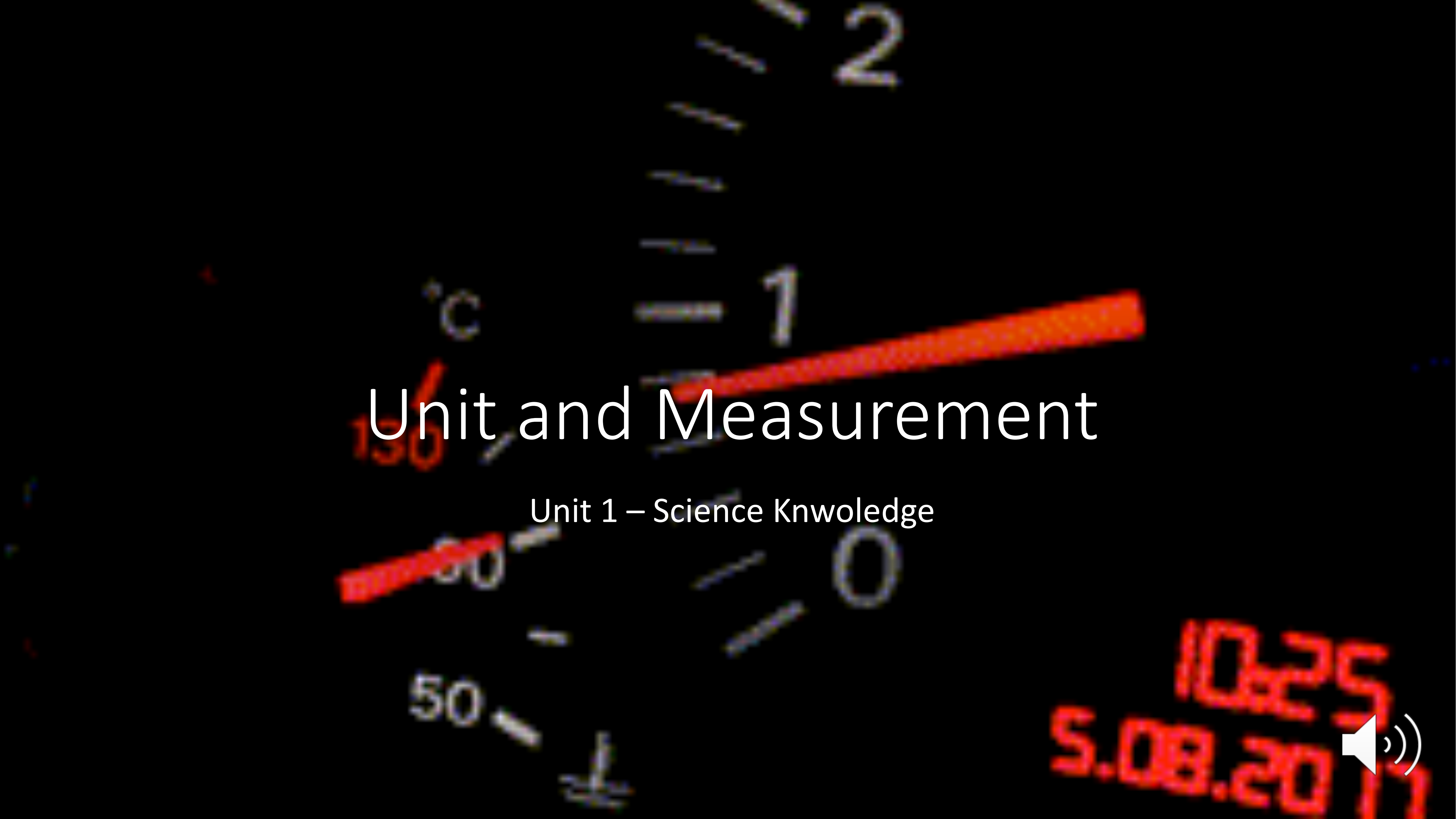


Unit and Measurement

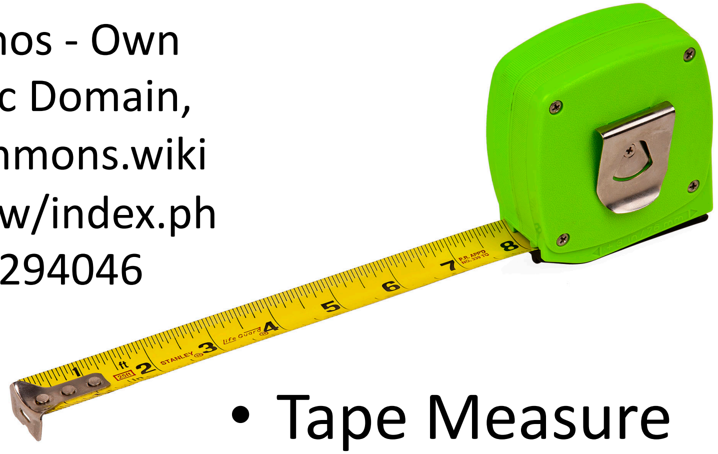
Unit 1 – Science Knwoledge

Learn Objectives

- Know different measurement and know how to use them
- Understand the SI System
  - SI Base Units
  - Meter, kg, L, mL, etc
- Unit Conversion
- Know significant figures
- Know and understand different types of errors
- Know how to calculate average value and uncertainty

