Measurement Techniques

Quantity	Accuracy	Instrument
Length	1 cm	Tape
	0.1 cm	Ruler
	0.01 cm	Vernier caliper
	0.001 cm	Micrometer screw gauge
Volume	1 cm^3	Measuring cylinder
	0.05 cm^3	Pipette/burette
Time	1 min	Clock
	0.01 sec	Stopwatch
	x-axis scale	Time base of C.R.O
Angle	0.5°	Protractor
Temperature	1 °C	Thermometer
	0.5 °C	Thermocouple
P.d	0.01 V	Voltmeter
Current	0.01 A	Ammeter
	0.0001 A	Galvanometer

Using CRO.

- A Cathode-Ray Oscilloscope is a laboratory instrument used to display, measure and analyse waveforms of electrical circuits
- An A.C. current on an oscilloscope is represented as a transverse wave. Therefore you can determine its frequency and amplitude
- The x-axis is the **time** and the y-axis is the **voltage** (or **y-gain)**

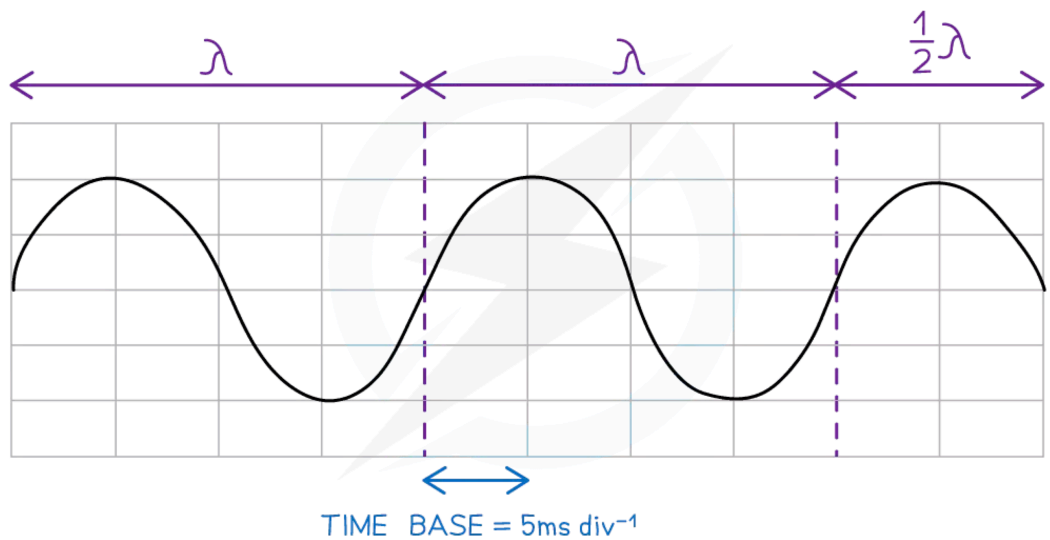


Diagram of Cathode-Ray Oscilloscope display showing wavelength and time-base setting

- The period of the wave can be determined from the **time-base** This is **how many seconds each division represents** measured commonly in **s div^{-1}** or **s cm^{-1}**
- Use as many wavelengths shown on the screen as possible to reduce uncertainties
- Dividing the total time by the number of wavelengths will give the time period *T* (Time taken for one complete oscillation)
- The **frequency** is then determined through **1/T**

