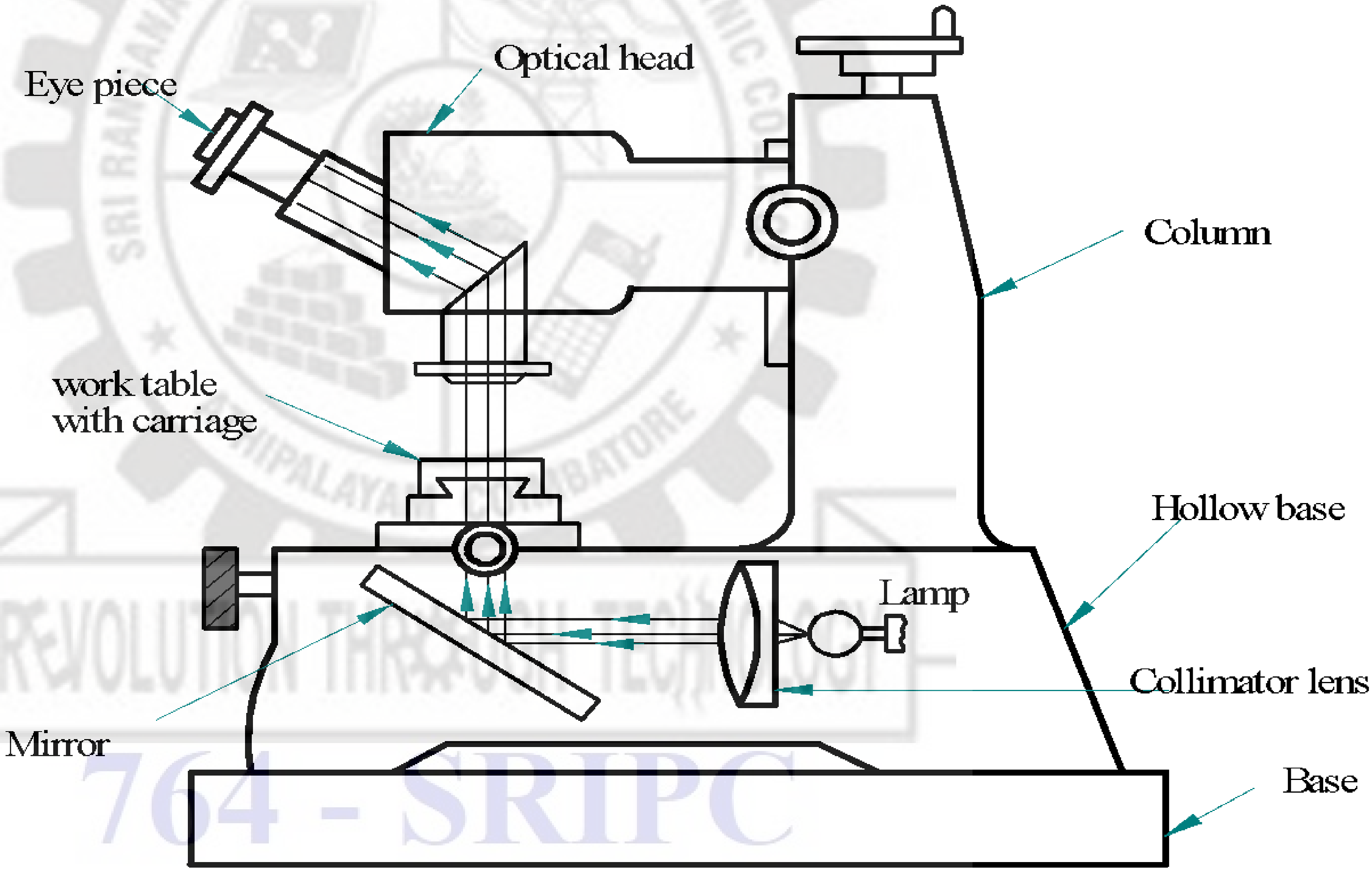
764 - SRIPC

Pitch Measuring machine

- With the micrometer reading zero on the scale, the indicator is moved along to bring the stylus opposite to the first thread space and is clamped in position.
- The indicator is then adjusted radially until the stylus engages between the thread flanks and the pointer K is opposite to the line mark.
- When the pointer is accurately in position, the micrometer reading is noted.
- The stylus is then moved along into the next thread space, by rotation of micrometer and a second reading is taken.
- The difference between the two readings gives the pitch of the thread.

PROGRESS THROUGH KNOWLEDGE
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Toolmaker's microscope



764 - SRIPC

Toolmaker's microscope

- Toolmaker's microscope is based on the principle of optics. It consists of a heavy hollow base accommodating the illuminating unit.
- On the top surface of the base, the work table carriage is supported and its movement is controlled by micrometer screws.
- The column carries the microscope unit & various interchangeable eye pieces.
- Light from the lamp is collimated and reflected as parallel beam by the mirror.
- On its way up this beam collects the image of the object to be inspected and this enters the microscope's eyepiece.
- A shadow image of the part passes through the objective of the optical head and is projected to a glass screen.

