FACULTY OF MECHANICAL ENGINEERING

SKMM 1912 EXPERIMENTAL METHODS

UNIVERSITI TEKNOLOGI MALAYSIA

WHAT WILL BE DELIVERED?

Methods of measurement for:

- Linear dimensions
- Mass, weight, forces and torque
- Pressure
- Temperature

WHAT SHOULD STUDENT LEARN?

- concept
- design
- application
- limitation

of various apparatus for the measurement for linear dimensions, forces, pressure and temperature.

LINEAR DIMENSIONS

TOOLS TO MEASURE LINEAR DIMENSIONS

- Ruler
- Caliper
- Vernier calipers
- Screw gauges
- Dial gauges

LINEAR DIMENSIONS - RULERS

Normal - straight

Folding ruler

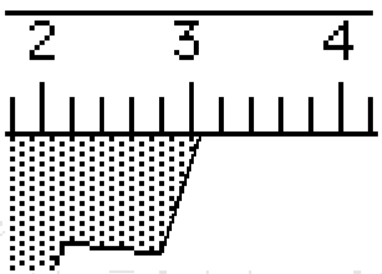
ACCURACY OF RULER

Estimating and Accuracy of Scale Divisions

When estimatimg, it is important that our estimation be as accurate as possible. However, no matter how well we can make the estimate, there is always some uncertainty introduced in our reading. There are two independant sources of this uncertainty. The first arises from the estimating process itself, while the second is due to the precision of the measuring device.

Estimating:

In the present case the simplest estimate is to assign a value half way along the interval. We could then report the reading as 3.1 +/- 0.1 units. This is based on the observation that the measurement is larger than 3.0 units, smaller than 3.2 units, together with the fact that adding or subtracting o.1 units would bring us to at least one of the nearby scale divisions.



Still we might do better than this. In the expanded view we can see that the edge of the figure only reaches about a third of the way beyond 3.0 units. So one third of the interval is 0.0666... units (which we round to 0.07 here), giving an estimate for w as w = 3.07 +/- .07 units. In this case adding or subtracting 0.07 units would bring us to a known scale division. You might argue that adding 0.03 units will bring us up to 3.1 units which we are confident is too large, so that an estimate of our uncertainty could be as small as 0.03 units. While this is true this small uncertainty would have to be viewed as the most optimistic report of our estimating process. A reasonable compromise could be found by reporting w to be w = 3.07 +/- 0.05 units.

LINEAR DIMENSIONS - CALIPERS

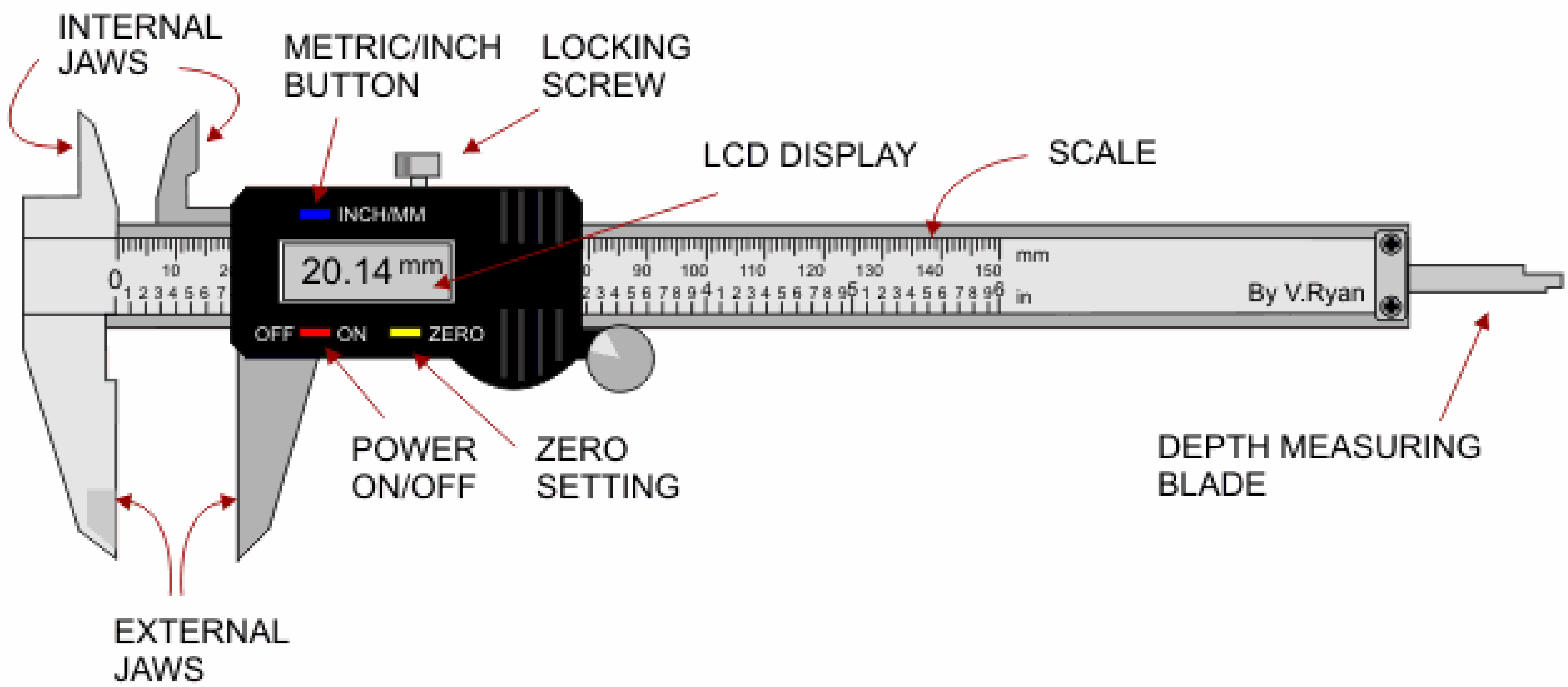
‘outside’ caliper

‘inside’ caliper

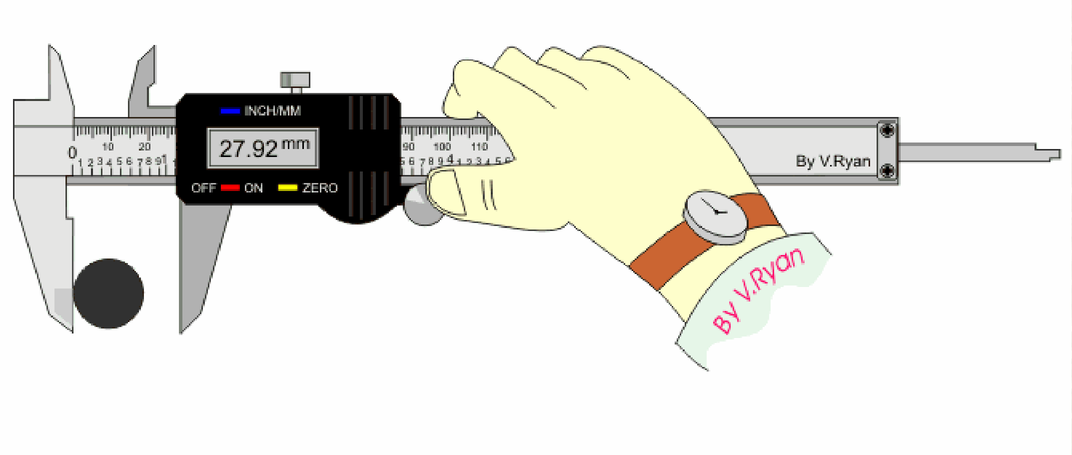
Used together with rulers

LINEAR DIMENSIONS - VERNIER CALIPERS

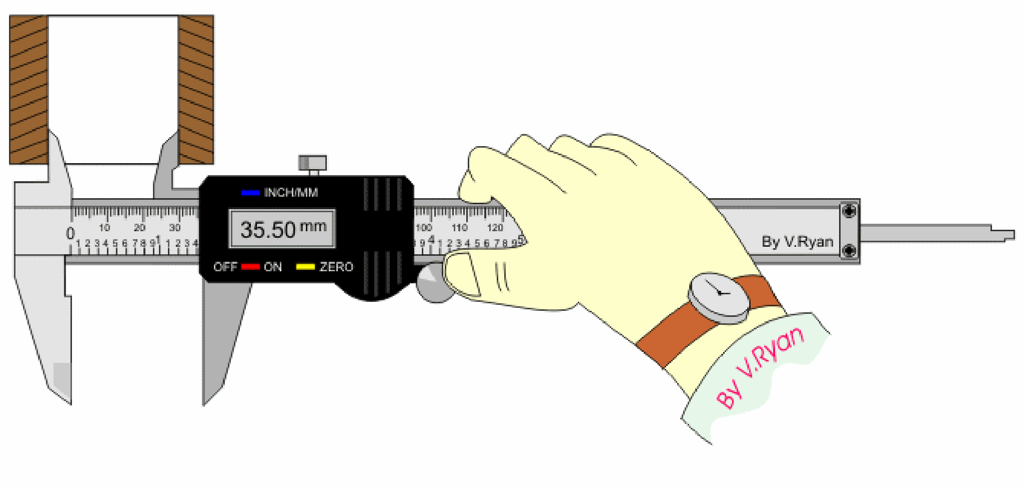
LINEAR DIMENSIONS – DIGITAL VERNIER CALIPERS