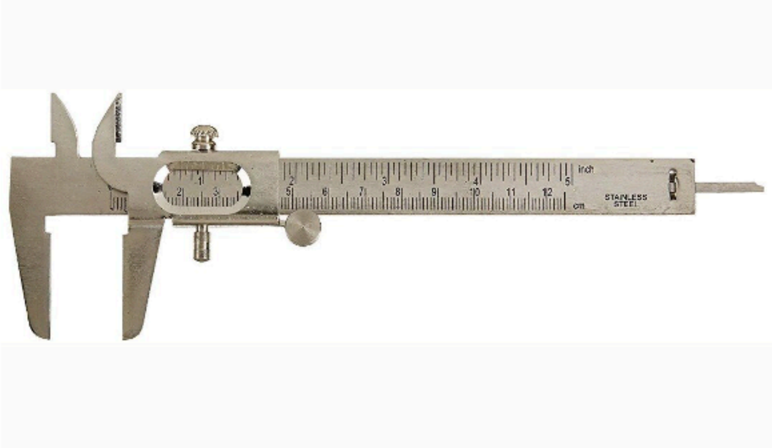
Measurement Tools

- Micrometer



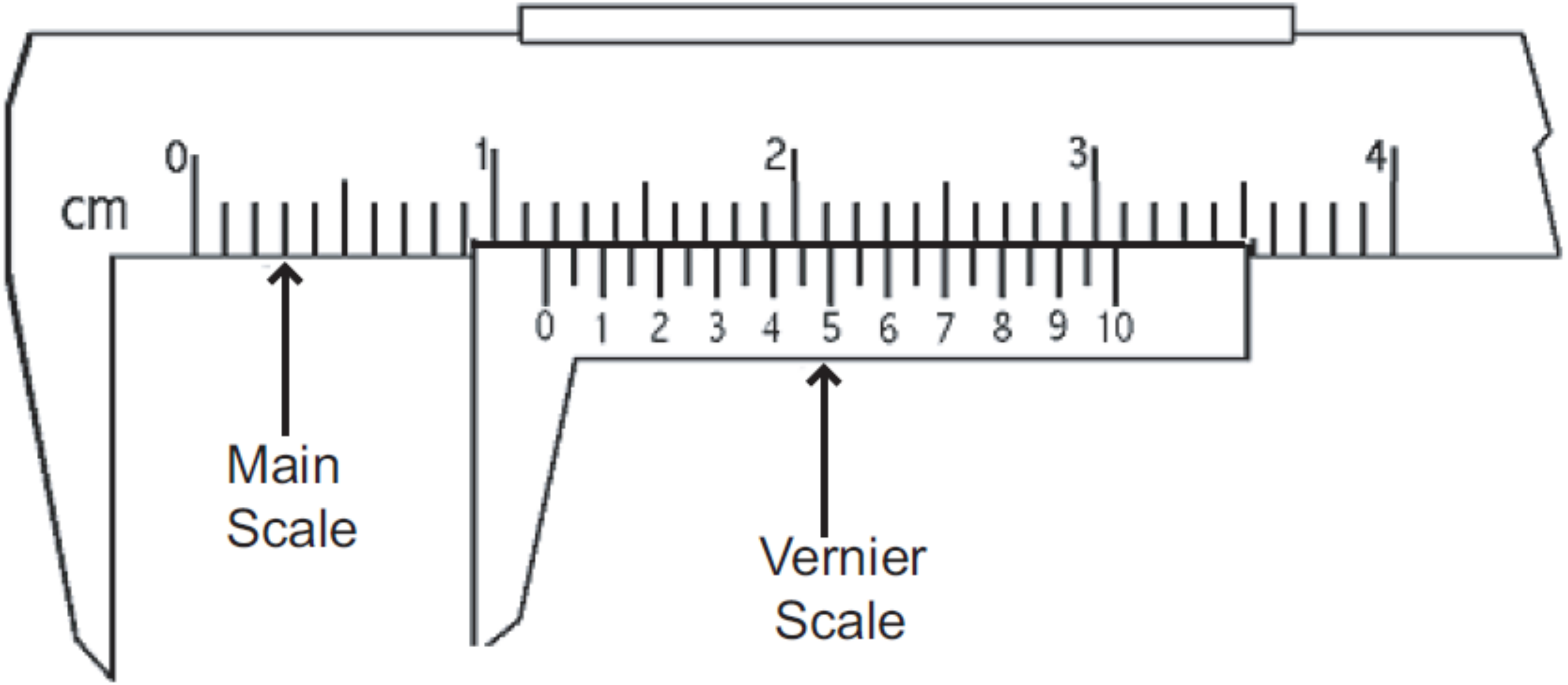
- Tape Measure

vernier caliper



- Tape Measure

Vernier Caliper



Read a Vernier Caliper

- Follow these steps to read the vernier scale:
- Read the main scale. (Last whole increment visible before the 0 (zero) mark)
- Read the secondary scale measurement. (Division that lines up best with a mark on the main scale.)
- Add the two measurements together.

Significant Figures

- The number of figits used to express a number carries information about how precise the number is known

Counting Significant Number

Number	Significant number	Why?	Scientific Motation
786	3	In a integer, all digits count if the last digit is not zero.	7.86×10^{2}
859000	3	Zero at the en does not count because its reliability is uncertainty. For example 859999.999999 = 859000	8.59×10^{5}