764 - SRIPC

Toolmaker's microscope

- Cross lines are engraved on the ground glass screen which can be rotated through 360º and measurements are made by these cross lines.
- Different types of graduated screens and engraved screens are used for measuring different elements. For ex, a revolving screen for measurement of screw threads will contain all the basic profiles standard threads in various pitch ranges & included angles.
- Screw thread parameters such as pitch, flank angle, depth of thread, etc. may be measured by matching the projected image of the thread with the master profile obtained from a standard thread.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

TOOLMAKER'S MICROSCOPE

764 - SRIPC

TOOLMAKER'S MICROSCOPE

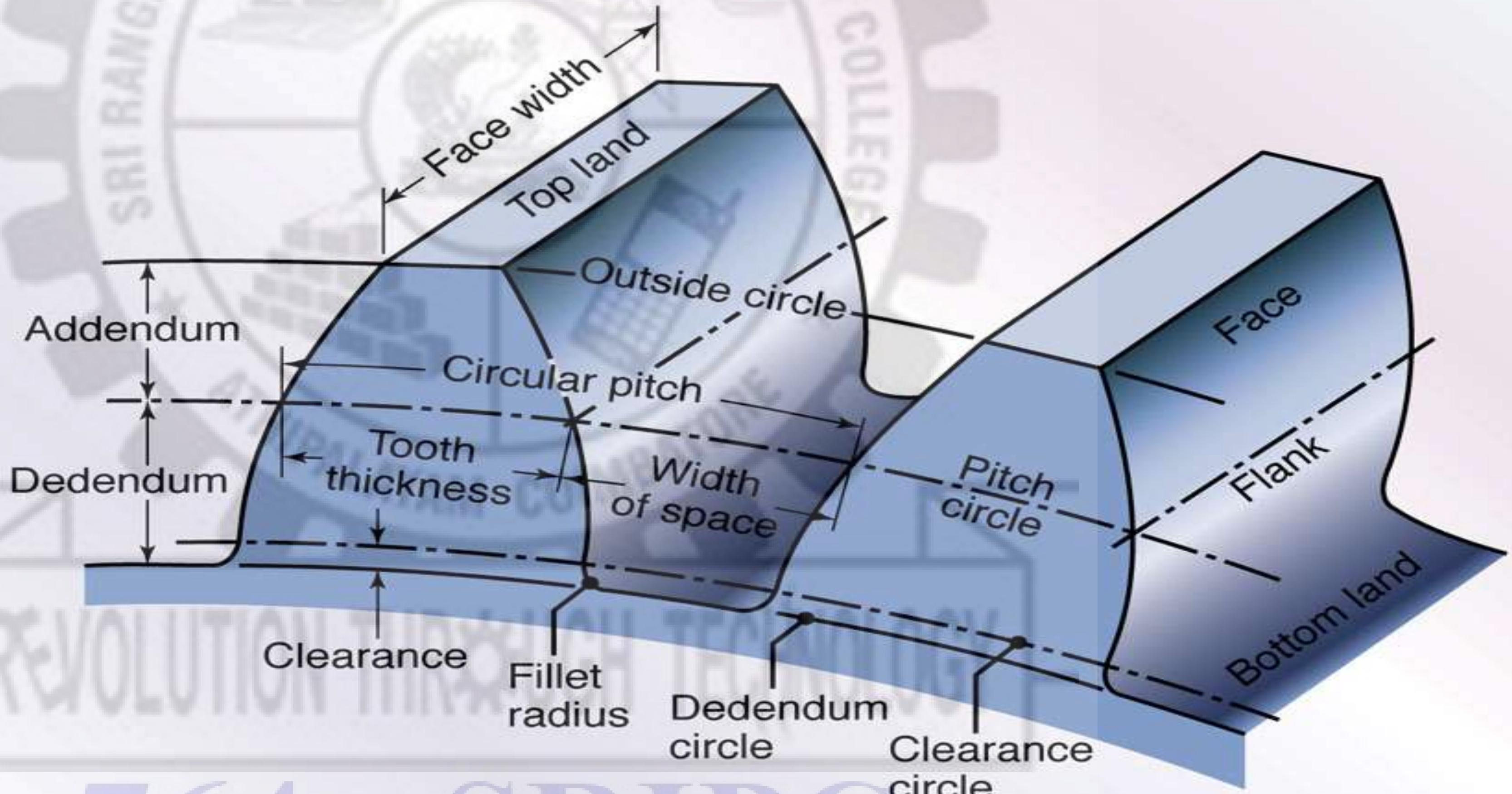
764 - SRIPC

Gear tooth measurement

- Gears are mainly used for transmission of motion & power and must be of accurate profile to obtain exact velocity ratio.
- Two commonly used profiles of gear teeth are the *Involute profile* & the *Cycloidal profile*
- Involute is defined as the path described by a point on an inextensible cord which is unwound from a stationary cylinder.
- Cycloid is defined as the curve traced by a point on the rim of a circle which rolls without slipping on a fixed straight line.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

GEAR TOOTH NOMENCLATURE



764 - SRIPC

GEAR TOOTH NOMENCLATURE

- *Base circle*: It is the circle from which gear teeth profiles are generated.
- *Pitch circle:* It is an imaginary circle which by pure rolling action, would produce the same motion as the toothed wheel. The size of the gear is usually specified by the pitch circle diameter.
- *Pitch point*: It is a common point of contact between two pitch circles of two meshing gear wheels.
- *Pressure angle*: It is the angle between the common normal to two gear teeth at the point of contact and the common tangent at the pitch point.

