

Chapter-One

Physical quantities, units and measurements



AAU, 2019

Base quantities and units

Base quantity	Symbol	Base unit	Unit symbols	Instruments
Mass	m	kilogram	Kg	Beam or lever balance, top pan balance
Length	l	metre	m	Meter rule, ruler, vernier calipers, micrometer screwgauge
Time	t	seconds	S	Clocks, stop watch
Temperature	T	Kelvin	K	Thermometer, thermocouple
Current	I	ampere	A	Ammeter, multimeter

Multiplying or dividing by base quantities produces derived quantities

Derived quantity	symbol		Unit symbol
Area	A	Meter squared	m ²
Density	ρ	Kilogram per metre cubed	Kgm ⁻³
Work and energy	W & E	Joules	Kgm ² s ⁻²
Pressure	P	Pascal	

- Some quantities are dimensionless, eg., relative density

Examples of derived quantity

QUANTITY	TYPICAL SYMBOL	UNIT & TYPICAL SYMBOL	INSTRUMENT OF MEASUREMENT	CALCULATING EQUATION
Area	A	m ² , cm ² , mm ²		Circle = πr^2 or $(\pi d)/4$ Square = side x side or l^2
Volume	V	m ³ , cm ³ , mm ³ , ml, l, (1ml = 1cm ³ 1000cm ³ =1l	Beaker, conical flask, volumetric flask, pipette, burette, graduated measuring cylinder	Sphere = $4/3 (\pi r^3)$ Cylinder = $\pi r^2 h$ Rectangular block = LxBxH
Density	ρ	Kg/m ³ , g/cm ³	Hydrometer	$\rho = m/v$
Force	F	N or kgm/s ²	Spring balance	$F = mxa$, $W = mxg$
Relative density		none		ρ_s / ρ_w
Speed or velocity	v	m/s		$v = x/t$
Acceleration	a	m/s ²		$a = \frac{v-u}{t}$
Work or energy used	W	Joule or Nm		$W = Fx$
Power	p	Watt		$\frac{\text{(Work or energy used)}}{\text{Time taken}}$

QUANTITY	TYPICAL SYMBOL	UNIT & TYPICAL SYMBOL	INSTRUMENT OF MEASUREMENT	CALCULATING EQUATION
Unit charge	q (=e=1.6x10 ⁻¹⁹ C)	Coulomb – C		Q = nq
Number of charge carriers	n			
Total quantity of charge	Q	Coulomb –C		
Current	I	Ampere - A	Ammeter	I=V/R
Voltage (Potential difference, p.d. Electromotive force e.m.f.)	V	Volt - V	Voltmeter	V=IR
Resistance	R	Ohm - Ω	Ohmmeter	R=V/I
Electrical potential Energy	E	Joule-J (& kilowatt hour / KWh = 1000Wx1h= 1000x3600=3,6000,000J	Joulemeter	W=E=QV ; E = Pt; E=IVt,; E=I ² Rt; E = (V ² /R)t
Electrical Work	W	Joule - J(& kilowatt hour / KWh	Joulemeter	W= E= QV
Power	P	Watt		P=IV = I ² R = V ² /R

Common multiples and submultiples of units

unit	prefix	Symbol of prefix	Meaning
meter	Pico	p	$\times 10^{-12}$
	Nano	n	$\times 10^{-9}$
	Micro	μ	$\times 10^{-6}$
	Milli	m	$\times 10^{-3}$
	Centi	c	$\times 10^{-2}$
	Deci	d	$\times 10^{-1}$
	Deca	da	$\times 10^1$
	hecto	h	$\times 10^2$
	kilo	k	$\times 10^3$
	Mega	M	$\times 10^6$
	giga	G	$\times 10^9$
	tera	T	$\times 10^{12}$

submultiples

multiples

Standard form: expression of a number in the form $x \times 10^n$

- Contains a number (not zero before the decimal point and n is a positive or negative power or index
- Enables small / large numbers to be expressed in more convenient form

Significant figures

- Indicates presence of the
 - ...the limits of reliability of the number
 - ... the precision of the number depends on the amount of sig. figs.
- Note: zeros in front of a number are not significant
 - Zeros between non zero digits are significant
 - Zeros at the end of a number may or may not be significant
 - Non zero digits in a number are significant.