100	1	Zero at the en does not count because its reliability is uncertainty.	1×10^{2}
0.004900	4	Zero at the end count, those at the front does not count	4.9×10^{-3}
8.38485×10^{5}	6	Cuase 8.38485 has six significant digits	8.38485

Uncertainty and Errors

Types of Uncertainty

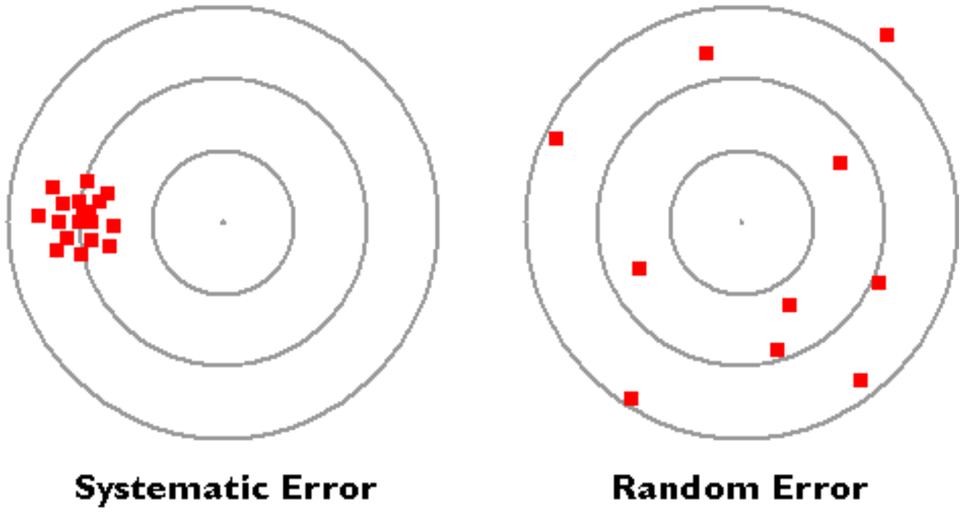
- Systematic and random

Systematic Error: A systematic is a consistent, repeatable error

- E.g: If you use a ruler to measure the length of a book, the ruler itself might contain some measuring inaccuracy

Random Error

- Random Error: Error caused by unknown and unpredictable changes in the experiment. These changes may occur in the measuring instruments or in the environmental conditions.
- E.g: You record the amount of time for a student to run 100 meters, but you might start the timer earlier or later, causing random error.