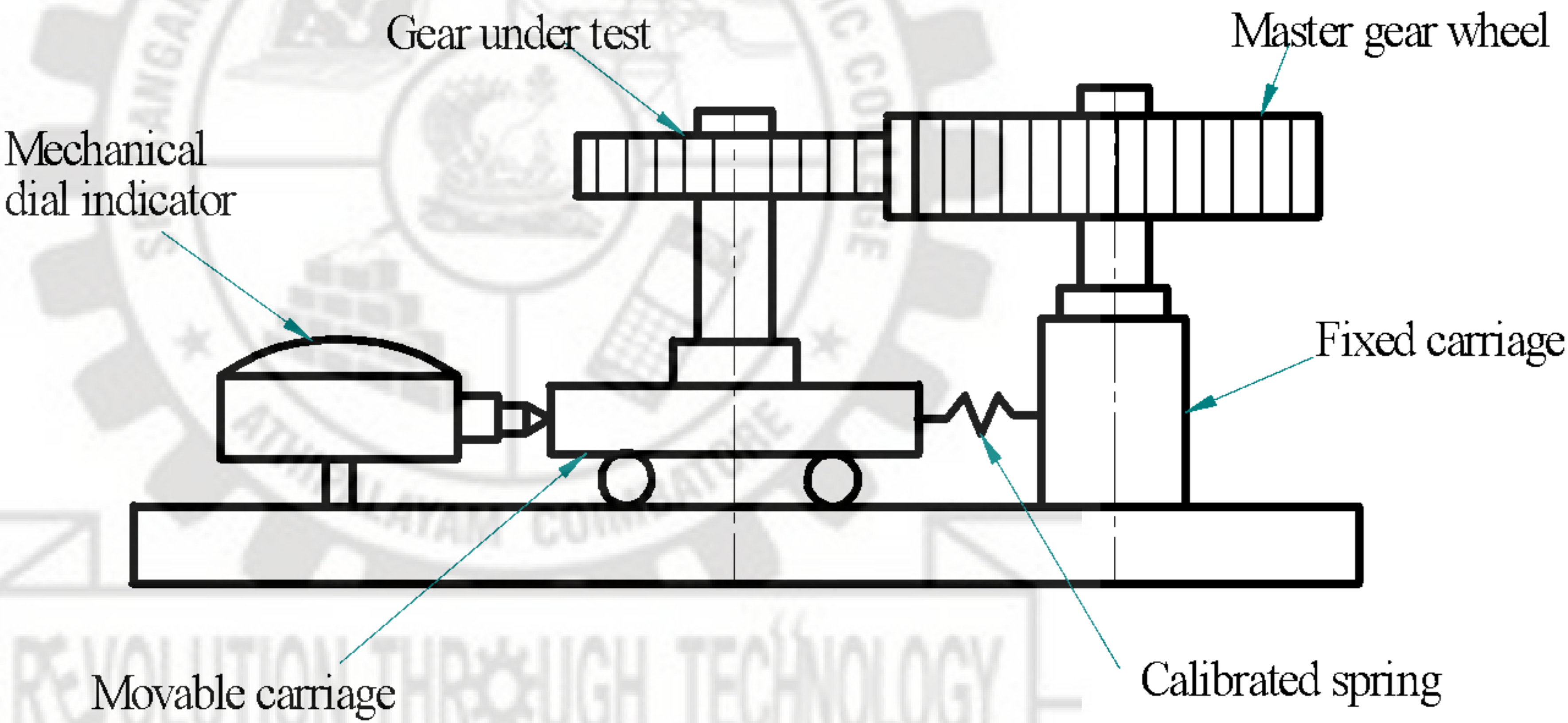
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

GEAR TOOTH NOMENCLATURE

- *Addendum:* It is the radial distance from the pitch circle to the tip of the tooth.
- *Dedendum:* It is the radial distance from the pitch circle to the root of the tooth.
- *Face :* It is the part of the tooth surface which is above the pitch surface.
- *Flank :* It is the part of the tooth surface which is below the pitch surface.
- *Circular pitch :* It is the distance measured on the circumference of the pitch circle from a point on one tooth to the corresponding point on the adjacent tooth.
- *Module:* It is the ratio of the pitch circle diameter in millimeters to the number of teeth.
- *Face width:* It is the width of the gear tooth measured parallel to its axis.

764 - SRIPC

Checking of composite error (Rolling gear test)



PARKINSON GEAR TESTER

764 - SRIPC

Rolling gear Test

- This test is commonly used in mass production of gear wheels as it takes less time & gives accurate results.
- The composite errors can be checked by measuring the variations of center distance when the gear to be tested is rotated under spring pressure against a master gear.
- This test reveals any errors in the tooth form, pitch and concentricity of the pitch circle as these errors will cause variation of center distance.
- Two carriages are one fixed and the other movable are mounted on the base. The movable carriage is spring loaded towards the fixed carriage.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Parkinson gear tester