SCALES

CALIBRATION – Checking the scale of the instrument against an accepted standard to ensure accuracy of readings

- Divide the scale into appropriate number of intervals/graduation marks
- Fix or set the scale to ensure accuracy of absolute values...eliminate zero error
- Linear scale – equal changes in the value of the physical quantities being measured (measuring cylinder)
- Non-linear scale- equal changes in the value being measured relates to unequal changes on the scale being measured (conical flask)
- Analogue scale – pointer continuously deflects over calibrated scale
- Digital scale (uses light emitting diode (LED) or light crystal display (LCD)...makes small increments from one value to the next

Sensitivity, accuracy, range

Sensitivity- response of the instrument to a unit change of input...greater response-more sensitive the instrument (microammeter vs milliammeter)

Accuracy – final results produced that has minimized/ acknowledged errors contained in the apparatus (depends on the instrument's calibration/correct absolute value) or procedures used... how close a measured value is to the true value.

Precision – making observations/taking readings with the greatest possible exactness... how close the measured values are to each other...depends on the instrument's calibration and estimation between two readings on the instrument...

Scientific precision- give answers based on the least precise measurement, eg. Measurements of a block: 1.534m x 0.236m x 0.057m... 0.057m is the least precise with 2 significant figures, so the answer will also be with 2 sig.figs.

Range – interval between maximum and minimum values of a quantity that the instrument can measure



Low Accuracy
High Precision



High Accuracy
Low Precision



High Accuracy
High Precision

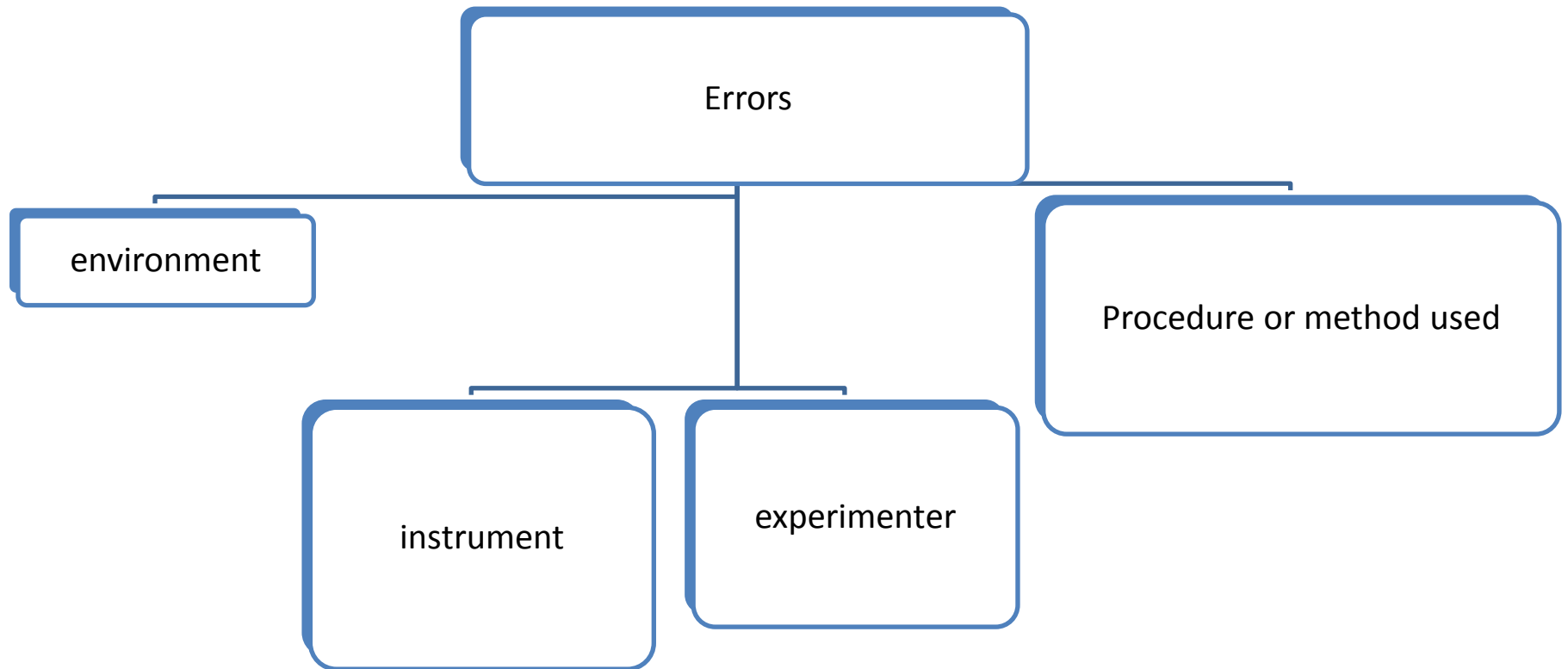
- Systematic Error... error that occurs repeatedly over time and is often due to a problem with the instrument or reagents
- Random Error... error that occurs without any pattern and is usually not due to an inherent property of the instrument or reagents but to human error.