Reduce Random Error

- Doing repeated measurement (Multiple trials of experiment)
- Take an average value of multiples trails of data to get a more accurate estimate of the result.
- Calculate uncertainty: reading uncertainty = $\pm$ half of its samllest precision
  - There might be reading uncertainty when you are measuring
  - Precision refers to the closeness of two or more measurements to each other

Reading Uncertianty

- Best estimate $\pm$ uncertainty
  - Always round the experimental measurement or result to the same decimal place as the uncertainty
- For Example
  - 54.6mL $\pm$ 0.05ml is wrong
  - 54.60mL $\pm$ 0.05ml is correct

  - **Wrong**: 1.237 s ± 0.1 s
    Correct: 1.2 s ± 0.1 s

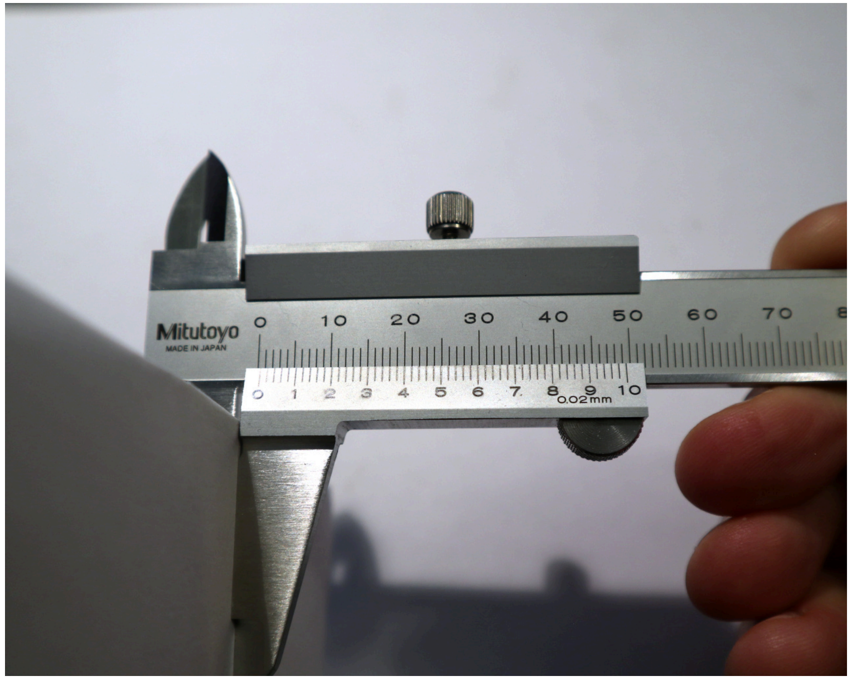
Reading Uncertainty Example

- The smallest precision of the beaker is 25mL. The uncertainty is 25mL/2 = 12.25 mL
- The volum of the liquid is somewhere between 175mL and 200 mL.
- The average value = (175 +200)/2 = 187.50 mL
- Reading with uncertainty: 187.50mL$\pm$12.25mL