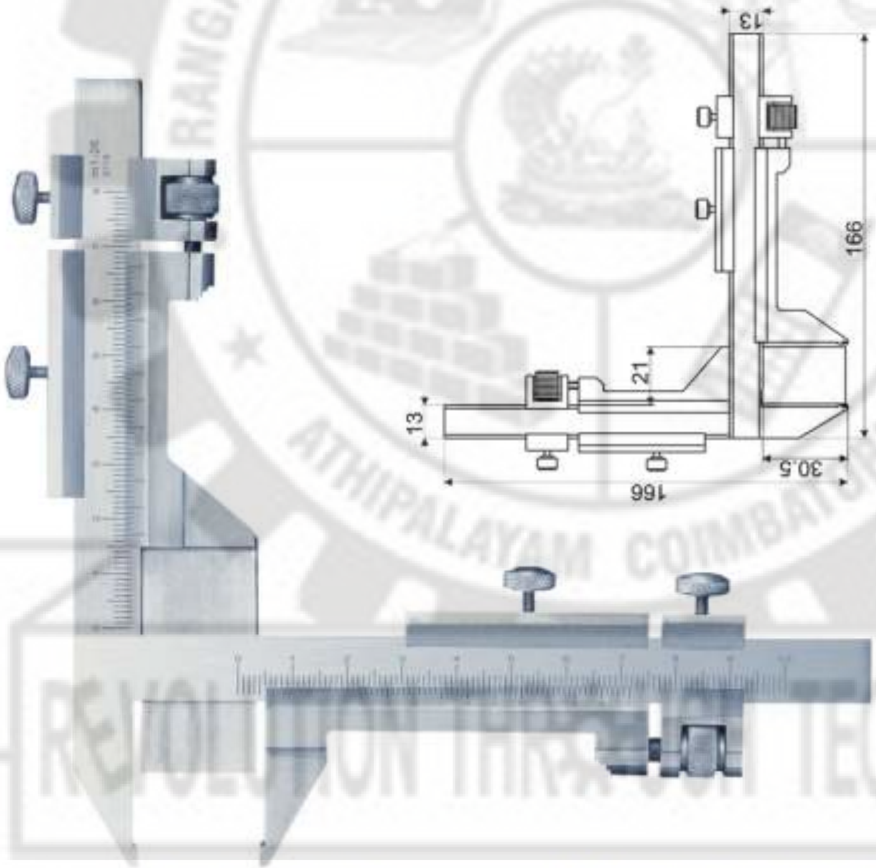
- Two spindles are mounted in a parallel plane on each carriage and are made to suit the bore of the gear wheels.
- A dial gauge is made to rest against the movable carriage.
- The master gear is mounted on the fixed carriage spindle while the gear to be tested is mounted on the movable carriage.
- The dial gauge is then adjusted to zero & the two gears in mesh are rotated by hand and the variations in the dial gauge readings are observed.

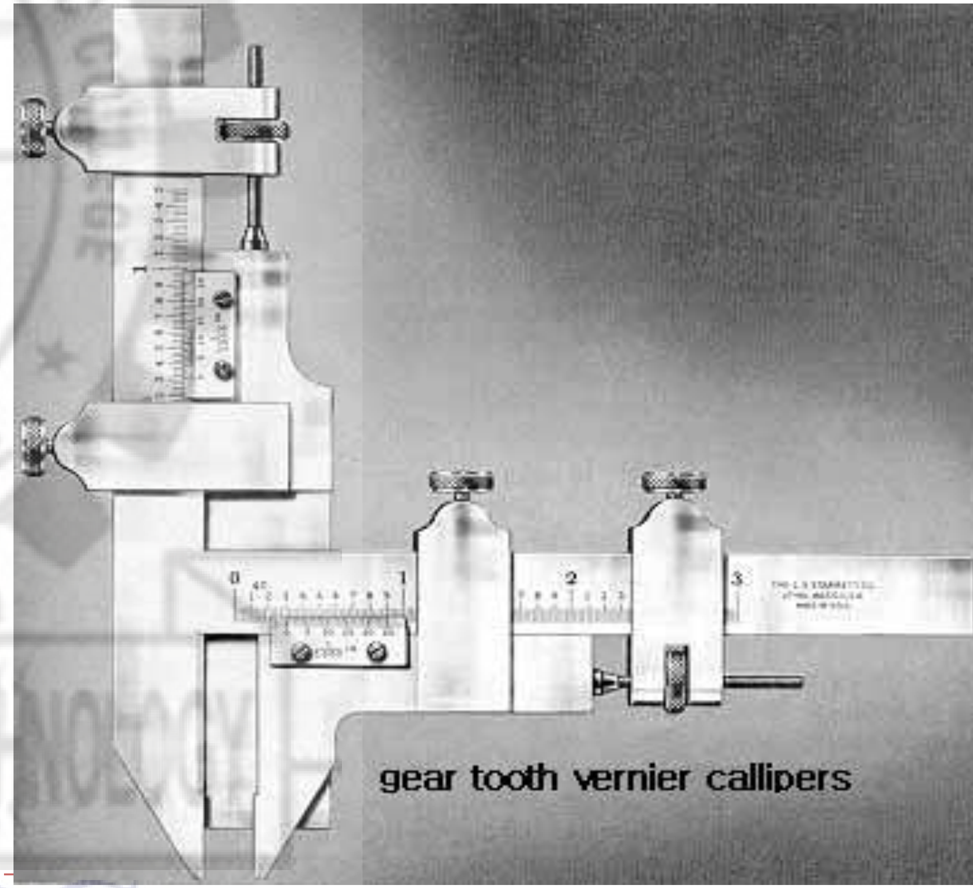
REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