- **Systematic Error** occurs when all measurements or observations, using a given method, deviate to the same degree from the true value. Therefore, it occurs regularly and with constant magnitude. You can measure it when recognized, and it can be eliminated. This type of error is:
 - Also known as bias of the method
 - Known as positive bias when the observed value is greater than the true one
 - Known as negative bias when the observed value is less than the true one
 - Not unusual
 - Recognized through quality control
 - Investigated by trouble-shooting

Random Error is responsible for the imprecision of test performance. The term is also applied to single occurrence accidental errors that can be identified.

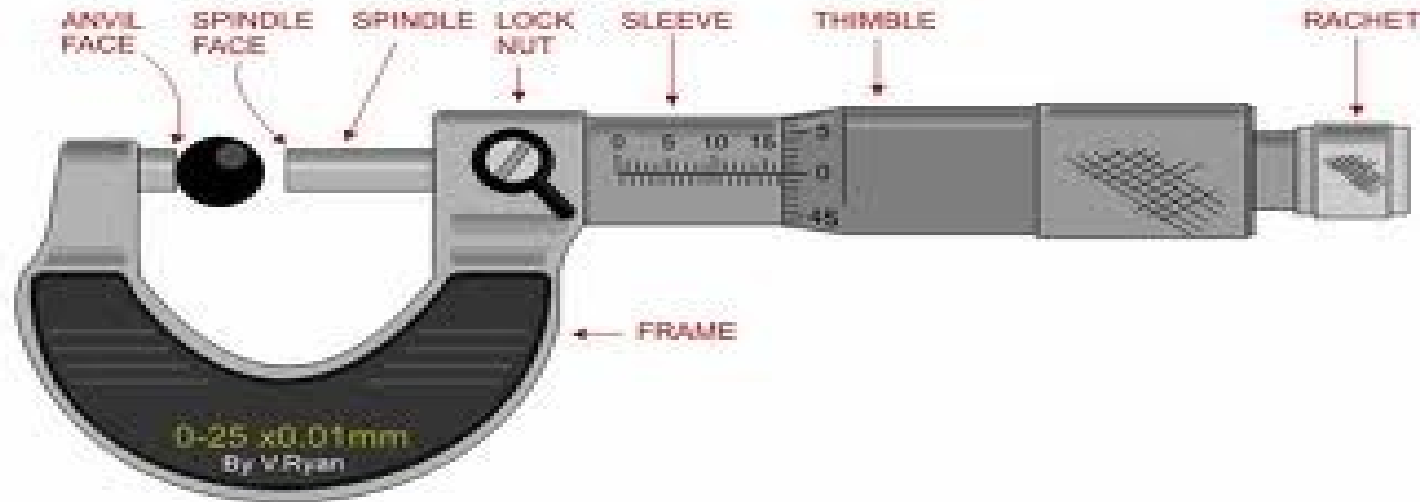
It is a chance event that:

- may be due to sporadic malfunction of any component in the instrument systems and processes of the laboratory;
- often is due to a mistake made by one or more persons;
- is much more difficult to detect than systematic error and frequently the cause is not identified;
- Quality Control and Quality Assurance processes usually fail to detect because of the random nature of the causative event;
- is detected best by a Supervisor's review of reports—looking for 'nonsense' values, other anomalies, or trends in reported values which suggest a drift away from the expected result.

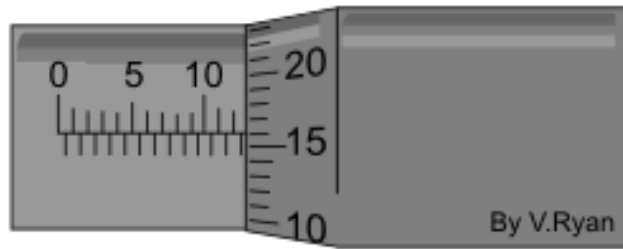


- Environment
 - draughts
 - Temp.or pressure conditions
 - Corrosion on the instrument
 - Magnetic effects in elec. instruments
 - Humidity
 - Vibration
- Instrument
 - calibration
 - Zero error
 - Friction caused by sticking eg pivots
- Experimenter
 - Personal impairments
 - Uncertainty
 - Slow reaction time...repeat process
 - Timing 'off' or miscounts ... take reading several times
- Parallax errors
- Representing results using graphs can help identify odd readings, minimize errors in further calculations

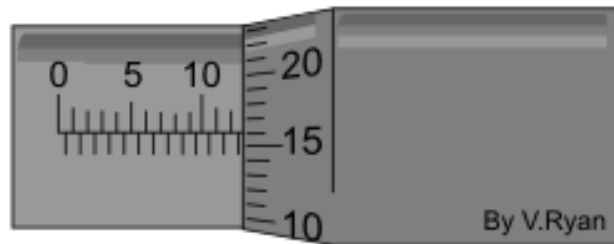
- The micrometer is a precision measuring instrument, used by engineers. Each revolution of the ratchet moves the spindle face 0.5mm towards the anvil face. The object to be measured is placed between the anvil face and the spindle face. The ratchet is turned clockwise until the object is 'trapped' between these two surfaces and the ratchet makes a 'clicking' noise. This means that the ratchet cannot be tightened any more and the measurement can be read.



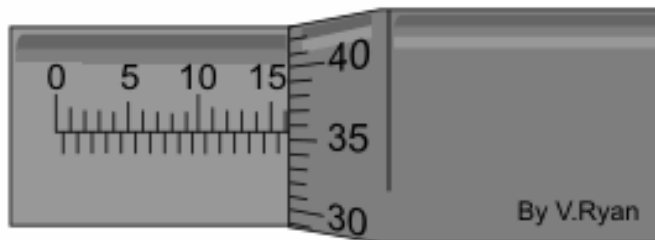
1. Read the scale on the sleeve. The example clearly shows 12 mm divisions.
2. Still reading the scale on the sleeve, a further $\frac{1}{2}$ mm (0.5) measurement can be seen on the bottom half of the scale. The measurement now reads 12.5mm.
3. Finally, the thimble scale shows 16 full divisions (these are hundredths of a mm). The final measurement is $12.5\text{mm} + 0.16\text{mm} = 12.66$



