Chapter 1: Introduction to Physics

What is Physics?

- Branch of science that studies the physical world (from atoms to the universe);
- Study of the nature of matter and energy and how they are related;
- Ability to understand or predict the outcome of activities occurring around you;
- Mathematics is the "language" of physics.

How do physicists study problems?

- Ask questions, researching, experimentation;
- Use mathematics to develop theories to explain experimental data;
- Apply the scientific method - all scientists study problems in an organized manner, using many techniques (Galileo Galilei).

Why learn Physics?

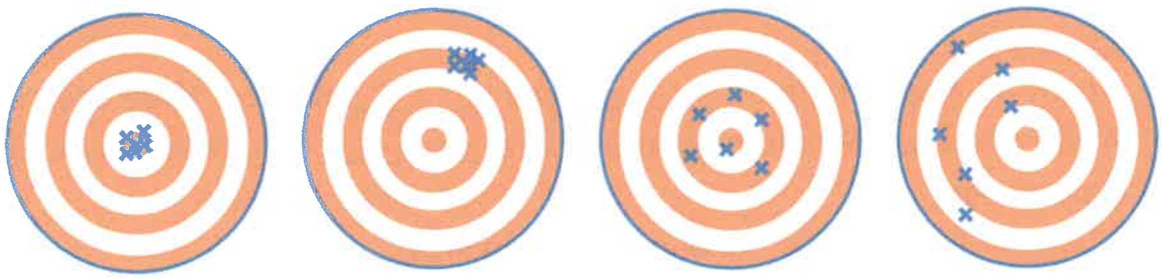
- Career preparation;
- Improve problem-solving skills;
- Better able to make informed decisions about questions related to science and technology.

Accuracy and Precision

- Exact numbers arise from counting.
- Measured quantities are approximate.
- Uncertainty of measurements depends on:

   a) skill of the measurer;
   b) size of the smallest unit on the measuring device;
   c) parallax.

- Precision refers to the degree of exactness of a measurement.
  * how many decimal places
- Accuracy is an indication of how close a measured value comes to the true value.

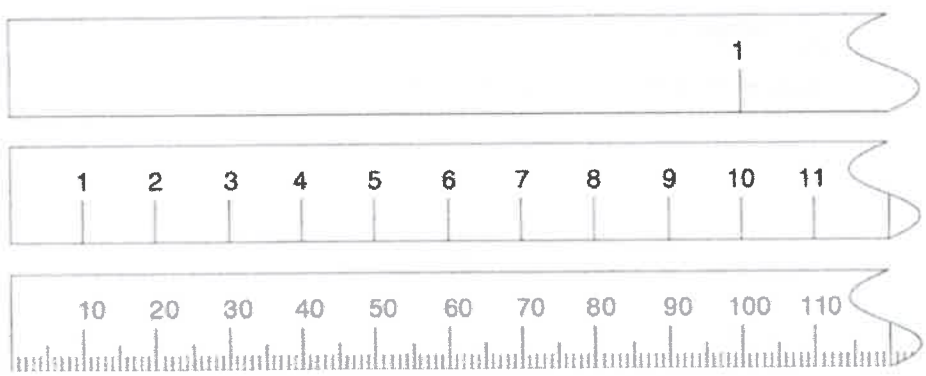


High Accuracy High Precision | Low Accuracy High Precision | High Accuracy Low Precision | Low Accuracy Low Precision

Because the precision of all measuring devices is limited, the number of digits that are valid for any measurement is also limited. Valid digits are called significant figures.

more precise

even more precise!



Significant Figures

- Digits that are certain plus a digit that estimates the fraction of the smallest unit of the measuring scale.
- Written measured quantities express:

  a) Quantity;

  b) Degree of precision.

Rules for Significant Figures:

1) Non-Zeros digits are always significant.

e.g., 26.837 m (5 significant figures - sf)

2) All final zeros after the decimal are significant.

e.g., 56.00 mm (4 sf)

3) Zeros between other significant digits are always significant.

e.g., 1 000 001 m (7 sf)
107.00 s (5 sf)

4) Zeros used solely for spacing the decimal can not be considered significant. *(This is the difficult rule :))*

e.g., 186 km is the same as 186 000 m (still 3 sf)
3.0 mm is the same as 0.0030 m (still 2 sf)

In other words, any zeros **after** the last non-zero number in a WHOLE NUMBER are not significant.