GEAR TESTER

764 - SRIPC

GEAR TOOTH VERNIER CALIPER





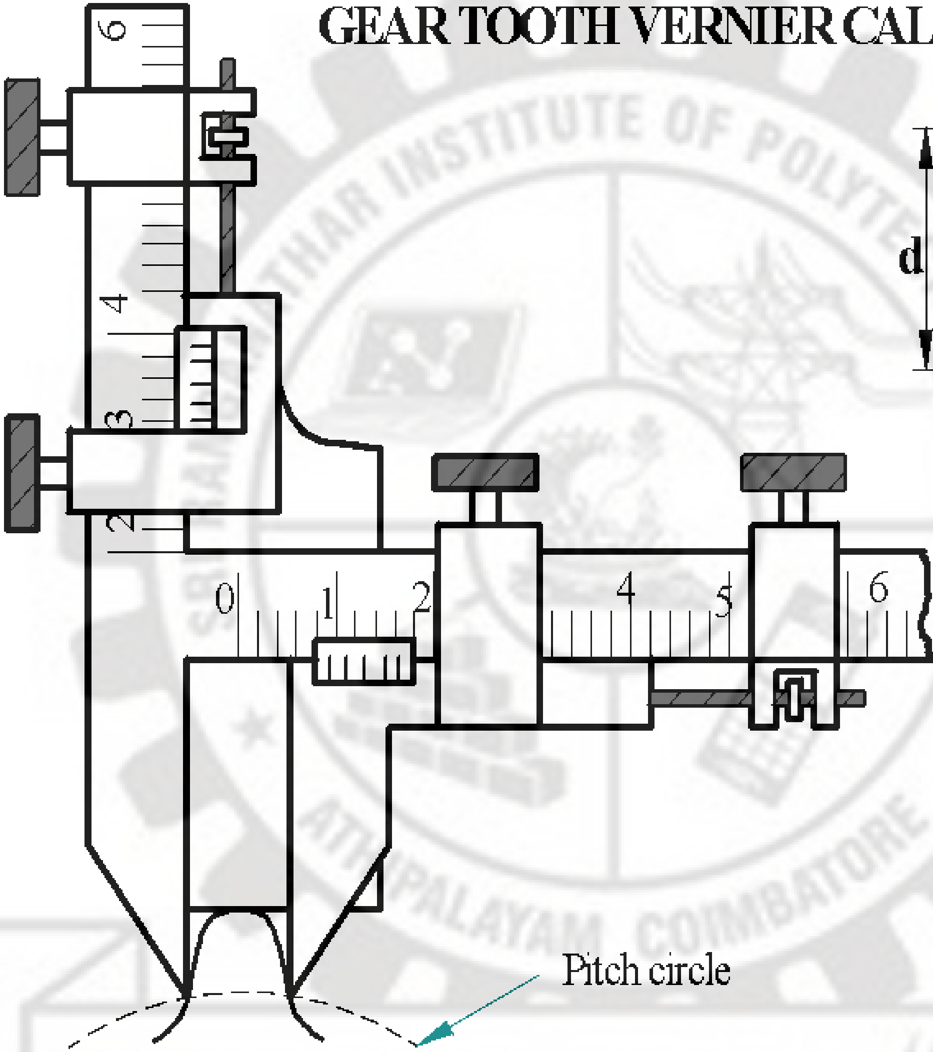
764 - SRIPC

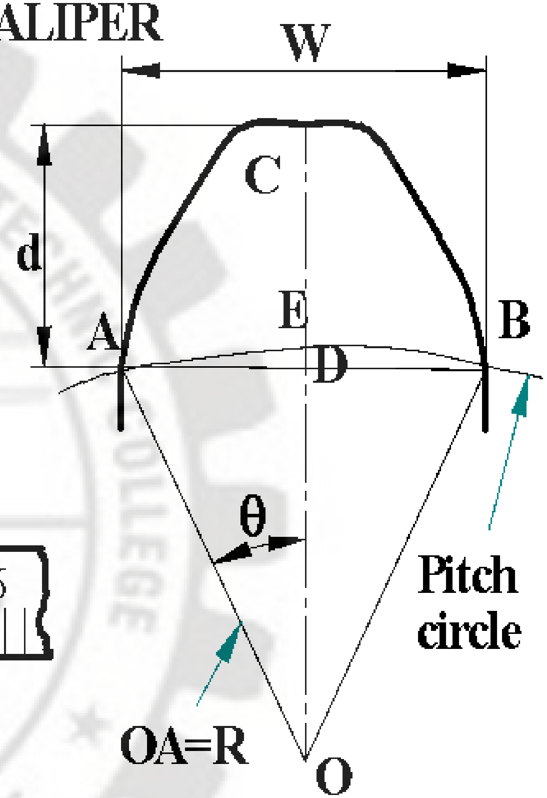
GEAR TOOTH VERNIER CALIPER

- The gear tooth thickness can be conveniently measured by a gear tooth vernier.
- Since the gear tooth thickness varies from the tip to the base circle of the tooth, the instrument must be capable of measuring the tooth thickness at a specified position on the tooth.
- The caliper has two vernier scales, the vertical vernier is used to set the depth (d) along the pitch circle from the top surface of the tooth at which width (w) has to be measured.
- The horizontal vernier scale is used to measure the width (w) of the teeth.

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

GEAR TOOTH VERNIER CALIPER





REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

GEAR TOOTH VERNIER CALIPER

- Considering one tooth, the theoretical values of *w* & *d* can be found which may be verified by the instrument.
- The fig shows the chord *ADB* which is width *w* but tooth thickness is arc distance *AEB.*
- Also the depth *d* adjusted on the instrument is slightly greater than the addendum *CE*, & hence the width *w* is called chordal thickness & *d* is called chordal addendum.