Uncertainty Table

Usually

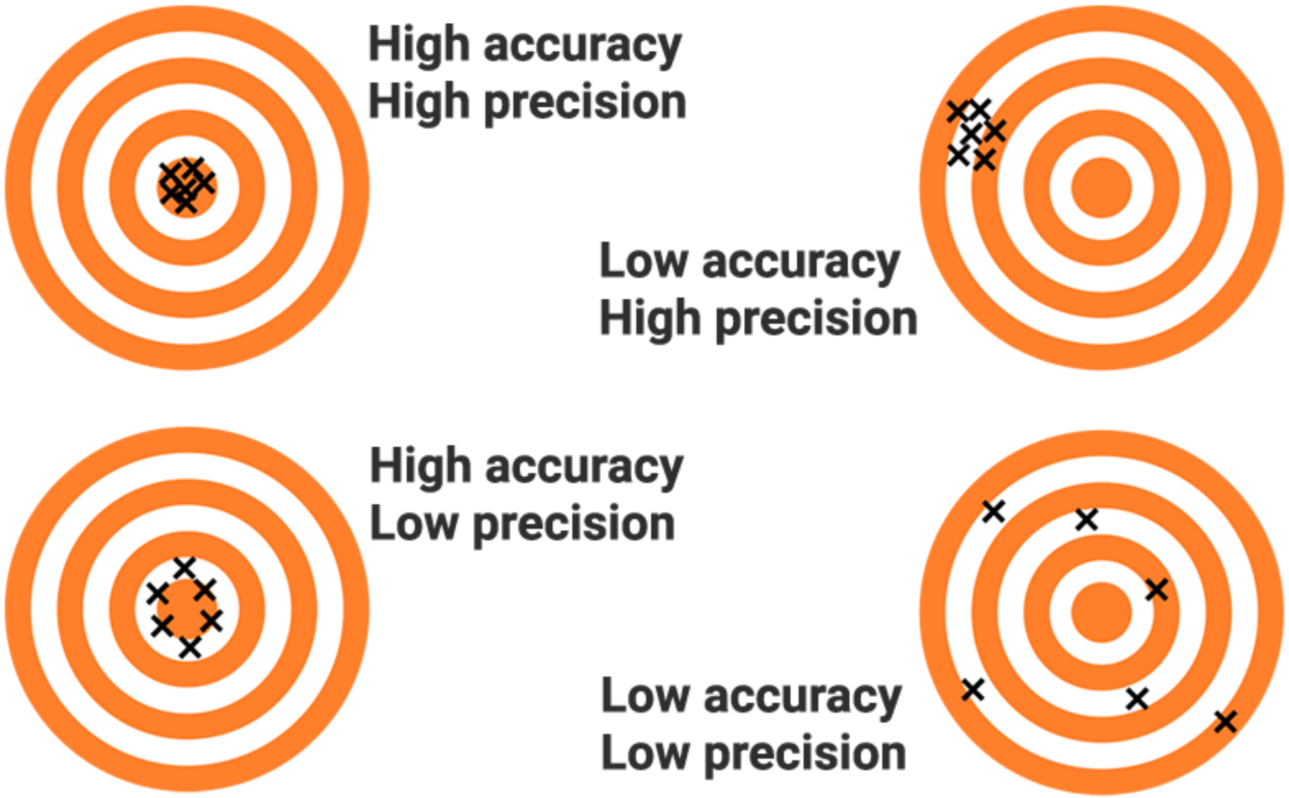
- Ruler: $\pm 0.05mm$
- Vernier calipers: $\pm$ 0.05mm
- Micrometer: $\pm$ 0.005mm



- The above measuring tools' uncertainties might changes
- The table only shows the fruquent cases

Accuracy And Precision

- Accuaracy: How close to the ture/theoretical value
- Precison: is the closeness of the measurements to each other.



Average, Uncertainty

- $\frac{sum\ of\ all\ terms}{number\ of\ terms} = \frac{x_1+x_2+x_3+\cdots+x_N}{N} = \bar{x}$
- The average is the best estimate for the quantity x based on N measurement.
- $\Delta x = \frac{x_{max}-x_{min}}{2}$

Example 1

Length of a string are listed below

- 163,173,165, 164, 124, 178, 195, 187, 175, 174 (in cm)
- Average Value = $\frac{163+173+165+164+124+178+195+187+175+174}{10}$ = 169.8cm
- Uncertainty = $\frac{195-124}{2}$ = 35.5cm
- Result: 169.8cm$\pm$ 35.5 cm

Calculate the average value and uncertainty

Example 2

Pressure (Pa)	Pressure (Pa)	Pressure (Pa)
101504.0	101560.3	101567.1
101459.0	101541.0	101527.0
101435.6	101511.6	101511.6
101416.8	101493.1	101492.6
101396.6	101472.2	101471.8
101377.6	101454.0	101455.3
101356.5	101428.7	101431.6
101334.1	101413.6	101410.4
101319.5	101392.1	101389.6
101296.7	101367.1	101374.0