LINEAR DIMENSIONS – DIGITAL VERNIER CALIPERS

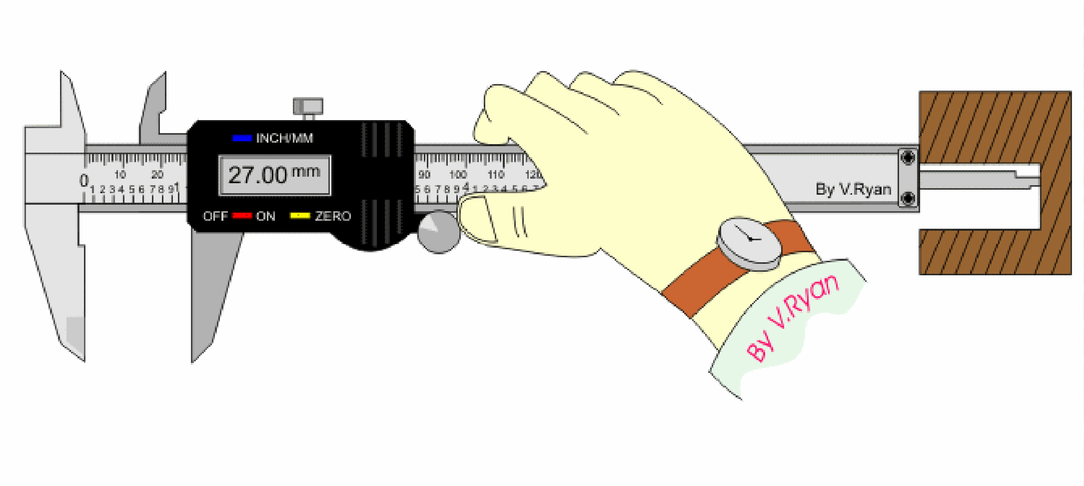


Measuring outside diameter



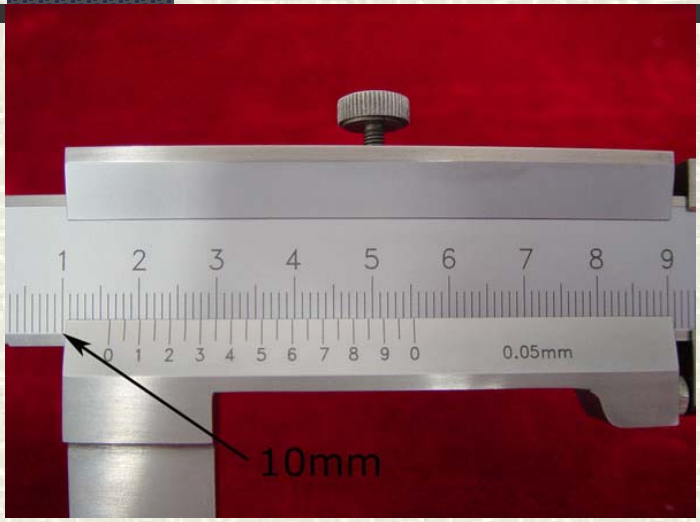
Measuring inside diameter

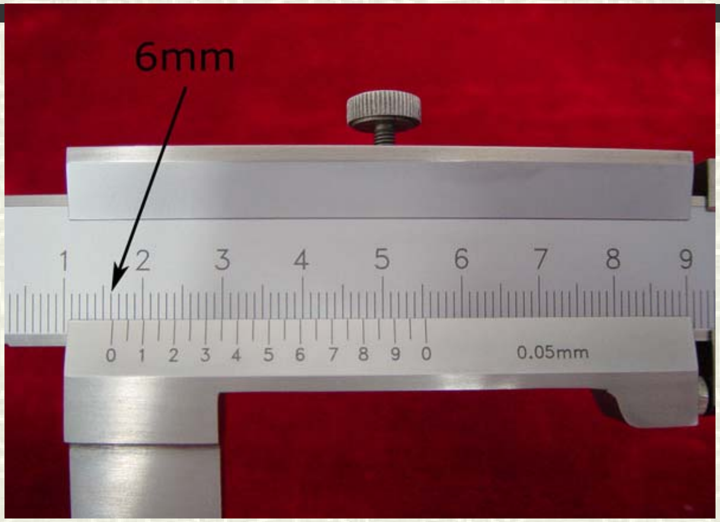
LINEAR DIMENSIONS – DIGITAL VERNIER CALIPERS

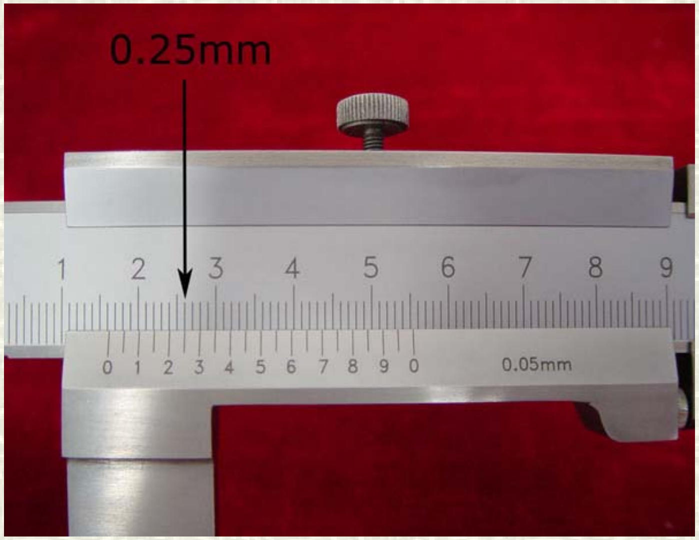


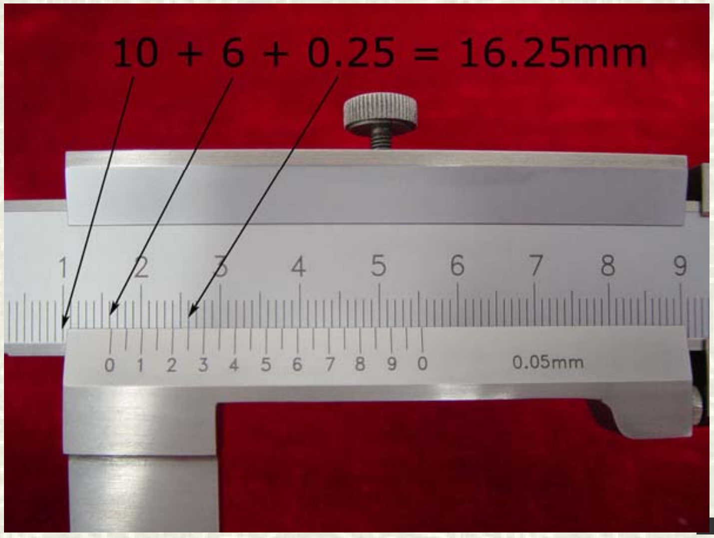
Measuring depth

LINEAR DIMENSIONS – DIGITAL VERNIER CALIPERS







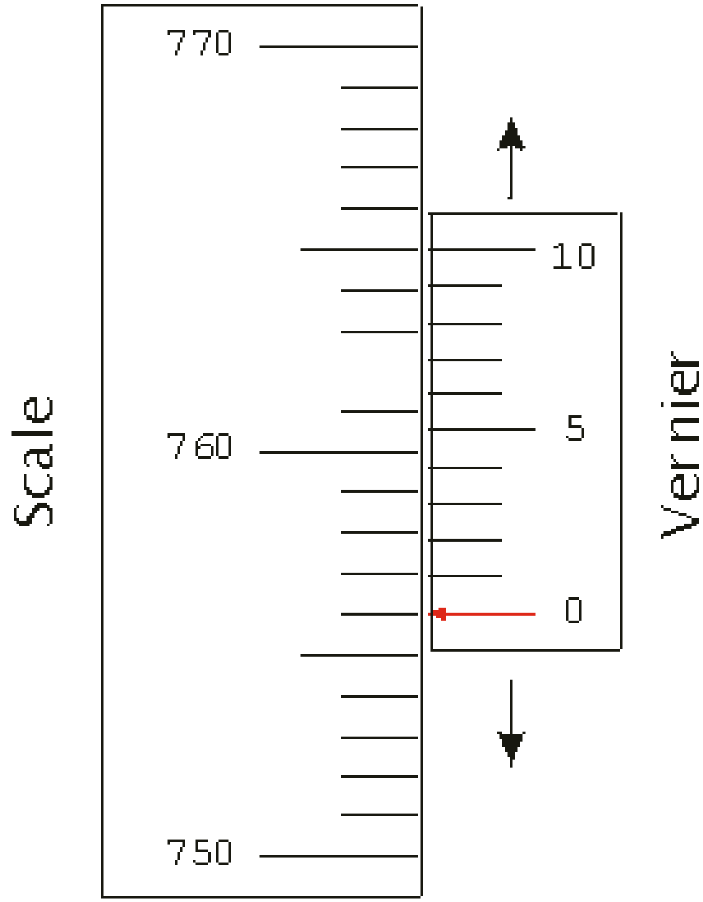


LINEAR DIMENSIONS – HOW TO READ A VERNIER

A *Vernier* allows a precise reading of some value. In the figure to the right, the Vernier moves up and down to measure a position on the Scale. This could be part of a barometer which reads atmospheric pressure.

The "pointer" is the line on the vernier labelled "0". Thus the measured position is almost exactly 756 in whatever units the scale is calibrated in.

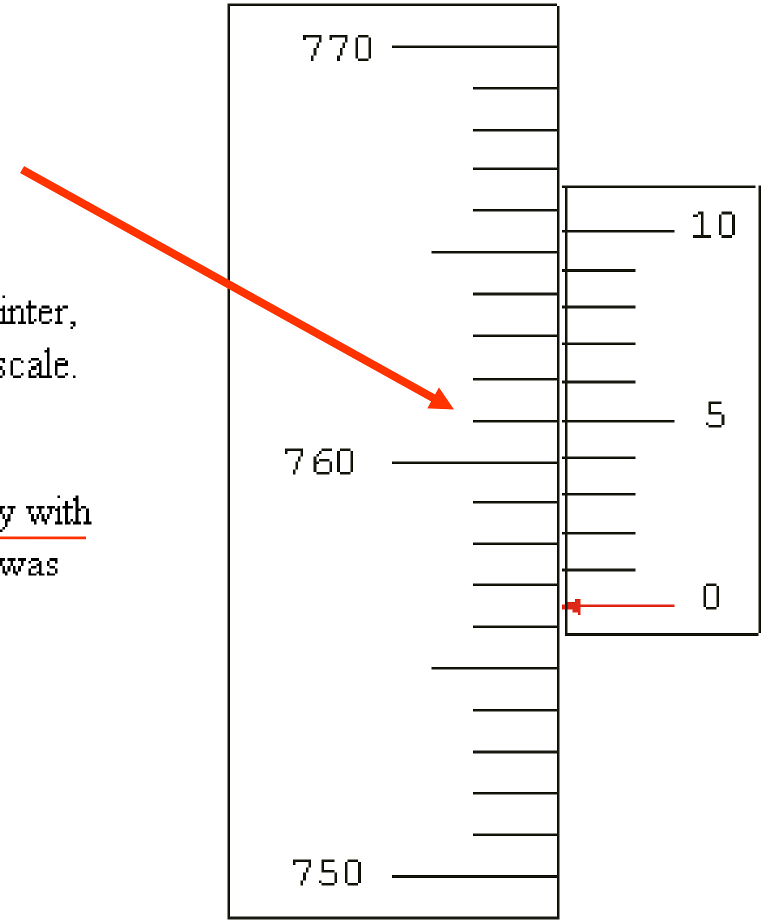
If you look closely you will see that the distance between the divisions on the vernier are not the same as the divisions on the scale. The 0 line on the vernier lines up at 756 on the scale, but the 10 line on the vernier lines up at 765 on the scale. Thus the distance between the divisions on the vernier are 90% of the distance between the divisions on the scale.



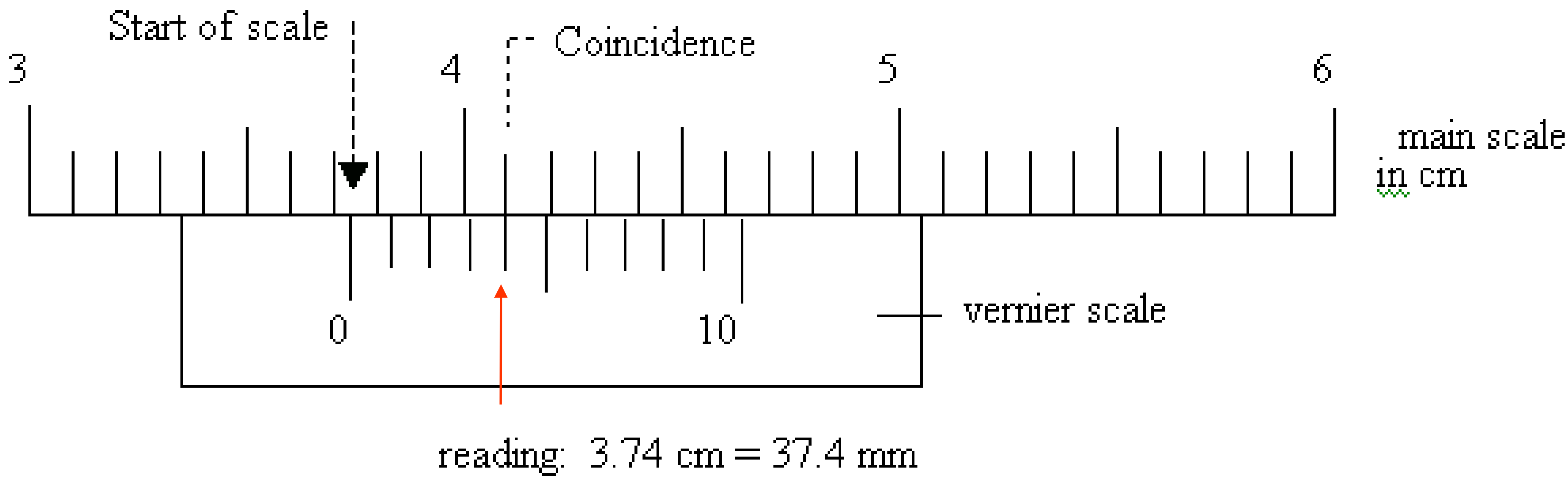
LINEAR DIMENSIONS - HOW TO READ A VERNIER

If we do another reading with the vernier at a different position, the pointer, the line marked 0, may not line up exactly with one of the lines on the scale. Here the "pointer" lines up at approximately 756.5 on the scale.