764 - SRIPC

From the fig, $w = AB = 2AD$. Also $\theta = \frac{360}{4N}$ where N is the number of teeth

In the triangle ADO, $w = 2AD = 2 \times AO\sin\theta = 2R\sin\frac{360}{4N}$

where R = pitch circle radius.

$$\text{Module } m = \frac{\text{Pitch circle dia}}{\text{No of teeth}} = \frac{2R}{N} \Rightarrow R = \frac{N \times m}{2}$$

$\therefore w = N \times m \sin\left(\frac{90}{N}\right)$. Also from the fig $d = (OC - OD)$

Addendum is equal to one module, $\Rightarrow OC = OE + CE = (R + m) = \frac{Nm}{2} + m$

Also $OD = R\cos\theta = \frac{Nm}{2}\cos\left(\frac{90}{N}\right) \Rightarrow d = \frac{Nm}{2} + m - \frac{Nm}{2}\cos\left(\frac{90}{N}\right)$

$$d = \frac{Nm}{2}\left[1 + \frac{2}{N} - \cos\left(\frac{90}{N}\right)\right]$$

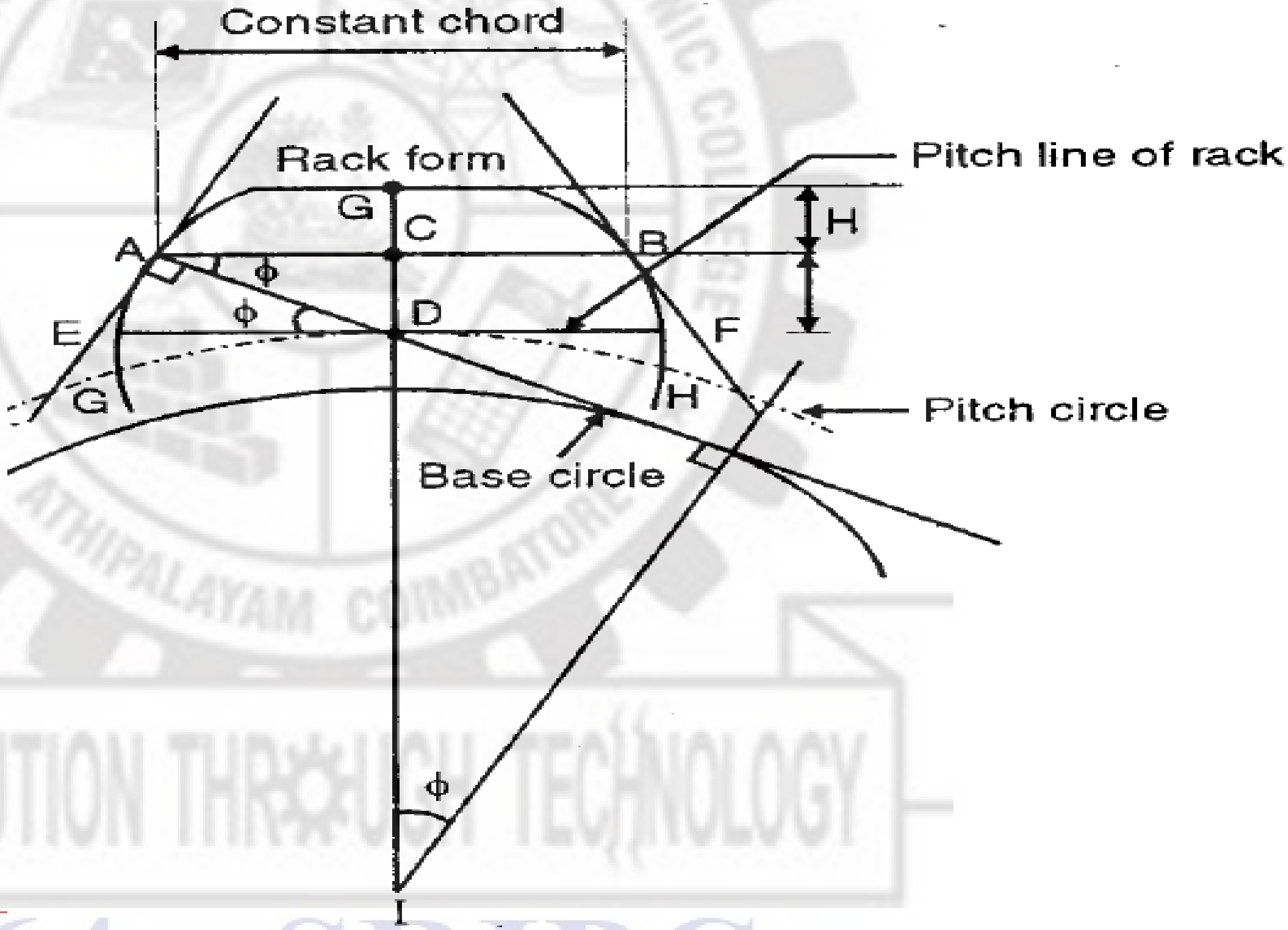
764 SRIPC

Constant Chord Method

- A constant chord is defined as, the chord, joining those points, on opposite faces of the tooth, which make contact with the mating teeth, when the center line of the tooth lies on the line of the gear centers.
- As the number of teeth varies in the gear tooth vernier Caliper method the value of tooth thickness wand the depth d can be changed.
- Constant chord of a gear is measured, where the tooth flanks, touch the flanks of the basic rack.
- The teeth of the rack are straight and inclined to their center lines at the pressure angle .
- When gear rotates and all teeth come in contact with the rack then for the given size of tooth, the contact always takes place at point A and B. i.e. distance AS remains constant and hence called as constant chord.