Example 2

Pressure	Pressure	Pressure	Max Pressure	Min Pressure	Pressure Uncertainty	Average Pressure
101504.0	101560.3	101567.1	101567.2	101503.9	31.6	101535.5
101459.0	101541.0	101527.0	101541.0	101459.0	41.0	101500.0
101435.6	101511.6	101511.6	101511.6	101435.6	38.0	101473.6
101416.8	101493.1	101492.6	101493.1	101416.8	38.1	101455.0
101396.6	101472.2	101471.8	101472.2	101396.6	37.8	101434.4
101377.6	101454.0	101455.3	101455.3	101377.6	38.9	101416.4
101356.5	101428.7	101431.6	101431.6	101356.4	37.6	101394.0
101334.1	101413.6	101410.4	101413.7	101334.1	39.8	101373.9
101319.5	101392.1	101389.6	101392.1	101319.5	36.3	101355.8
101296.7	101367.1	101374.0	101374.0	101296.7	38.7	101335.4

Propagation of Uncertainties

- 28.3cm ± 0.4 cm
  - 28.3 cm is the best estimate/mean value/average value, and 0.4 cm is the absolute uncertainty
  - $\frac{absolute\ value}{mean\ value}$ = fractional uncertainty = $\frac{0.4}{28.3}$ = 0.0141
  - Percentage uncertainty = 0.0141 x 100% = 1.41%

Propagation of Uncertainties

In General

- Absolute uncertainty = Δa
- Fractional uncertainty = $\frac{\Delta a}{a}$
- Percentage uncertainty = $\frac{\Delta a}{a} \times 100\%$

$a \pm \Delta a$

Best estimate $\pm$uncertainty

Uncertainty-Addition and Subtraction

- Calculate the estimate values, then $\pm$ all absolute uncertainty

Example

- A = 3.56 $\pm$ 0.23
- B = 193.34 $\pm$ 2.20
- A + B = (3.56+ 193.34) $\pm$ (0.23+2.20)
- B-A = (193.34- 3.56) $\pm$ (0.23+2.20)

Multiplication and Division

- Q = ab → $\frac{\Delta Q}{Q_o} = \frac{\Delta a}{a_o} + \frac{\Delta b}{b_o}$
- Q = $\frac{a}{b}$ → $\frac{\Delta Q}{Q_o} = \frac{\Delta a}{a_o} + \frac{\Delta b}{b_o}$
- Q = $\frac{ab}{c}$ → $\frac{\Delta Q}{Q_o} = \frac{\Delta a}{a_o} + \frac{\Delta b}{b_o} + \frac{\Delta c}{c_o}$

Work Example

- The side of a rectangle is measured to be a= 2.5cm± 0.1cm, and b=5.0cm $\pm$0.1cm. Find the area A of the reatangle

Work Example

- The side of a rectangle is measured to be a= 2.5cm$\pm$0.1cm, and b=5.0cm $\pm$0.1cm. Find the area A of the reatangle
- $\frac{\Delta a}{a_o} = \frac{0.1}{2.5} = 0.04 \text{ or } 4\%$
- $\frac{\Delta b}{b_o} = \frac{0.1}{5.0}$ = 0.02 or 2%
- $\frac{\Delta A}{A_o}$ = 0.04 +0.02 = 0.06
- A_o=(2.5×5.0) = 12.5 cm^2
- ΔA = (0.06)×(12.5) = 0.75cm^2

Final Answer

12.5 $cm^2 \pm 0.75cm^2$

Powers and Roots

- Q = a^b → $\frac{\Delta Q}{Q_o}$ = |b| $\frac{\Delta a}{a_o}$
- Q = $\sqrt[n]{a}$ → $\frac{\Delta Q}{Q_o} = \frac{1}{|n|} \times \frac{\Delta a}{a_o}$

Worked Example

- The length of a simple pendulum L is increased by 4%. What is the fractional increase in pendulum's period T. Given that T=$2\pi\sqrt{\frac{L}{g}}$

Worked Example

- The length of a simple pendulum L is increased by 4%. What is the fractional increase in pendulum's period T. Given that T=$2\pi\sqrt{\frac{L}{g}}$
- $\frac{\Delta T}{T_O} = \frac{1}{2} \times \frac{\Delta L}{L_O} = \frac{1}{2} \times 4\% = 2\%$
- The fractional increase in pendulum's period T in 2%

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