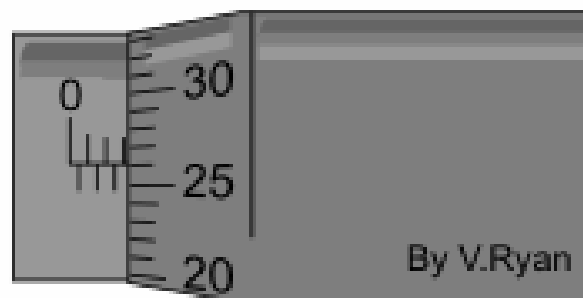
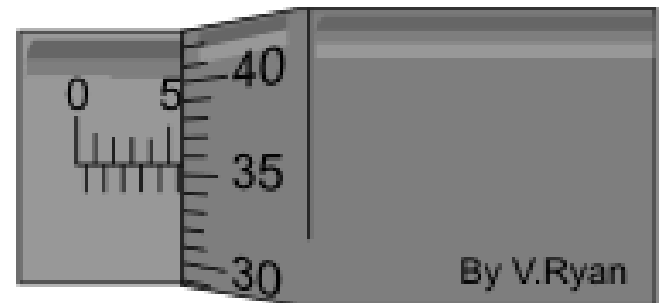
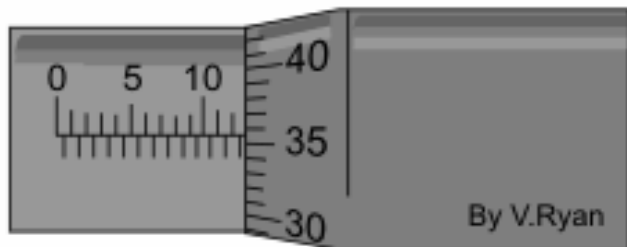
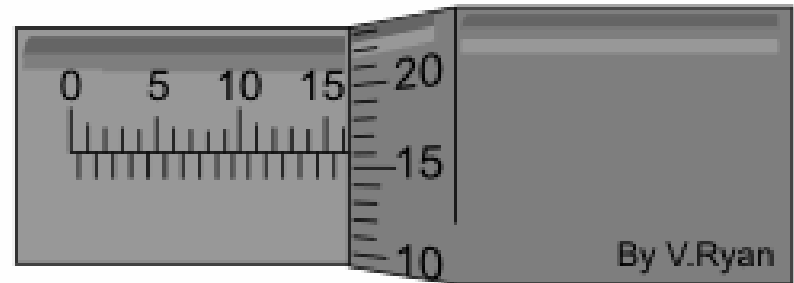
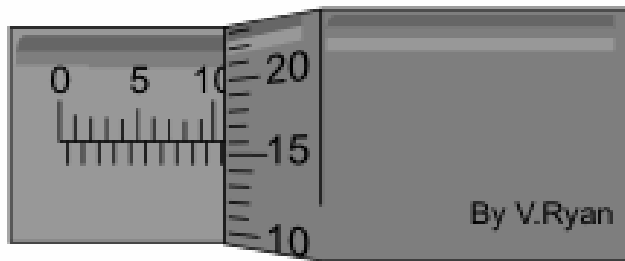
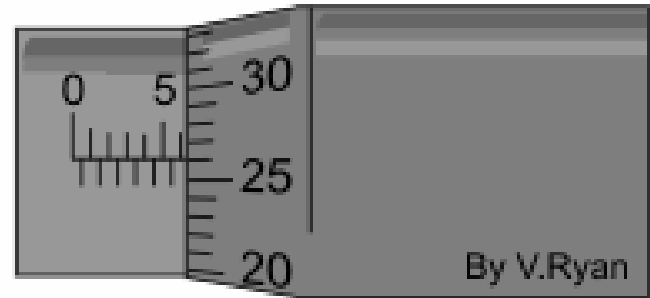
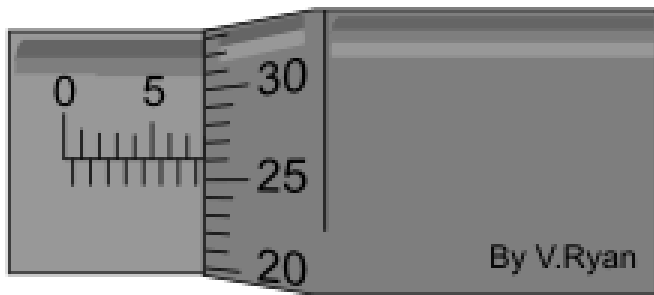
SLEEVE READS FULL mm = 12.00
 SLEEVE READS $\frac{1}{2}$ mm = 0.50
 THIMBLE READS = 0.16
TOTAL MEASUREMENT = 12.66mm