764 - SRIPC

Constant Chord Method



764 - SRIPC

Calculation

Derivation for calculating the chord length AB :

From the Fig. 3.16, $l\,(DE) = l\,(DF) = \text{Arc } DG$

and $\text{Arc } DG = \frac{1}{4} \times \text{circular pitch} = \frac{1}{4} \times \pi m$

$\therefore \; l\,(DE) = l\,(DF) = \frac{1}{4} \times \pi m$

Consider Δ DAE $\angle$ ADE = ϕ

$$\therefore \cos\phi = \frac{AD}{DE}$$

$$\therefore AD = DE \cos\phi$$

$$AD = \frac{1}{4} \times \pi m \cos\phi \qquad [\because \text{from Equation (i)}] \qquad \ldots(ii)$$

REVOLUTION THROUGH TECHNOLOGY
764 - SRIPC

Consider Δ DCA, $\angle$ CAD = ϕ

$$\therefore \quad \cos\phi = \frac{CA}{AD}$$

$$CA = AD \cos\phi$$

$$CA = \frac{1}{4}\pi m \cos\phi \cdot \cos\phi \qquad [\because \text{ from Equation (ii)}]$$

$$\therefore \quad CA = \frac{\cos^2\phi \cdot \pi m}{4}$$

From the Fig. 3.16,

$$\text{Chord length} \quad AB = 2 \times l\,(CA) = 2 \times \frac{\cos^2\phi \cdot \pi m}{4}$$

$$\boxed{\text{Chord length} = \frac{\pi m \cos^2\phi}{2}}$$

The depth h can be calculated as follow,

$$\text{From } \Delta \text{ DAC,} \quad \sin\phi = \frac{CD}{AD}$$

$$\therefore \quad CD = AD \cdot \sin\phi$$

$$= \frac{1}{4} \times \pi m \cdot \cos\phi \cdot \sin\phi \qquad [\because \text{ from Equation (ii)}] \quad \ldots\text{(iii)}$$

$$GD = GC + CD$$

$$\text{where} \quad GD = \text{addendum} = \text{module} \qquad (\because \text{ for metric gear})$$

$$\therefore \quad GD = m$$

$$\text{and} \quad CD = \frac{1}{4}\pi m \cos\phi \cdot \sin\phi \qquad [\because \text{ from Equation (iii)}]$$

$$\text{and} \quad GC = \text{depth} = h$$

$$\therefore \quad m = h + \frac{1}{4}\pi m \cos\phi \cdot \sin\phi$$

$$\therefore \quad h = m - \frac{1}{4}\pi m \cos\phi \cdot \sin\phi$$

$$\boxed{\therefore \text{ Depth } h = m\left[1 - \frac{1}{4}\pi \cos\phi \cdot \sin\phi\right]}$$

764 - SRIPC

Base Tangent Method

764 - SRIPC

Base Tangent Method

- It is the most commonly used method for checking the tooth thickness of gear.
- The advantage of this method is that, it depends only on one vernier reading unlike gear tooth vernier Caliper where we require two vernier readings.
- The base tangent length is the distance between the two parallel planes which are tangential to the opposing tooth flanks.
- PQ is the base tangent. The number of teeth over which the measurement is to be made for a particular gear is selected from the gear hand book

764 - SRIPC

Formulae in Base Tangent Method

- The base tangent length will consists of one base circular thickness of tooth and number of base pitches.
- Base tangent length = One base circular thickness + Number of base pitches
- Theoretically the base pitch is given by,