If you look you will see that only one line on the vernier lines up exactly with one of the lines on the scale, the 5 line. This means that our first guess was correct: the reading is 756.5.



LINEAR DIMENSIONS – HOW TO READ A VERNIER

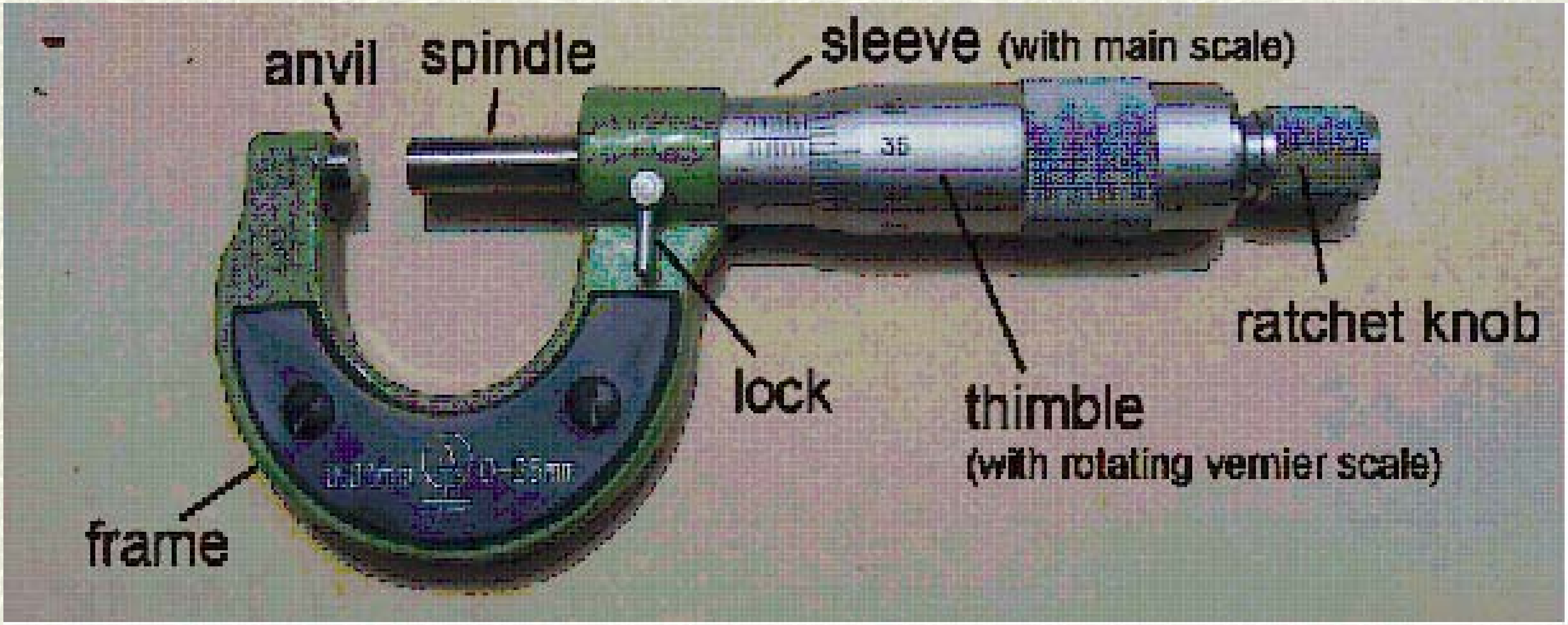


Scale reading = 3.70cm

Vernier reading = (0.1/10) x 4 = 0.04

Caliper reading = 3.74cm

LINEAR DIMENSIONS – SCREW GAUGE

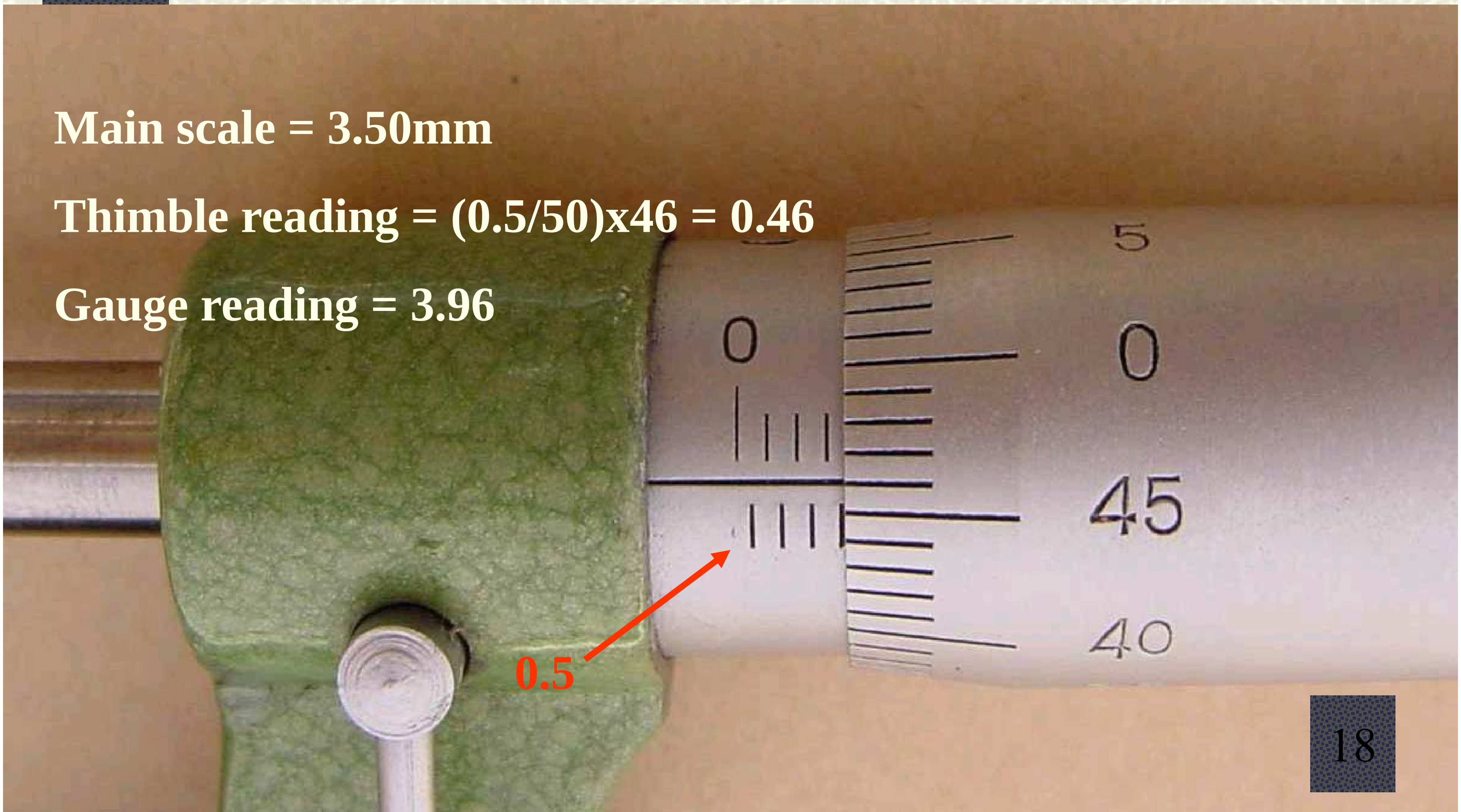


LINEAR DIMENSIONS – HOW TO READ SCREW GAUGES

Main scale = 3.50mm

Thimble reading = (0.5/50)x46 = 0.46

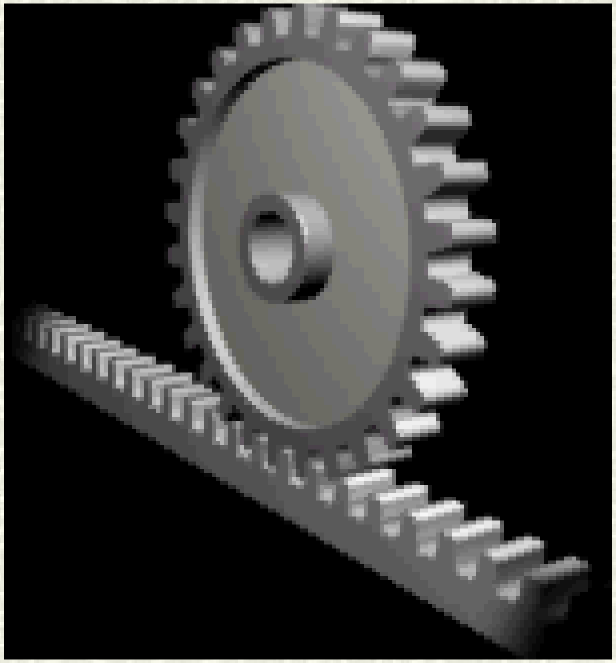
Gauge reading = 3.96



LINEAR DIMENSIONS – DIAL GAUGES

LINEAR DIMENSIONS – DIAL GAUGES

- For small displacement
- Mechanism based on plunger and rack and pinion system



LINEAR DIMENSIONS – DIAL GAUGES

Applications

- In a quality environment to check for consistency and accuracy in the manufacturing process.
- On the workshop floor to initially set up or calibrate a machine, prior to a production run.
- By toolmakers (mold makers) in the process of manufacturing precision tooling.
- In metal engineering workshops, where a typical application is the centering of a lathe's work piece in a four jaw chuck. The DTI is used to indicate the run out (the misalignment between the work piece's axis of rotational symmetry and the axis of rotation of the spindle) of the work piece, with the ultimate aim of reducing it to a suitably small range using small chuck jaw adjustments.
- In areas other than manufacturing where accurate measurements need to be recorded, e.g.:- physics.

THICKNESS GAUGES RANGE & ACCURACY

MODEL	GRADUATION & RANGE	GAUGE INSTALLED	MEASURING DEPTH	EFFECTIVE MEASURING RANGE
R1-A	0.001mm - 2mm	25F-RE	55mm	10mm
R1-B	0.01mm - 10mm	107F-RE	55mm	25mm
R1-C	0.01mm - 20mm	207F-PL	55mm	20mm
R2-A	0.001mm - 2mm	25F-RE	40mm	85mm
R2-B	0.01mm - 10mm	107F-PL	40mm	95mm
R2-C	0.01mm - 20mm	207F-PL	40mm	70mm
R5-A	0.001mm - 2mm	25F-RE	100mm	180mm
R5-B	0.01mm - 10mm	107F-RE	100mm	180mm
R5-C	0.01mm - 20mm	207F-PL	100mm	180mm

MEASUREMENT OF MASS, WEIGHT & FORCES

MASS, WEIGHT & FORCE

What is the concept of mass, weight and force?