SLEEVE READS FULL mm = 16.00
 SLEEVE READS $\frac{1}{2}$ mm = 0
 THIMBLE READS = 0.355
TOTAL MEASUREMENT = 16.355mm



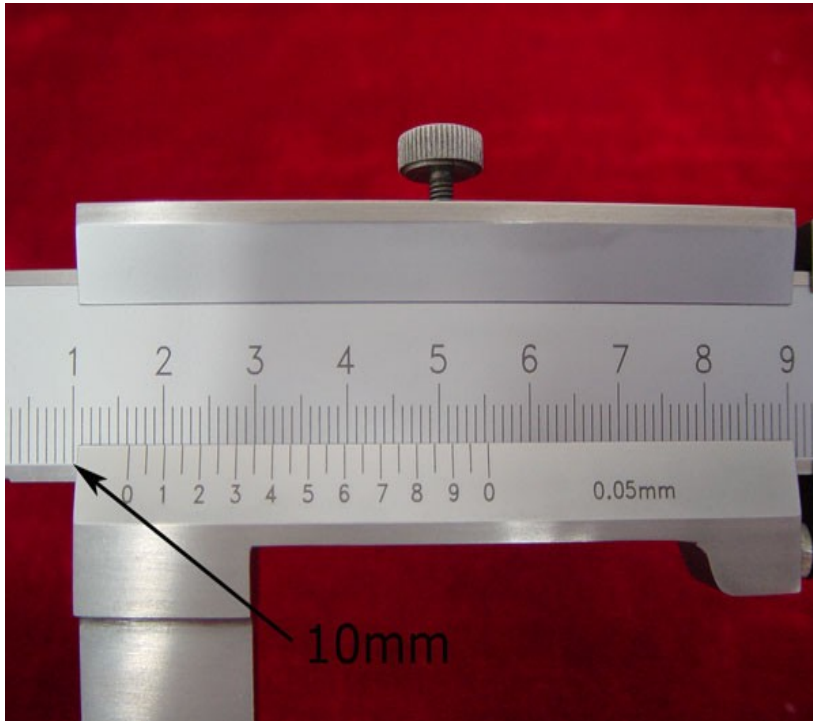
SLEEVE READS FULL mm = 7.00
 SLEEVE READS $\frac{1}{2}$ mm = 0.50
 THIMBLE READS = 0.26
TOTAL MEASUREMENT = 7.76mm