$$\text{Base pitch} = \pi m \cos\varphi$$

where φ is the pressure angle

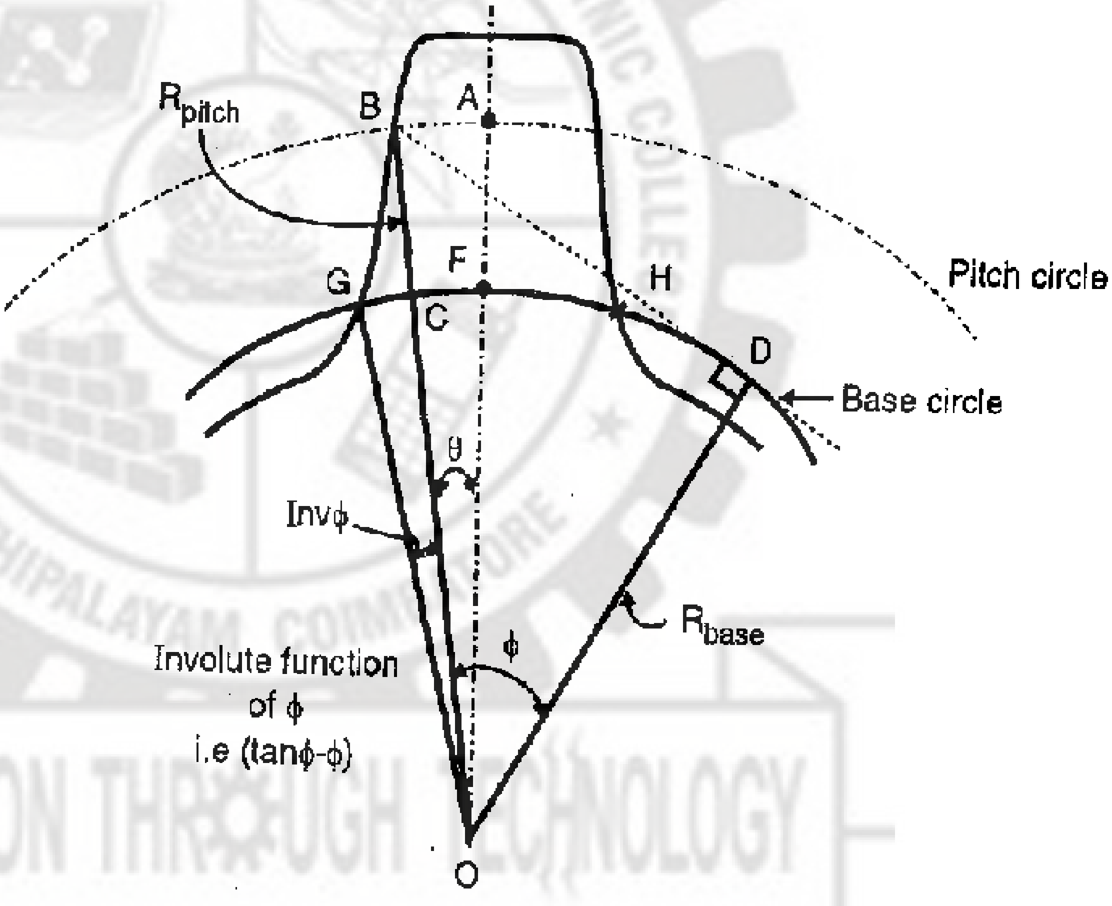
- If S is the number of tooth spaces contained in the base tangent length being measured then,

$$\text{Number of base pitches} = S \times \pi m \cos\varphi$$

- Base tangent length= Arc GH + Arc HI= Arc GH + S x $\pi m \cos\varphi$

764 - SRIPC

Base Tangent Method



764 - SRIPC

Calculation

The arc GH can be calculated as follows :

From the Fig. ,

$$\text{Arc GH} = 2 \times \text{Arc GF}$$

$$\text{Arc GH} = 2 \times (\text{Arc GC} + \text{Arc CF}) \quad \ldots(i)$$

As $\text{Arc} \dfrac{GC}{R_{base}}$ = Involute function of ϕ in radians $= \tan\phi - \phi$

$$\therefore \quad (\tan\phi - \phi) = \frac{\text{Arc GC}}{R_{base}}$$

$$\therefore \quad \text{Arc GC} = R_{base} \times (\tan\phi - \phi) \quad \ldots(ii)$$

As we know, $\cos\phi = \dfrac{OD}{OB} = \dfrac{D_{base}}{D_{pitch}} = \dfrac{R_{base}}{R_{pitch}}$

764 - SRIPC

$$\therefore \quad R_{base} = R_{pitch} \times \cos\phi = \frac{Nm}{2} \cos\phi$$

Substituting R_{base} in Equation (ii)

$$\therefore \quad \text{Arc GC} = \frac{Nm}{2} \cdot \cos\phi \cdot (\tan\phi - \phi)$$

$$\text{Now,} \quad \text{As Arc BA} = \frac{1}{4} \times \text{circular pitch} = \frac{1}{4} \times \pi m$$

764 - SRIPC

and from the Fig. , $\theta = \frac{\text{Arc BA}}{R_{pitch}}$

$$\theta = \frac{\frac{1}{4}\pi m}{\frac{Nm}{2}} = \frac{1}{4}\pi m \times \frac{2}{N m}$$

$$\theta = \frac{\pi}{2N} \qquad \text{...(iv)}$$

Also from the Fig. , $\theta = \frac{\text{Arc CF}}{R_{base}}$

$$\therefore \text{Arc CF} = R_{base} \times \theta$$

$$= \frac{Nm}{2} \times \cos\phi \times \frac{\pi}{2N} \qquad \text{[from Equations (iii) and (iv)]}$$

Now, From Equation (i) $\text{Arc GH} = 2 \times [(\text{Arc GC} + \text{Arc CF})]$

$$= 2 \times \left[\left(\frac{Nm}{2} \cdot \cos\phi \cdot (\tan\phi - \phi) \right) + \left(\frac{Nm}{2} \cos\phi \times \frac{\pi}{2N} \right) \right]$$

$$= Nm \cos\phi \left[(\tan\phi - \phi) + \frac{\pi}{2N} \right]$$

Now Base tangent length $= \text{Arc GH} + S \times \pi m \cos\phi$

SRI RANGANATHAR INSTITUTE OF POLYTECHNIC COLLEGE ATHIPALAYAM COIMBATORE REVOLUTION THROUGH TECHNOLOGY 764 - SRIPC

$$= Nm\cos\phi\left[(\tan\phi - \phi) + \frac{\pi}{2N}\right] + S \times \pi\, m\cos\phi$$

$$\text{Base tangent length} = Nm\cos\phi\left[(\tan\phi - \phi) + \frac{\pi}{2N} + \frac{S\pi}{N}\right]$$

where N = Number of teeth

m = Module

ϕ = Pressure angle (radian)

S = Number of tooth spaces in base tangent length

764 - SRIPC