If an object has a mass of 1 kg on the earth, it would have a mass of 1 kg on the moon, even though it would weigh only one-sixth as much.

Weight Calculation

MASS, WEIGHT & FORCE – DEFINITION OF MASS

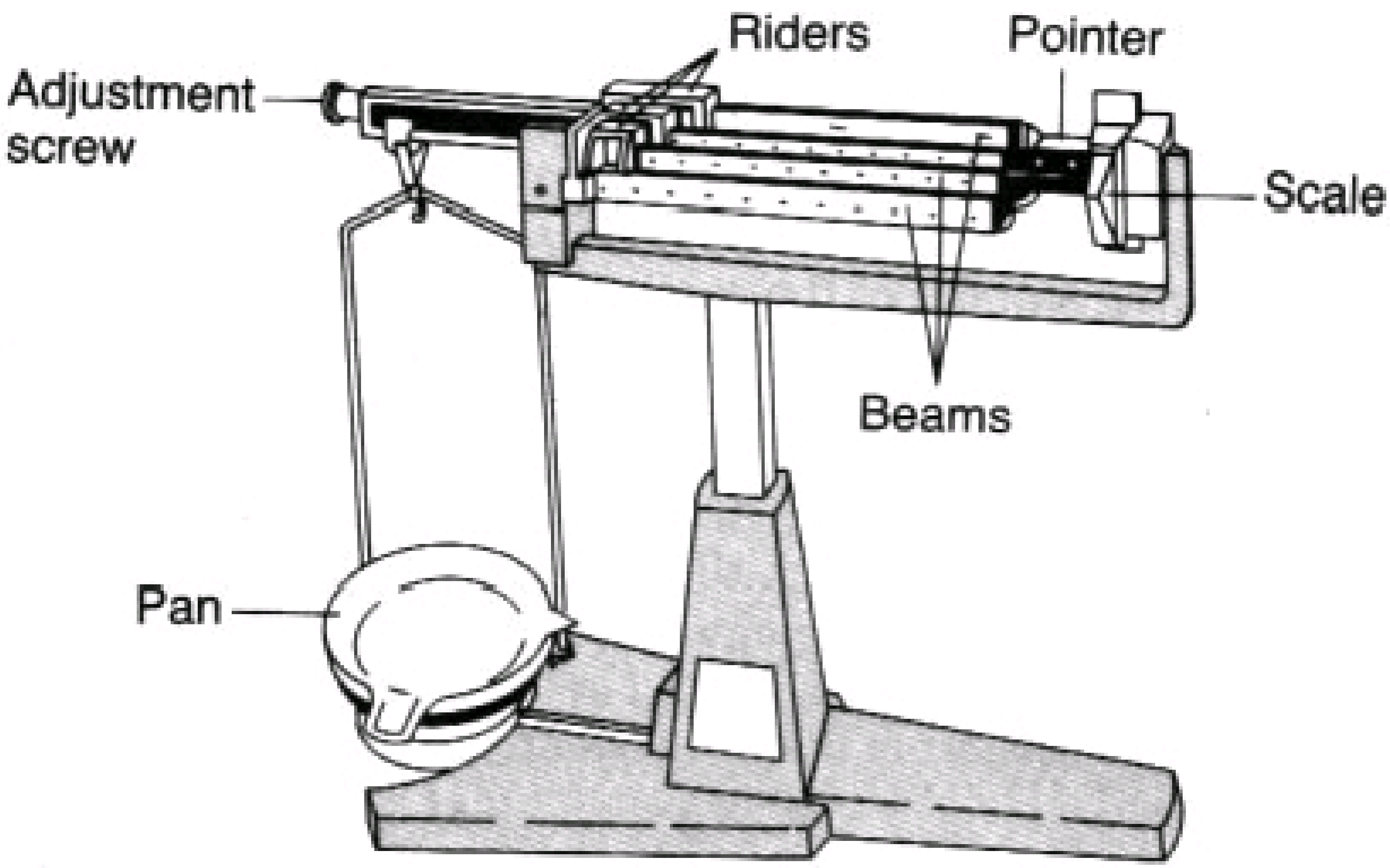
Mass (symbolized *m*) is a dimensionless quantity representing the amount of matter in a particle or object.

Mass is measured by determining the extent to which a particle or object resists a change in its direction or speed when a force is applied.

The standard unit of mass in the International System (SI) is the kilogram (kg).

MEASUREMENT OF MASS – EQUIPMENT

MEASUREMENT OF MASS – EQUIPMENT



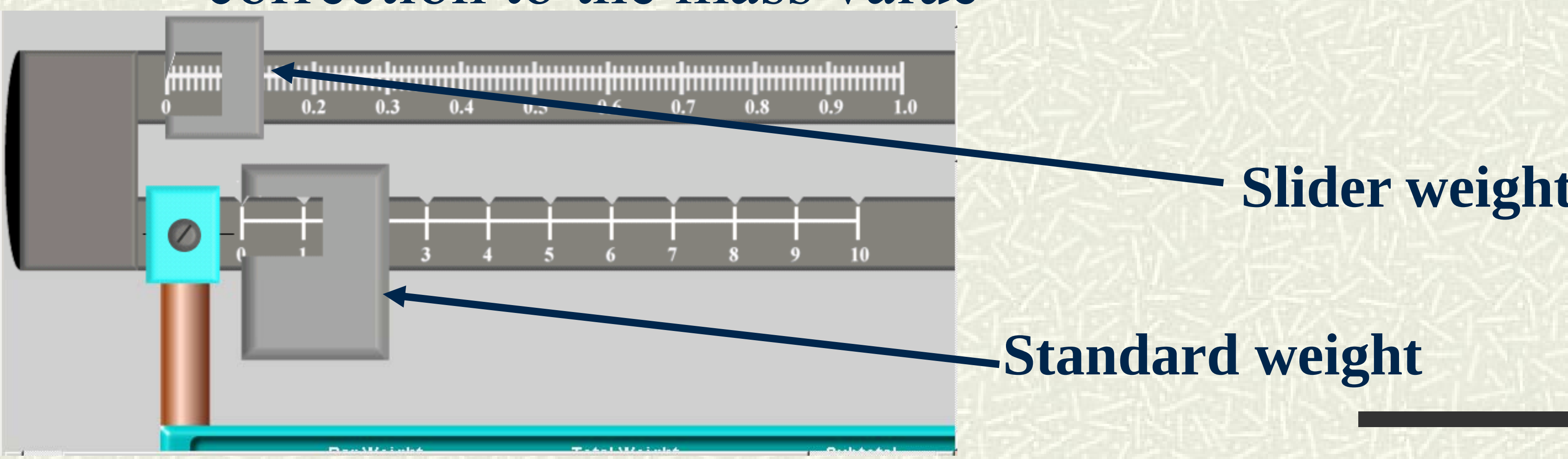
MEASUREMENT OF MASS – EQUIPMENT

MEASUREMENT OF MASS – PRINCIPLE

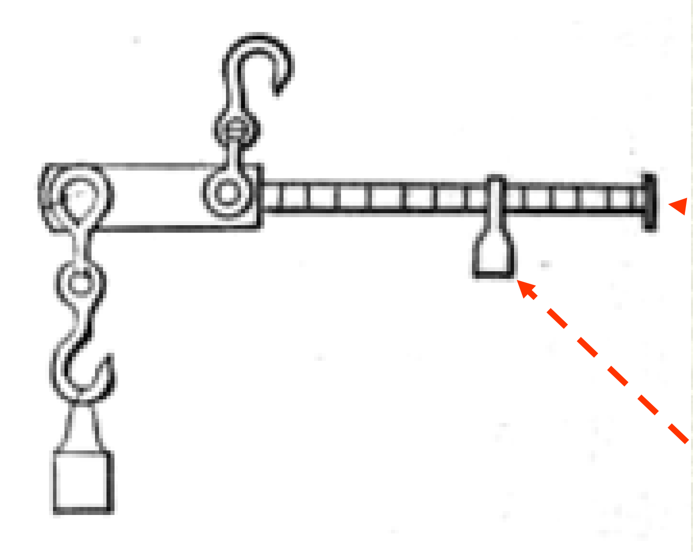
In its conventional form, this class of measuring instrument compares the sample, placed in a weighing pan (weighing **basin**) and suspended from one end of a beam with a standard mass or combination of standard masses in a scale pan (scale basin) suspended from the other end

MEASUREMENT OF MASS – PRINCIPLE

To weigh an object in the measuring pan, standard weights are added to the scale pan until the beam is in equilibrium as closely as possible. Then a slider weight usually present is moved along a scale on or parallel to the beam (and attached to it) until fine balance is achieved. The slider position gives a fine correction to the mass value



MEASUREMENT OF MASS – STEELYARD BALANCE



The steelyard comprises a balance beam which is suspended from a **pivot** (or fulcrum) which is very close to one end of the beam. The two parts of the beam which **flank** the pivot are the arms.

The arm from which the object to be weighed (the **load**) is hung is short and is located close to the pivot point. The other arm is longer, is graduated and incorporates a **counterweight** which can be moved along the arm until the two arms are balanced about the pivot, at which time the weight of the load is indicated by the position of the counterweight

MEASUREMENT OF MASS – STEELYARD BALANCE

19th century Roman steelyard from Pompeii

MEASUREMENT OF MASS – SPECIAL NOTES

Precise measurements are achieved by

- ensuring that the fulcrum of the beam is friction-free
- by attaching a pointer to the beam which amplifies any deviation from a balance position; and finally
- by using the lever principle, which allows fractional weights to be applied by movement of a small weight along the measuring arm of the beam
- allowing for the buoyancy in air, whose effect depends on the densities of the weights and the sample.

MASS, WEIGHT & FORCE – DEFINITION OF WEIGHT & FORCE

- Weight (symbolized *w*) is a quantity representing the force exerted on a particle or object by an acceleration field, particularly the gravitational field of the Earth at the surface. In the International System of Units (SI), weight can be expressed in terms of the force, in Newtons, exerted on a mass in a gravitational field.
- The weight of an object is the force of gravity on the object and may be defined as the mass times the acceleration of gravity, $w = mg$.

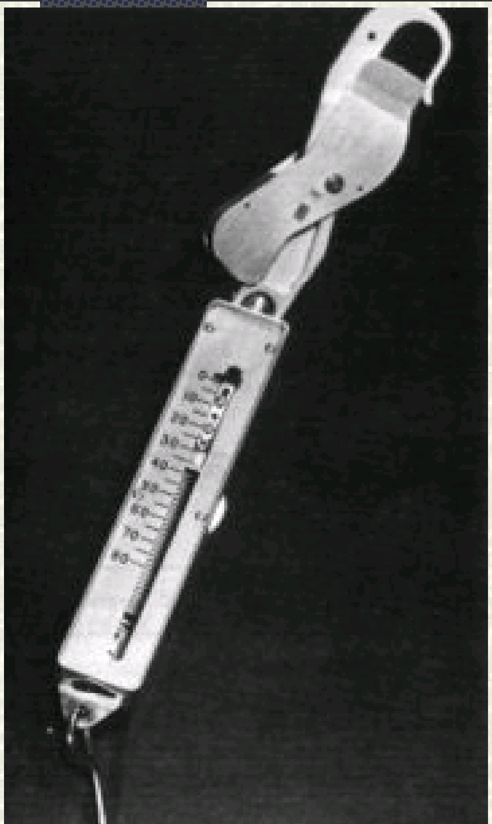
MASS, WEIGHT & FORCE – MEASUREMENT OF FORCE

- When an elastic body is subjected to stress, its dimension or shape changes in proportion to the applied stress over a range of stresses
- This led to Hooke's law which states that ***strain, the relative change in dimension, is proportional to stress***. If the stress applied to a body goes beyond a certain value known as the elastic limit , the body does not return to its original state once the stress is removed. Hooke's law applies only in the region below the elastic limit.
- Because measurement of distortion or of motion provides the means of determining the magnitude of a force, Newton's and Hooke's laws are key concepts in force measurements.