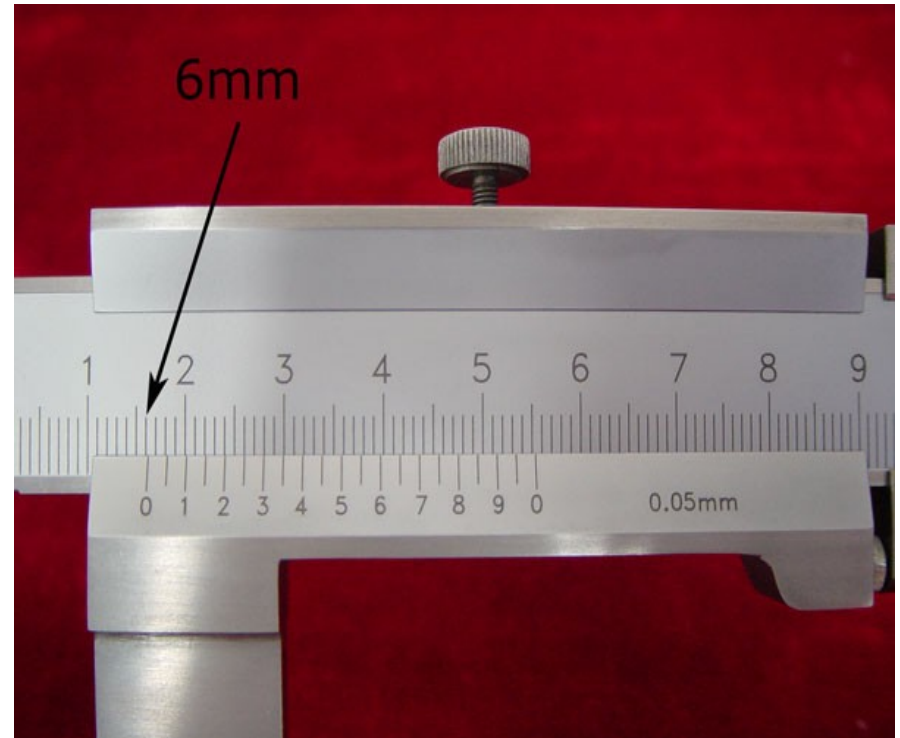
Vernier caliper

- Has jaws you can place around an object, and on the other side jaws made to fit inside an object. These secondary jaws are for measuring the inside diameter of an object. Also, a stiff bar extends from the caliper as you open it that can be used to measure depth.
- The basic steps are as follows:
 1. Preparation to take the measurement, loosen the locking screw and move the slider to check if the vernier scale works properly. Before measuring, do make sure the caliper reads 0 when fully closed. If the reading is not 0, adjust the caliper's jaws until you get a 0 reading. If you can't adjust the caliper, you will have to remember to add to subtract the correct offset from your final reading. Clean the measuring surfaces of both vernier caliper and the object, then you can take the measurement.
 2. Close the jaws lightly on the item which you want to measure. If you are measuring something round, be sure the axis of the part is perpendicular to the caliper. Namely, make sure you are measuring the full diameter. An ordinary caliper has jaws you can place around an object, and on the other side jaws made to fit inside an object. These secondary jaws are for measuring the inside diameter of an object. Also, a stiff bar extends from the caliper as you open it that can be used to measure depth.

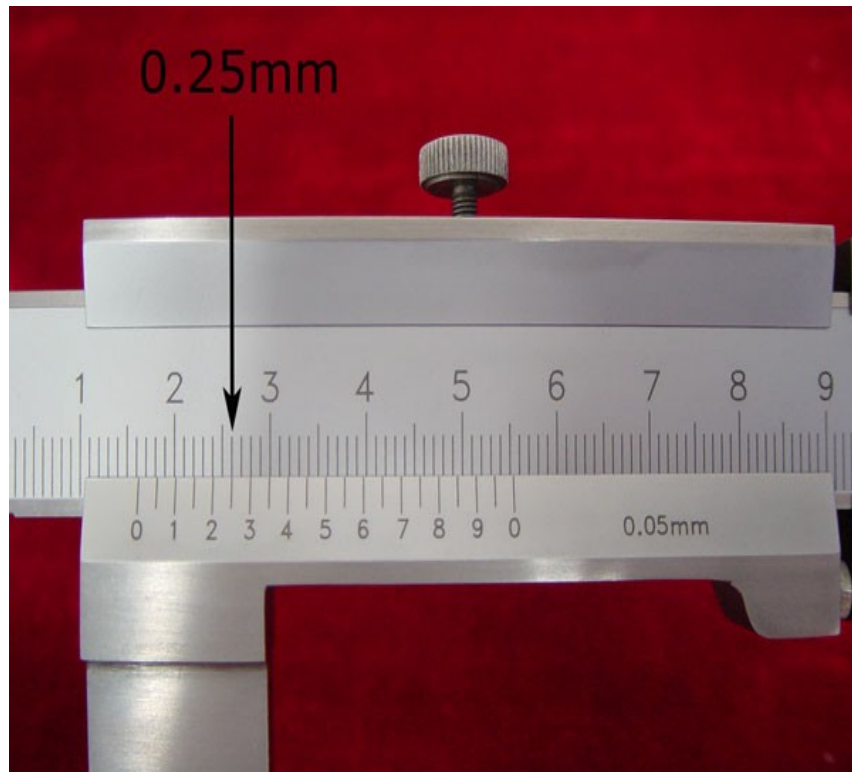
- 1) Read the centimeter mark on the fixed scale to the left of the 0-mark on the vernier scale. (10mm on the fixed caliper)