2.4 km is the same as 2400 m (still 2 sf)
3 000 000 g is the same as 3 Mg (still 1 sf)

Any zeros before the first non-zero number in a DECIMAL are not significant.

32 mg = 0.0032 g (still 2 sf)
0.02050 m = 2.050 cm (4 sf)

*** To avoid confusion, express in scientific notation:

1.86×10^5 m (3 sig. figs.)
1.860×10^5 m (4 sig. figs.)
3.0×10^{-3} m (2 sig. figs.)

Practice:

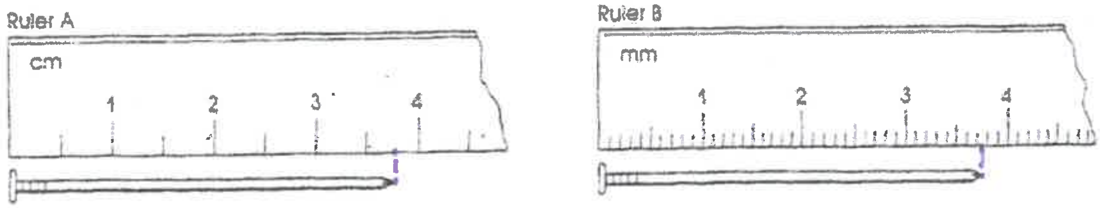
1. 2804 m 4 sf
2. 284 m 3 sf
3. 0.0029 m 2 sf
4. 0.003068 m 4 sf
5. 4.60×10^5 m 3 sf
6. 783 100 kg 4 sf

Accuracy and Precision

Accuracy is an indication of how close a measured value comes to the true value. Precision refers to the amount of uncertainty in the measurement. A mass reading such as 3.52 g, that has three significant digits, for example, is more precise than a reading such as 3.5 g, that has only two significant digits.

Two identical nails are placed alongside the scale of two different centimeter rulers, as illustrated below.

Ruler A Ruler B



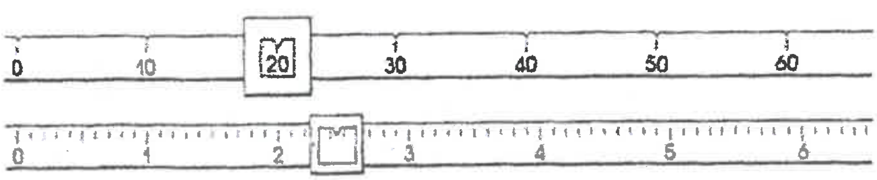
1. Complete the following chart.

	RULER A	RULER B
Smallest division of ruler	0.5cm	1mm
Length of nail as measurable on ruler	3.8cm	3.75cm or 37.5mm
Number of significant digits	2sf	3sf
Uncertainty (± cm)	±0.1cm	±0.01cm

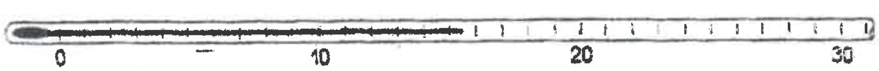
2. Which ruler allows for the more precise measurement? B Why?
The divisions on the ruler are smaller, allowing for a more precise measurement.

3. A micrometer determines that the actual length of the nail is 3.8001 cm. Which of the above measurements is more accurate? A Why?
The measurement 3.8cm is closer to 3.8001cm than 3.75cm → closer to the "true" value.

4. Read the mass shown on the balance diagram below. Record to the nearest 0.01 g. 22.43g



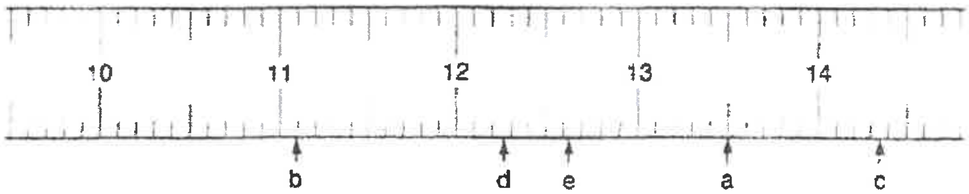
5. Read the temperature shown on the diagram of a metric thermometer. Record to the nearest 0.1°C:
15.5°C



For the instruments shown below, record the correct reading.