MEASUREMENT OF FORCE – EQUIPMENT

- Equipment that can be used to measure force:
  - Spring scale
  - Proving ring
  - Load cell and Strain gauge

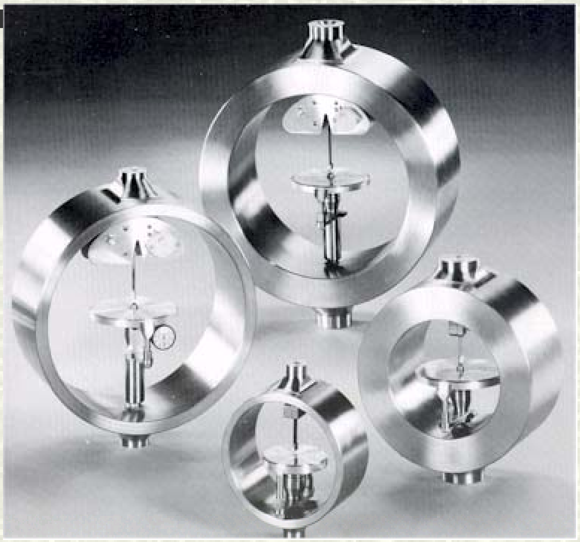
MEASUREMENT OF FORCE – SPRING BALANCE

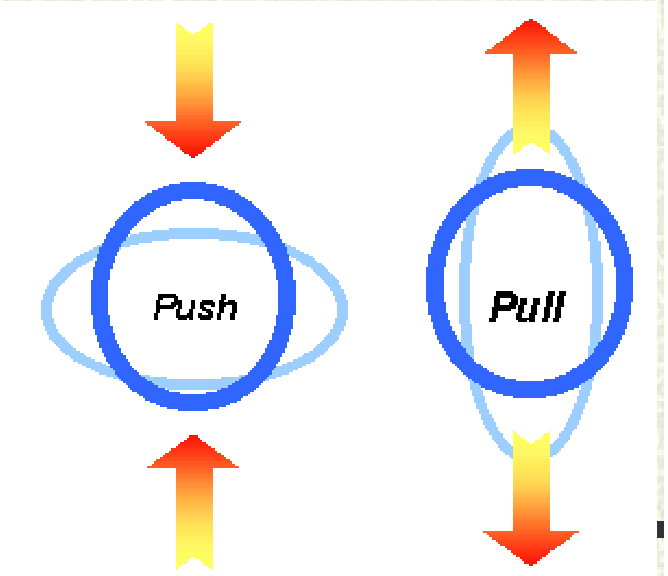


- ❖Use a spring with a known spring constant (Hooke's law) and measure the displacement of the spring to produce an estimate of the gravitational force applied by the object.
- ❖Typically measure force
- ❖Cannot be used for commercial applications unless their springs are temperature compensated or used at a fairly constant temperature

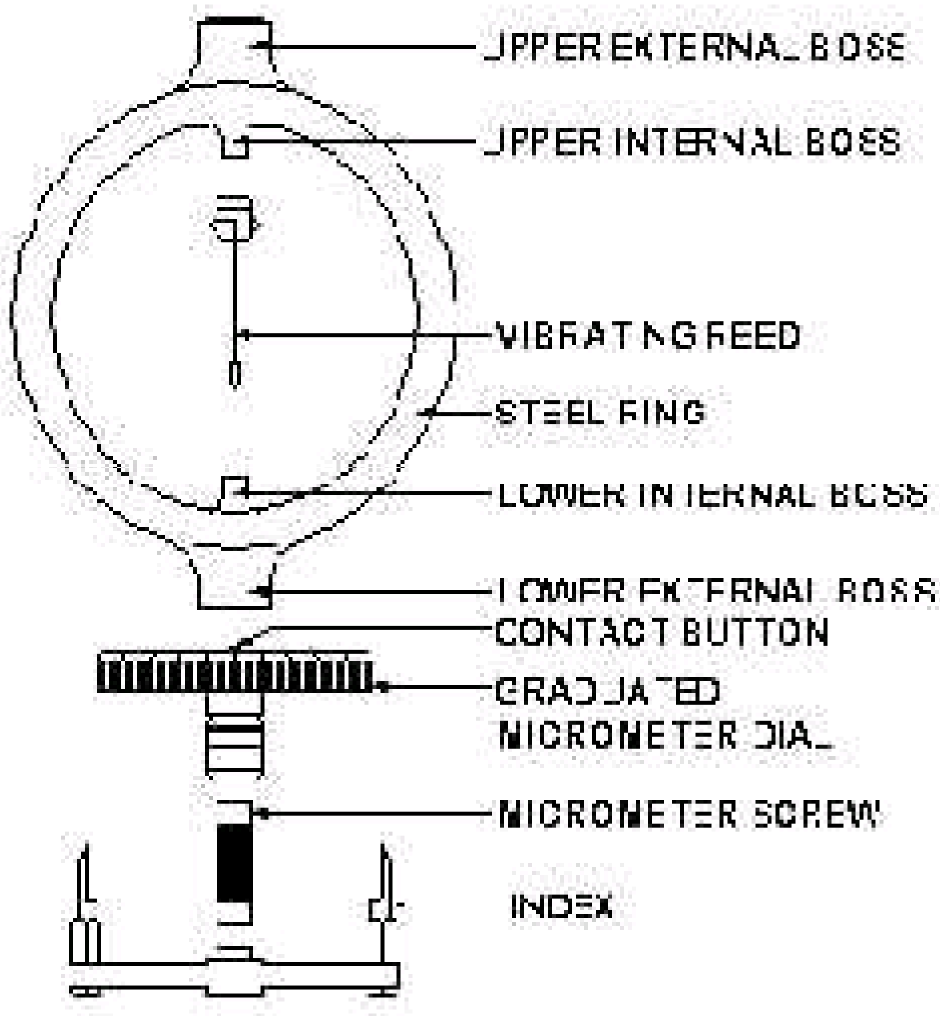
MEASUREMENT OF FORCE – PROVING RING

A proving ring consists of an elastic ring in which the deflection of the ring when loaded along a diameter is measured by means of a micrometer screw and a vibrating reed.





PROVING RING

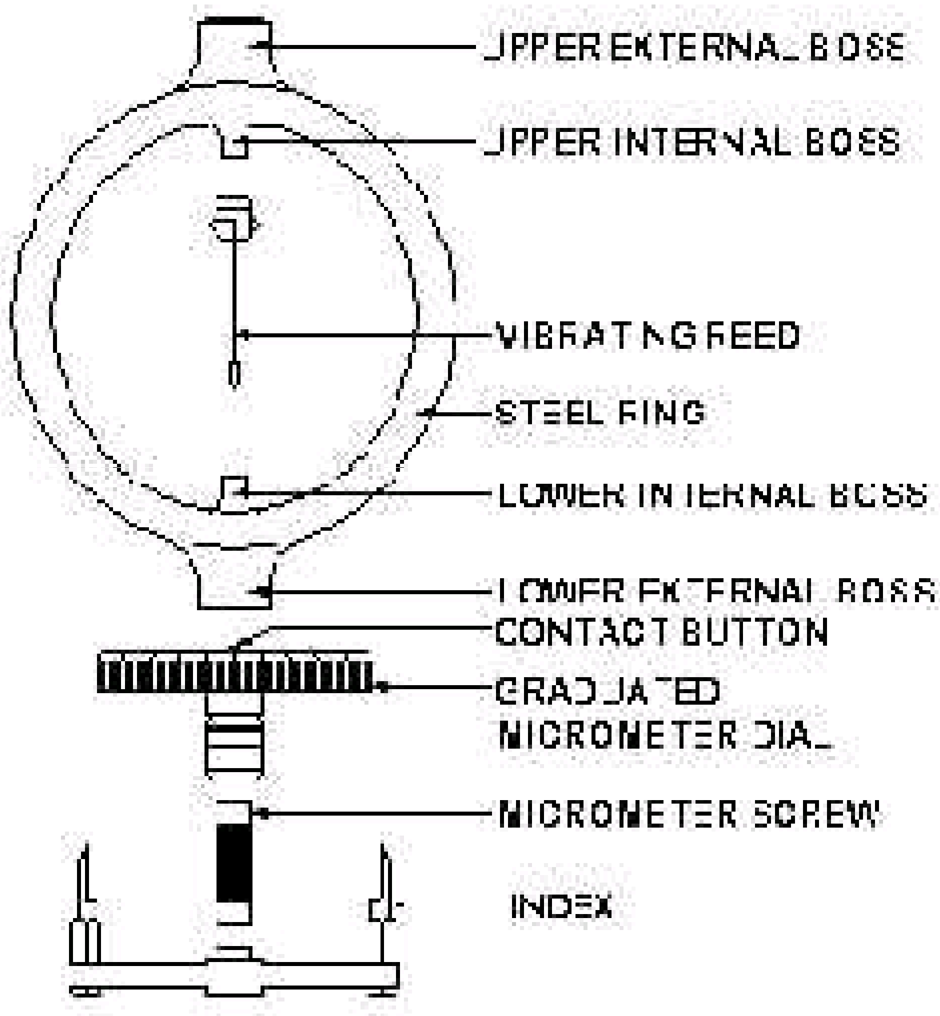


The proving ring consists of two main elements, the ring itself and the diameter-measuring system,

Forces are applied to the ring through the external bosses.

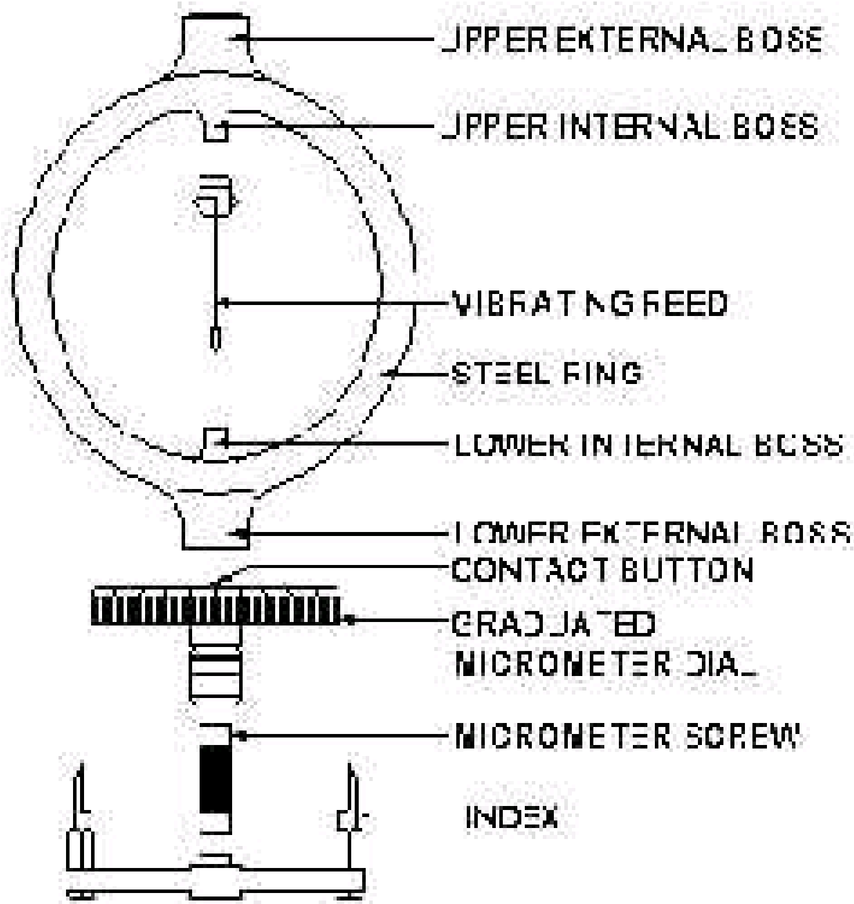
The resulting change in diameter, referred to as the deflection of the ring, is measured with a micrometer screw and the vibrating reed mounted diametrically within the ring.