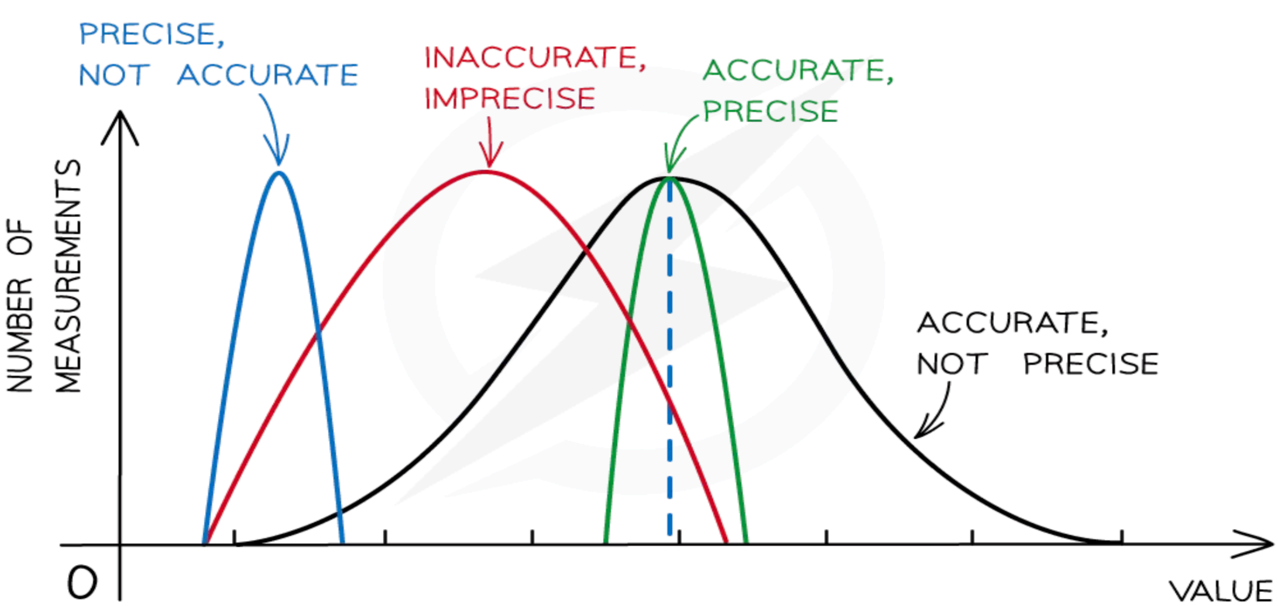
Systematic and Random Errors

Systematic error:

- Constant error in one direction; too big or too small
- Cannot be eliminated by repeating or averaging
- If systematic error small, measurement accurate
- Accuracy: refers to degree of agreement between result of a measurement and true value of quantity.

Random error:

- Random fluctuations or scatter about a true value
- Can be reduced by repeating and averaging
- When random error small, measurement precise
- **Precision:** refers to degree of agreement of repeated measurements of the same quantity (regardless of whether it is correct or not)



Representing precision and accuracy on a graph

Calculation Involving Errors

- **Absolute uncertainty: where uncertainty is given as a fixed quantity.**

  For a quantity $x = (2.0 \pm 0.1)mm$

  Absolute uncertainty $= \Delta x = \pm 0.1mm$

- **Fractional uncertainty: where uncertainty is given as a fraction of the measurement.**

  For a quantity $x = (2.0 \pm 0.1)mm$

  Fractional uncertainty $= \dfrac{\Delta x}{x} = 0.05$

- **Percentage uncertainty: where uncertainty is given as a percentage of the measurement.**

  For a quantity $x = (2.0 \pm 0.1)mm$

  Percentage uncertainty $= \dfrac{\Delta x}{x} \times 100\,\% = 5\,\%$

Combining Uncertainties:

- **Adding / subtracting data – add the absolute uncertainties**

  For example; Diameter of outer layer of tyre$(d_1) = 55.0 \pm 0.5cm$

  Diameter of inner layer of tyre$(d_2) = 20.0 \pm 0.8cm$

  so, difference in diameter $= 55.0 - 20.0cm = 35.0cm$

  and uncertainity in difference $= \pm(0.5 + 0.8)cm = 1.3cm$

  $$\therefore d_1 - d_2 = 35.0 \pm 1.3cm$$

- **Multiplying / dividing data – add the percentage uncertainties**

  For example; Distance $= 50.0 \pm 0.1m$

  Time $= 5.00 \pm 0.05s$

  $$\text{speed(V)} = \frac{Distance(s)}{Time(t)} = \frac{s}{t} = \frac{50.0}{5.00} = 10.0ms^{-1}$$