1.

Metric Ruler

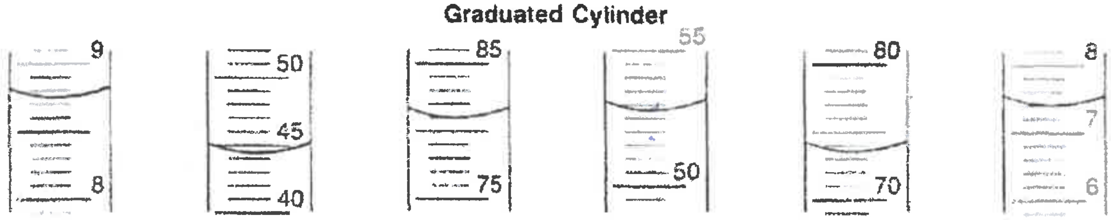


a. 13.50 cm b. 11.10cm c. 14.36cm d. 12.27cm e. 12.62cm

Balance

2.

Graduated Cylinder



a. 8.75mL b. 44.5mL c. 81.0 mL d. 52.7mL e. 73.5mL f. 7.40 mL

Types of Errors in Measurements

- **Systemic Errors:** inaccuracies due to the measuring instrument

  Ex. 1 End of metre stick is worn away (measurements would be high)

  Ex. 2 Mass balance hasn't been calibrated so that it always reads high

- **Random Errors:** inaccuracies due to estimation/variation

  Ex. 1 Four measurements taken on the width of your textbook could be

  0.126 m, 0.123 m. 0.122 m and 0.121 m.

  Ex.2 Variations on desk surface can affect sliding friction of wooden block

- **Other Errors:** Inaccuracies due to interaction between the experimenter and the instrument (starting timer too late; not waiting for thermometer to reach equilibrium before reading)

Operations with Significant Figures

The result of any mathematical operation with measurements can never be more precise than the least precise measurement.

Addition and Subtraction

- Round off the calculation to correspond with the least **precise** measurement.
- Significant figures after the decimal point should never be **more** than the least precise measurement.

i.e.,

$$\begin{array}{r} 24.686\ \text{m} \\ 2.343\ \text{m} \\ +3.21\ \ \text{m} \\ \hline 30.289\ \text{m} \end{array}$$

+3.21 m ← nearest hundredth

30.289 m ↩ Round up

= 30.29 m ← nearest hundredth

i.e., 5.65×10^2 m – 1.56 m

= 565 m – 1.56 m ← nearest whole metre

= 563.44 m

= 563 **m** ← Nearest whole metre

Multiplication and Division

- Round off calculation to have the Same **number** of significant figures as the **factor** with the least significant figures.
- Units are also either multiplied or divided (and sometimes cancelled out).

i.e.,

$$\begin{array}{r} 3.22\ \text{cm} \\ \times\ \ 2.1\ \text{cm} \\ \hline 6.762\ \text{cm}^2 \end{array}$$

3.22 cm ← 3 s.f.

2.1 cm ← 2 s.f.

= 6.8 cm^2 ← 2 s.f.

i.e., $\dfrac{36.5\ \text{m}}{3.414\ \text{s}}$

36.5 m ← 3 s.f.

3.414 s ← 4 s.f.

= 10.691 m/s

= 10.7 **m/s** ← 3 s.f.

Practice:

1. Add (a) 6.201 cm, 7.4 cm, 0.68 cm, and 12.0 cm

$$6.201\ cm + 7.4\ cm + 0.68\ cm + 12.0\ cm = 26.281\ cm$$

12.0 cm ← least precise (nearest tenth)

$= 26.3\ cm$

(b) 12.6 m, 1.7×10^2 m

$$12.6\ m + 170\ m = 182.6\ m$$

170 m ← precise to nearest "10s"

$= 180\ m$ or $1.8 \times 10^2\ m$

2. Subtract (a) 8.264 g from 10.8 g

$$10.8\ g - 8.264\ g = 2.536\ g$$

10.8 g ← nearest tenth

$= 2.5\ g$

(b) 0.4168 m from 475 m

$$475\ m - 0.4168\ m = 474.58\ m$$

475 m ← nearest whole metre

$= 475\ m$

3. Multiply (a) 131 cm x 2.3 cm

2.3 cm ← 2 s.f.