PROVING RING



The micrometer screw and the vibrating reed are attached to the internal bosses of the ring. In modern rings, the upper and lower internal and external bosses are machined as an integral part of the ring to avoid mechanical interferences during the application of the force.

PROVING RING



To read the diameter of the ring, the vibrating reed is set in motion by gently tapping it with a pencil. As the reed is vibrating, the micrometer screw on the spindle is adjusted until the button on the spindle just contacts the vibrating reed, dampening out its vibrations. When this occurs a characteristic buzzing sound is produced. At this point a reading of the micrometer dial indicates the diameter of the ring.

MEASUREMENT OF FORCE – LOAD CELL

A **load cell** is an electronic device (transducer) that is used to convert a force into an electrical signal.

It happens in two stages;

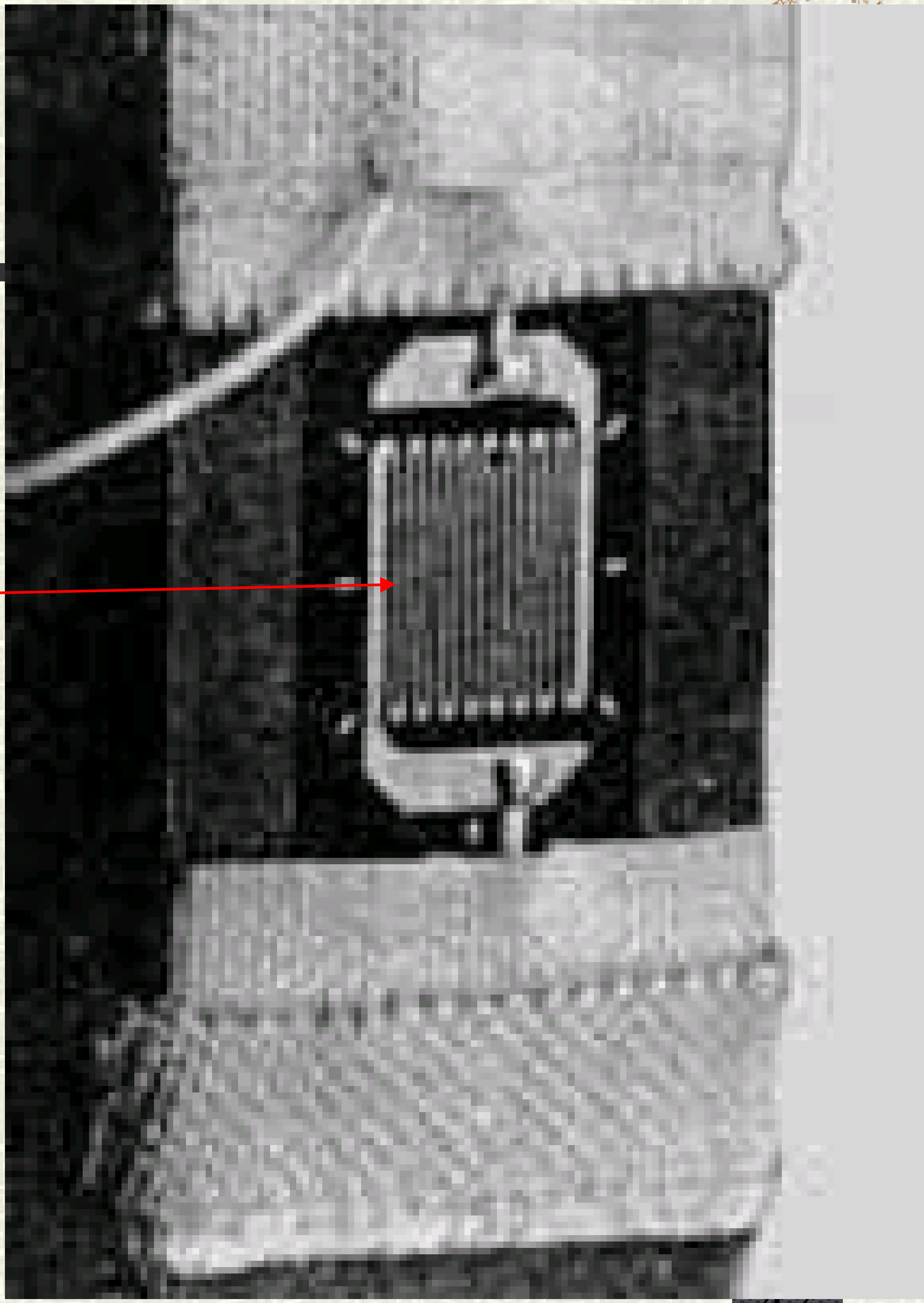
(1) mechanical force is sensed using a strain gauge

(2) the strain gauge converts the deformation (strain) to electrical signals.

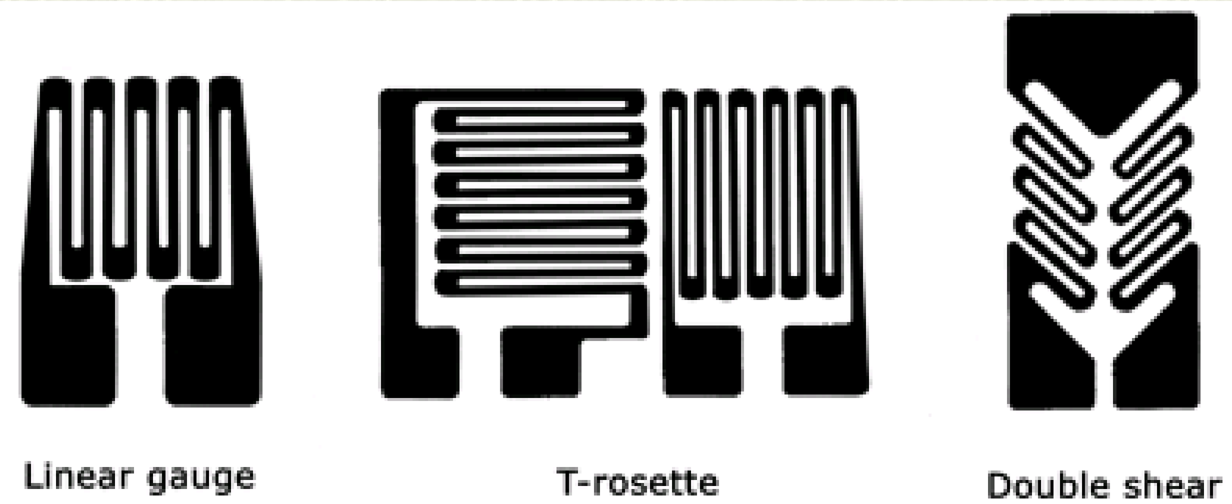
A load cell usually consists of four strain gauges in a wheatstone bridge configuration, The output of the transducer is plugged into an algorithm to calculate the force applied to the transducer.

LOAD CELL

STRAIN GAUGE



MEASUREMENT OF FORCE – STRAIN GAUGE



MEASUREMENT OF FORCE – STRAIN GAUGE

When external forces are applied to a stationary object, stress and strain are the result.

Stress is defined as the object's internal resisting forces, and strain is defined as the displacement and deformation that occur.

Strain may be compressive or tensile and is typically measured by strain gages.

It was Lord Kelvin who first reported in 1856 that metallic conductors subjected to mechanical strain exhibit a change in their electrical resistance.

MEASUREMENT OF FORCE – STRAIN GAUGE

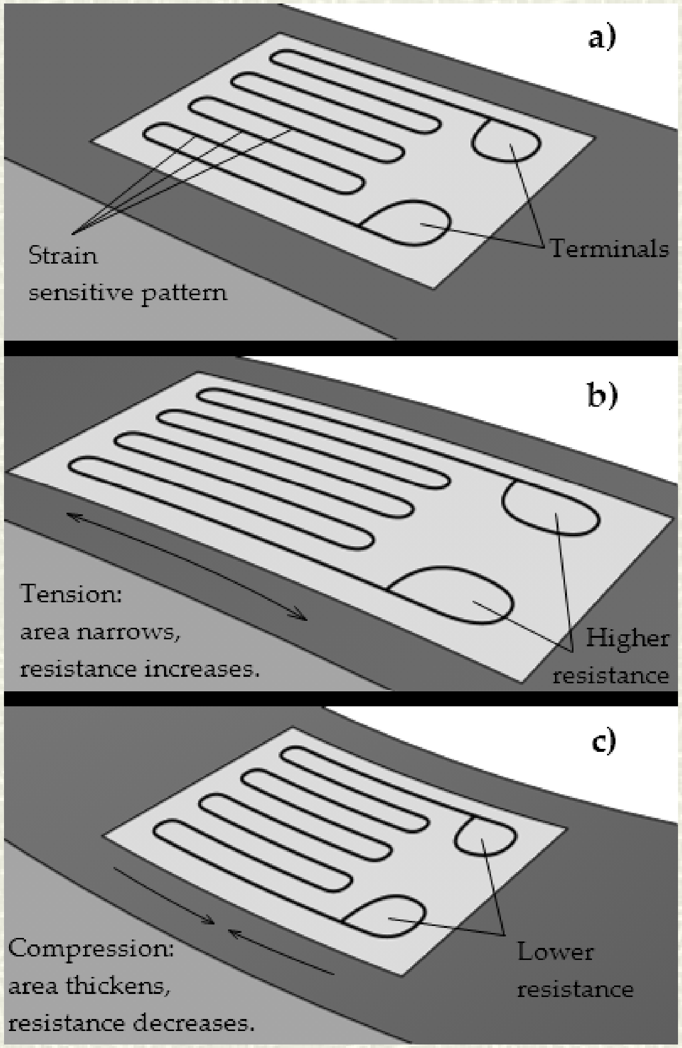
A strain gauge is a device used to measure deformation (strain) of an object.

The most common type of strain gauge consists of an insulating flexible backing which supports a metallic foil pattern.

The gauge is attached to the object by a suitable adhesive.

As the object is deformed, the foil is deformed, causing its electrical resistance to change.