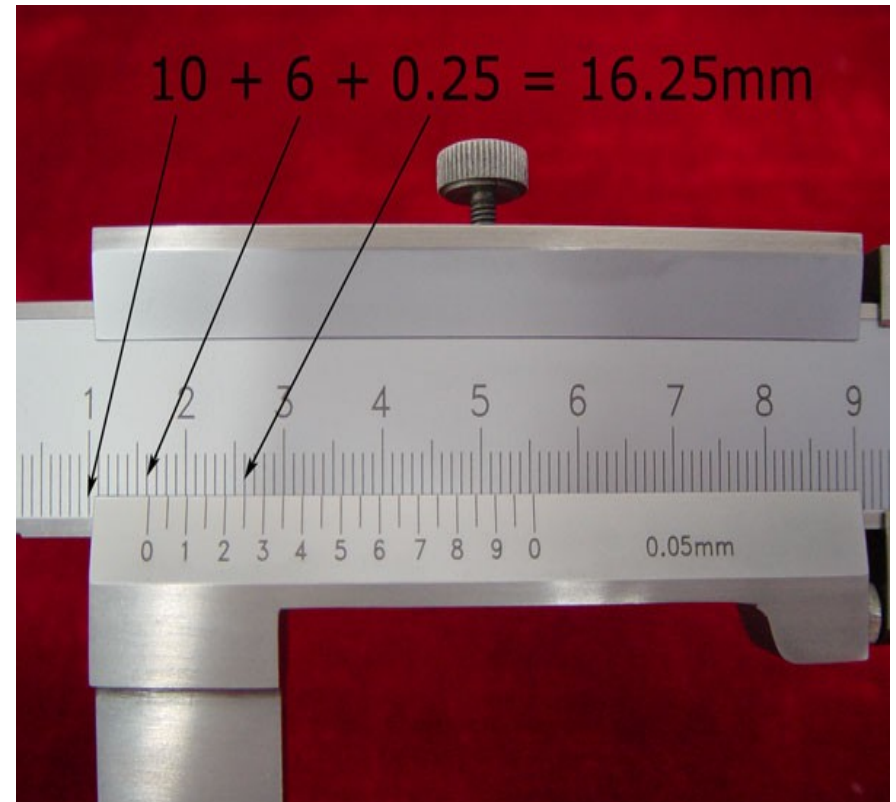
- 2) Find the millimeter mark on the fixed scale that is just to the left of the 0-mark on the vernier scale. (6mm on the fixed caliper)



3) Look along the ten marks on the vernier scale and the millimeter marks on the adjacent fixed scale, until you find the two that most nearly line up. (0.25mm on the vernier scale)



4) To get the correct reading, simply add this found digit to your previous reading. (10mm + 6mm + 0.25mm = 16.25 mm)



4.Maintenance

Clean the surface of the vernier caliper with dry and clean cloth (or soaked with cleaning oil) and stock in a dry environment if it stands idle for a long time.