  $$\frac{\Delta v}{v} = \left(\frac{\Delta s}{s} + \frac{\Delta t}{t}\right) = \left(\frac{0.1}{50.0} + \frac{0.05}{5.00}\right) = 0.012$$

  $$\therefore absolute\ uncertainties(\Delta v) = 0.012 \times 10.0 = \pm\, 0.12ms^{-1}$$

  so, $v = 10.0 \pm 0.12ms^{-1}$

- **Raising to a power – multiply the uncertainty by the power**

For example; $Volume(V) = \frac{4}{3}\pi r^3$

$$r = 2.50 \pm 0.02cm$$

$$V = \frac{4}{3}\pi\left(2.50\right)^3 = 65.5cm^3$$

$$\frac{\Delta V}{V} = \left(3 \times \frac{\Delta r}{r}\right) = \left(3 \times \frac{0.02}{2.50}\right) = 0.024$$

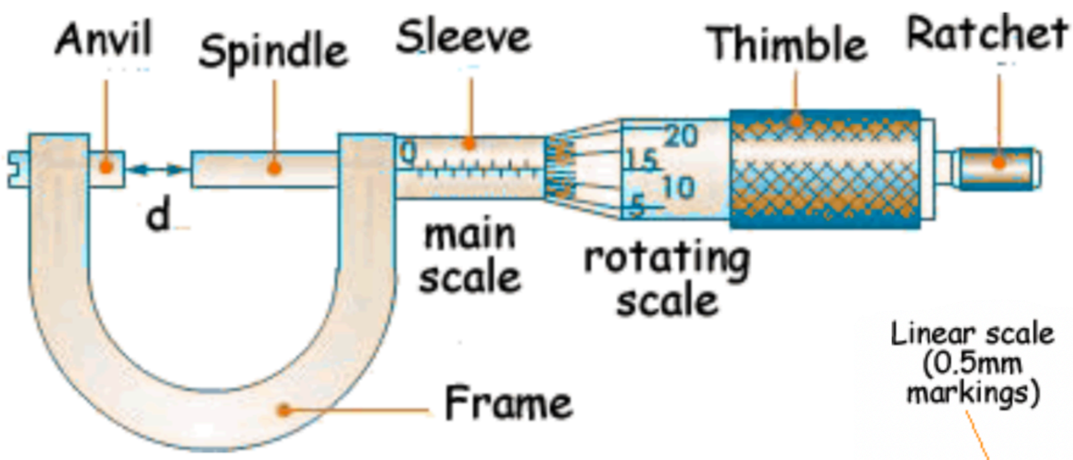
$$\therefore absolute\ uncertainity(V) = 0.024 \times 65.5 = 1.57cm^3$$

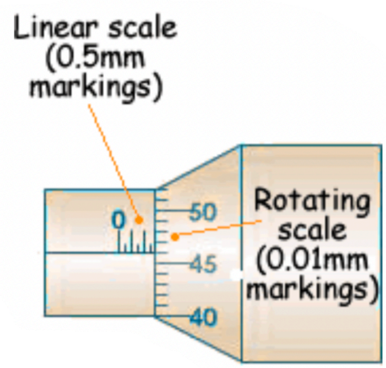
so, $V = 65.5 \pm 1.57cm^3$

Significant Figures

- **Actual error: recorded to only 1 significant figure**
- **Number of decimal places for a calculated quantity is equal to number of decimal places in actual error.**
- **During a practical, when calculating using a measured quantity, give answers to the same significant figure as the measurement or one less.**

Micrometer Screw Gauge





- Measures objects up to 0.01mm
- Place object between **anvil** & **spindle**
- Rotate **thimble** until object firmly held by jaws
- Add together value from main scale and rotating scale

Vernier Scale

Measures objects up to 0.1mm

- Place object on rule
- Push slide scale to edge of object.
- The sliding scale is 0.9mm long & is divided into 10 equal divisions.
- Check which line division on sliding scale matches with a line division on rule
- Subtract the value from the sliding scale ($0.09 \times Divisions$) by the value from the rule.