MEASUREMENT OF FORCE – STRAIN GAUGE



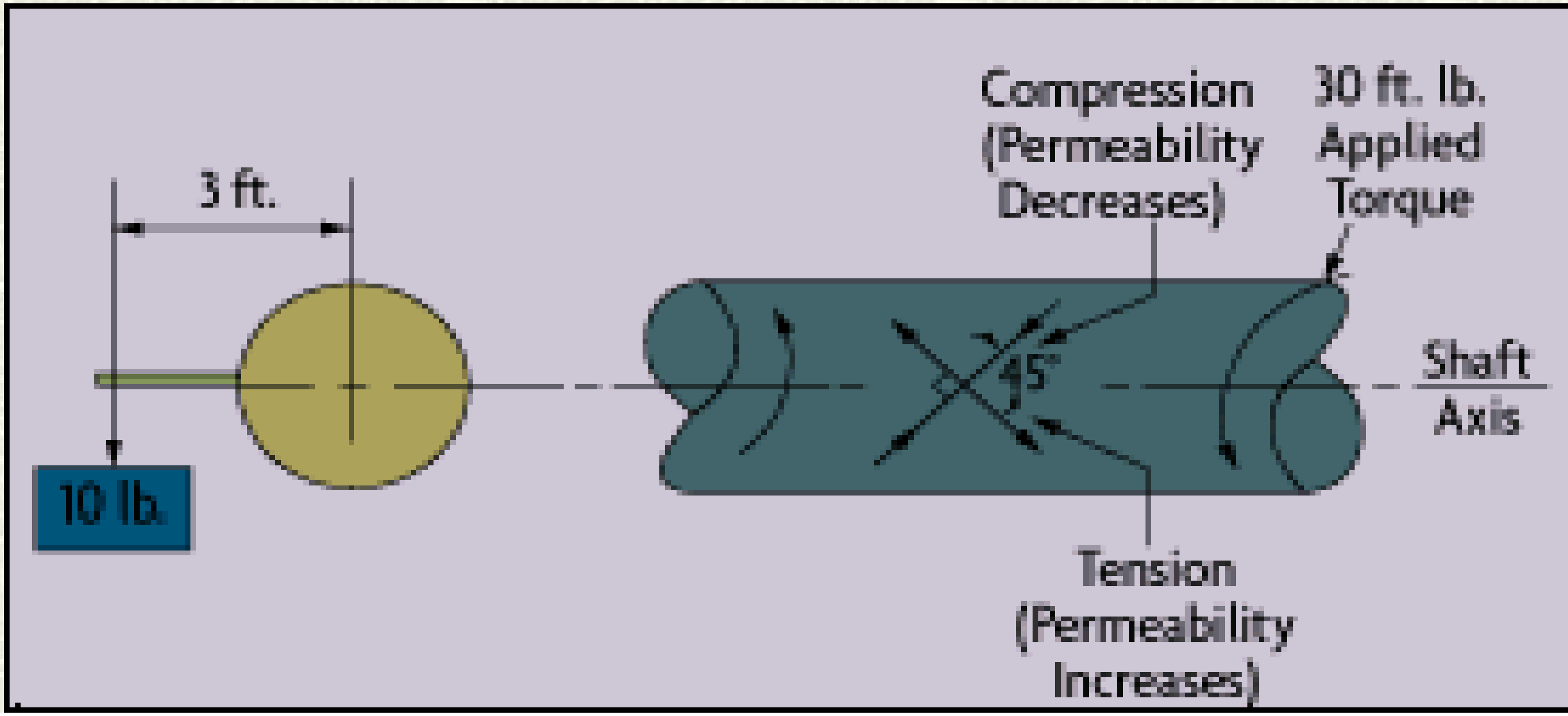
MEASUREMENT OF TORQUE

MEASUREMENT OF TORQUE EQUIPMENT

1. Torque transducer (with strain gauge)
2. Angular displacement

MEASUREMENT OF TORQUE – STRAIN GAUGE

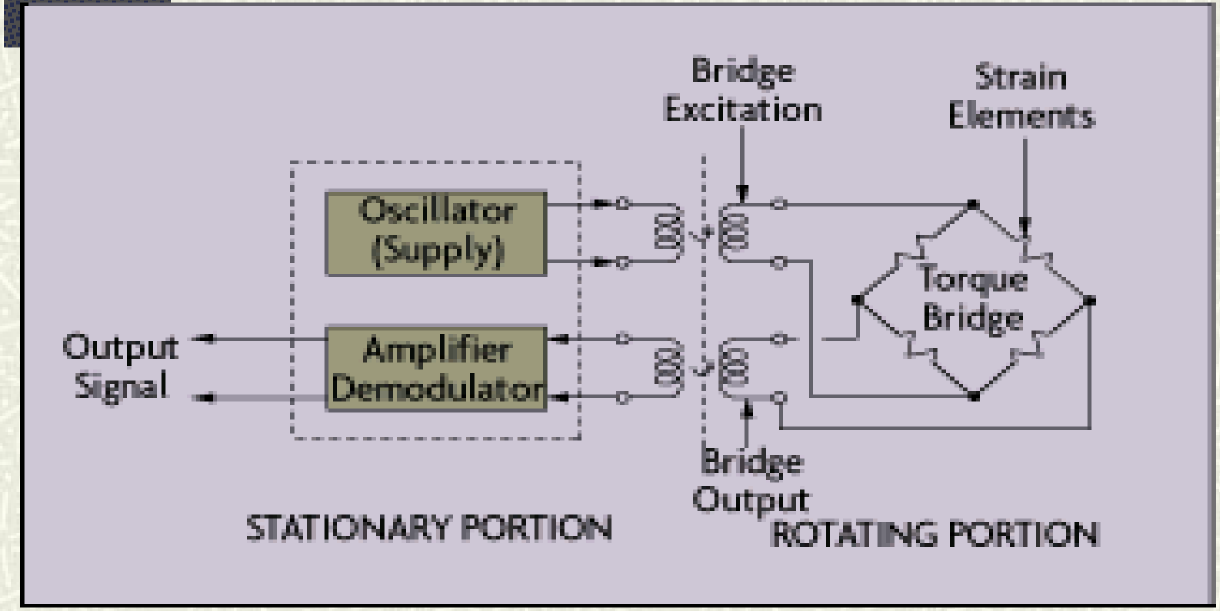
Torque is measured by either sensing the actual shaft deflection caused by a twisting force, or by detecting the effects of this deflection. The surface of a shaft under torque will experience compression and tension, as shown.



MEASUREMENT OF TORQUE - STRAIN GAUGE

To measure torque, strain gauge elements usually are mounted in pairs on the shaft, one gauge measuring the increase in length (in the direction in which the surface is under tension), the other measuring the decrease in length in the other direction.

MEASUREMENT OF TORQUE – STRAIN GAUGE



The torque sensor can be connected to its power source and signal conditioning electronics via a slip ring

Another method is through induction coupling. Excitation voltage for the strain gauge is inductively coupled, and the strain gauge output is converted to a modulated pulse frequency. Maximum speed of such an arrangement is 15,000 rpm.

MEASUREMENT OF TORQUE – ANGULAR DISPLACEMENT

Proximity and displacement sensors also can detect torque by measuring the angular displacement between a shaft's two ends.

By fixing two identical toothed wheels to the shaft at some distance apart, the angular displacement caused by the torque can be measured.

MEASUREMENT OF TORQUE – MEASUREMENT OF POWER

- Measurement of torque is related to measurement of mechanical power
  - ➢power to drive a machine
  - ➢power produced by a machine
- Equipment used to measure power is dynamometer
- Three types of dynamometer
  - transmission dynamometer
  - driving dynamometer
  - absorption dynamometer

MEASUREMENT OF POWER – TRANSMISSION DYNAMOMETER

A dynamometer in which power is measured, without being absorbed or used up, during transmission

The **transmission dynamometer** transmits the force while **measuring the elastic twist** of the output shaft.

Also called **torsion meter** as it measure the torque on a shaft, and hence the horse power of an engine, esp. of a marine engine of high power, by measuring the amount of twist of a given length of the shaft.

MEASUREMENT OF POWER – DRIVING DYNAMOMETER

A dynamometer can also be used to determine the torque and power required to operate a driven machine such as a pump.

In that case, a motoring or driving dynamometer is used.

MEASUREMENT OF POWER – ABSORPTION DYNAMOMETER

Consists of an absorption unit, plus a means to measure torque and rotational speed.

It has some type of rotor in a housing. The rotor is coupled to the engine under test and is free to rotate.

Some means is provided to develop a braking torque between dynamometer's rotor and housing.

The means for developing torque can be frictional, hydraulic, electromagnetic etc. according to the type of absorption/driver unit

MEASUREMENT OF POWER – ABSORPTION DYNAMOMETER

- Three types of absorption dynamometer:

  - Mechanical
  - Electrical
  - Hydraulic

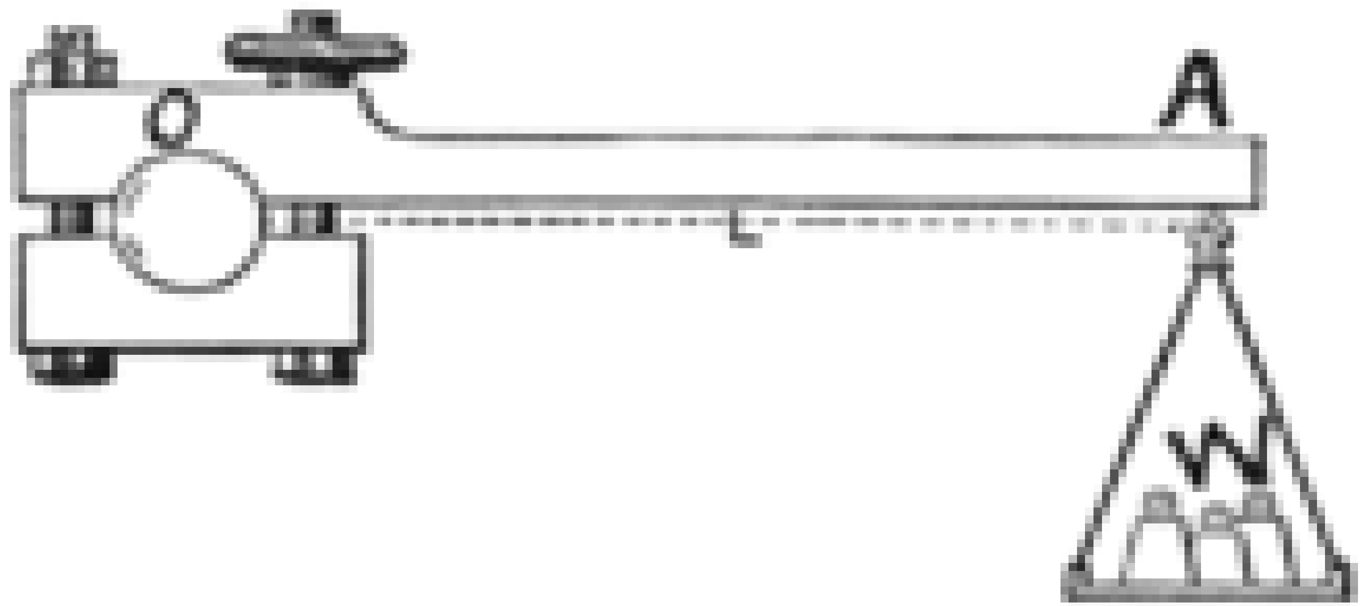
MEASUREMENT OF POWER – ABSORPTION DYNAMOMETER

Absorption dynamometers produce the torque that they measure by creating a constant restraint to the turning of a shaft by either mechanical friction, fluid friction, or electromagnetic induction.

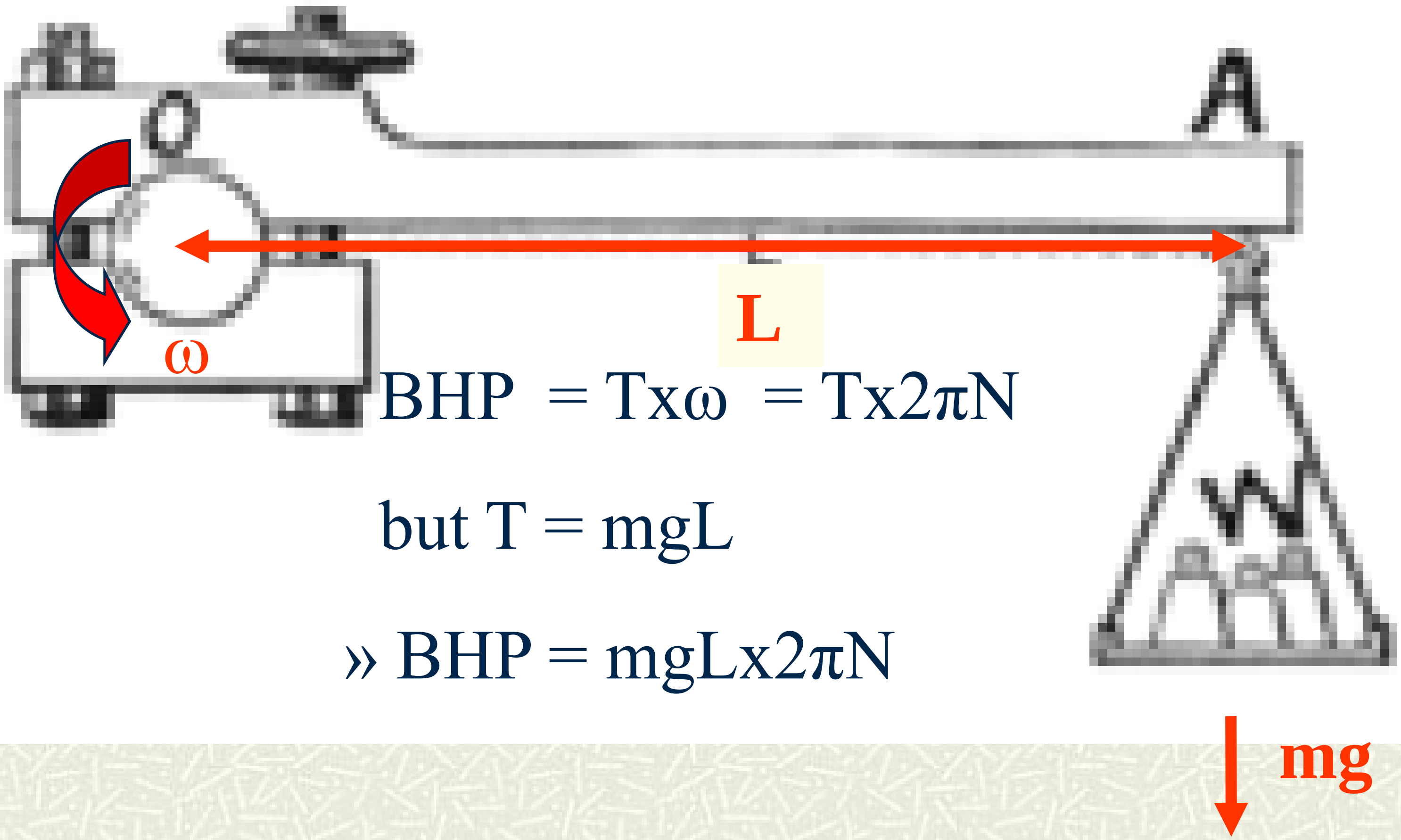
One example of mechanical friction is Prony brake.

Prony brake develops mechanical friction on the periphery of a rotating pulley by means of brake blocks that are squeezed against the wheel by tightening the bolts.

ABSORPTION DYNAMOMETER
- The Prony Brake



ABSORPTION DYNAMOMETER - The Prony Brake

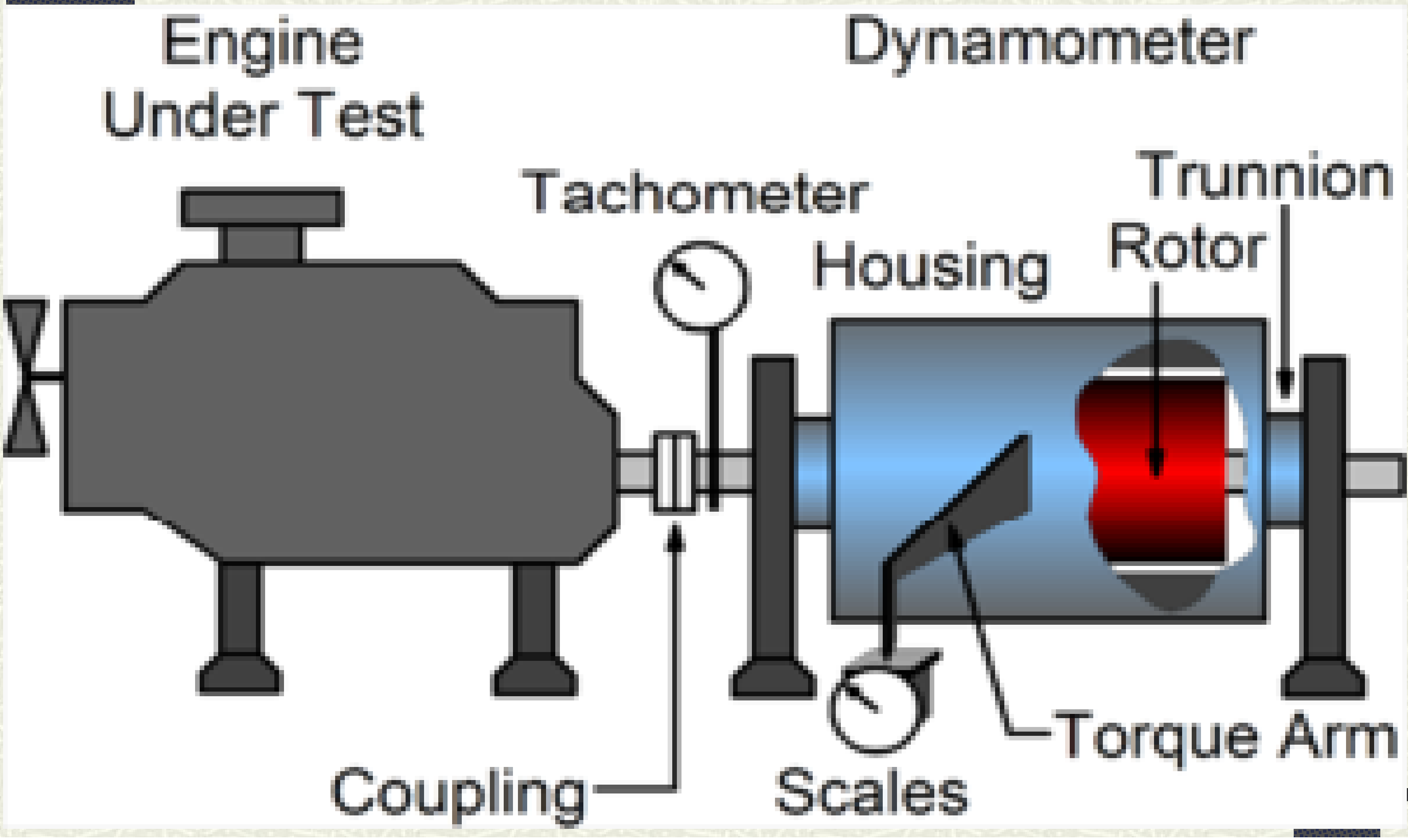


BHP = Txω = Tx2πN

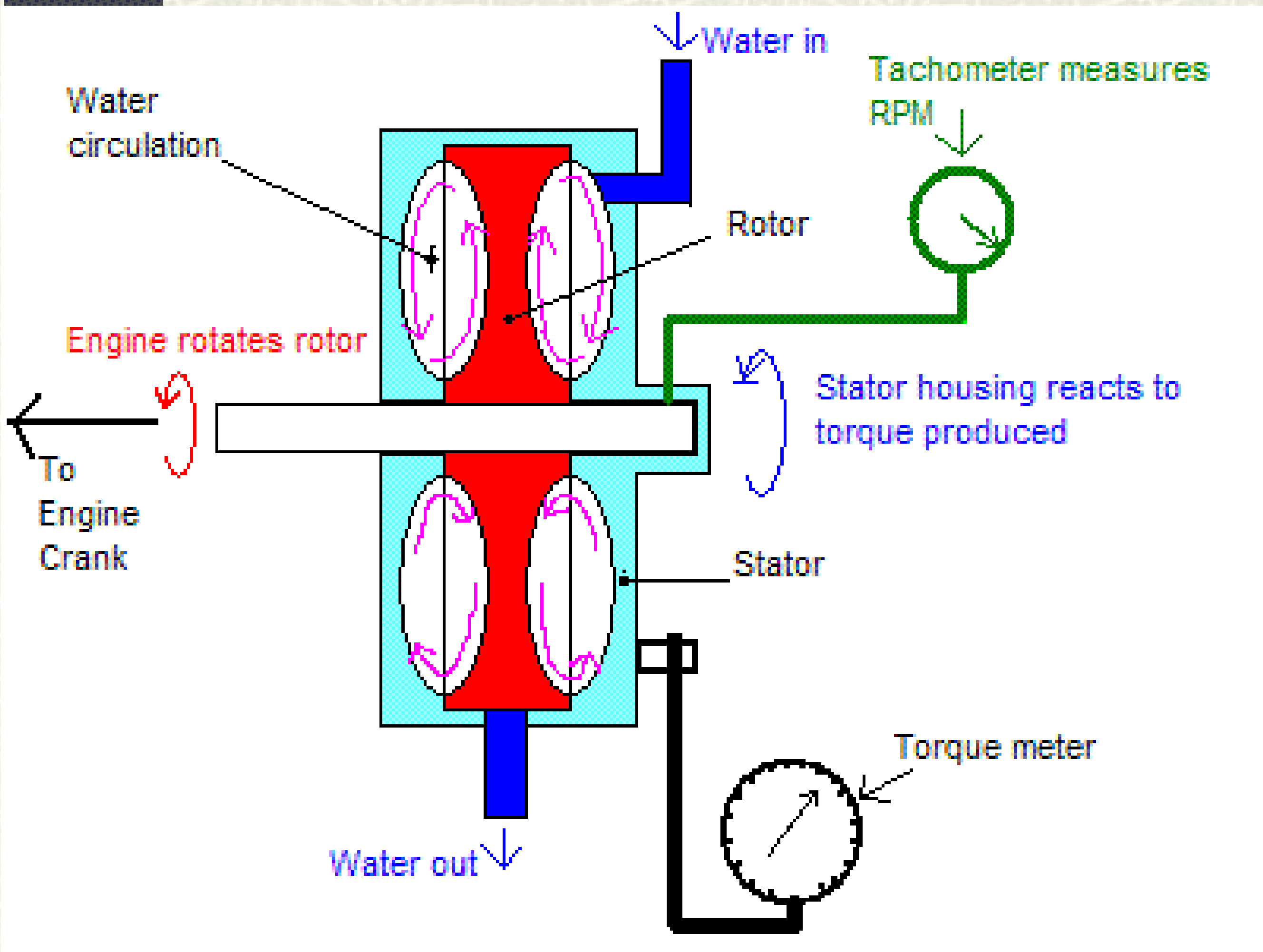
but T = mgL

» BHP = mgLx2πN

ABSORPTION DYNAMOMETER - Electrical Dynamometer



ABSORPTION DYNAMOMETER - Hydraulic Dynamometer



The housing attempts to rotate in response to the torque produced but is restrained by the scale or torque metering cell which measures the torque.

THE END