$= 301.3\ cm^2$

$= 3.0 \times 10^2\ cm^2$ (2 s.f.)

↑ Need sci. not. to express!

(b) 3.2145 km x 4.23 km

4.23 km ← 3 s.f.

$= 13.597\ km^2$

$= 13.6\ km^2$

4. Divide (a) 20.2 cm by 7.41 s

$2.726\ cm/s$

$= 2.73\ cm/s$

3 s.f.

(b) 3.1416 cm by 12.4 s

$0.25335\ cm/s$

$= 0.253\ cm/s$

Additional Practice

1. **Add or Subtract:**

a) 94.2953 + 53.641 + 89.8 = 237.7 (1 dec)

b) 4.37 + 12.8 = 17.2 (1 dec)

c) 6.18 + 54.762 = 60.94 (2 dec)

d) 28.3 - 4.3 = 24.0 (1 dec)

e) 65.5 - 41.641 = 23.9 (1 dec)

f) 7.92 + 3.465 + 25.22 = 36.61 (2 dec)

g) 58.831 - 6.6467 = 52.184 (3 dec)

h) 3.4 + 5.49 + 63.293 = 72.2 (1 dec)

i) 7.283 + 35.328 + 21.57 = 64.18 (2 dec)

j) 96.83 - 78.1 = 18.7 (1 dec)

k) 5.8 + 14.978 = 20.8 (1 dec)

l) 7.3413 - 2.341 = 5.000 (3 dec)

2. **Multiply or Divide:**

a) 4 x 752 = 3000 (1sf)
1sf

b) 0.032 x 14.90 = 0.48 (2 s.f.)
2sf

c) 48.74 x 0.0090 x 3100 = 1400 (2sf)
2sf 2sf

d) 0.62 x 8.3 = 5.1 (1 s.f.)
2sf

e) 0.0036 x 917 = 3.3 (2sf)
2sf

f) 0.05 x 53.6 x 3000 = 80 000 (1 sf)
1sf

g) 107 ÷ 96.66 = 1.11 (3sf)
3sf

h) 68.6 x 0.34 = 23 (2 sf)
2sf

i) 9090 ÷ 66.88 = 136 (3sf)
3sf

j) 50 ÷ 8.697 = 6 (1 sf)
1sf

k) 5800 ÷ 21.6 = 270 (2sf)
2sf

l) 14 x 0.004 = 0.06 (1sf)
1sf

Scientific Notation

- Used for very large or very small quantities
- The numerical part of a measurement is expressed as a number between 1 and 10 and multiplied by a whole number power of 10.

$$M \times 10^n$$

Where: $1 < M < 10$

n = integer

- Move decimal until 1 non-zero number remains on the left.

Examples: 5800 m = 5.8×10^3 m Larger by 3

0.000508 m = 5.08×10^{-4} m Reduced by 4

"Left is Larger, Right Reduce" (the Exponent)

Operations in Scientific Notation

Addition/Subtraction with Like Exponents

a) 4×10^8 m + 3×10^8 m = 7×10^8 m

b)

$$\begin{array}{r} 6.2 \times 10^{-3}\text{ m} \\ -\ \ 2.8 \times 10^{-3}\text{ m} \\ \hline 3.4 \times 10^{-3}\text{ m} \end{array}$$

Addition/Subtraction with Unlike Exponents

- convert measurements to a common exponent, then add or subtract.

a) 4.0×10^6 m + 3.0×10^5 m

= 4.0×10^6 m + 0.30×10^6 m * FIX 1 dec

= 4.3×10^6 m ← Round to 1 dec.

b) 4.0×10^{-6} kg − 3.0×10^{-7} kg

= 4.0×10^{-6} kg − 0.30×10^{-6} kg Least precise is tenth

= 3.7×10^{-6} kg

- all measurements need to be in the same units.

Multiplication Using Scientific Notation

- Multiply the values and add the exponents;
- units are multiplied.

Example:

$(3 \times 10^{6}\ m)(2 \times 10^{3}\ m)$
$= 6 \times 10^{((6+3)}\ m^{2}$
$= 6 \times 10^{9}\ m^{2}$

Division using Scientific Notation

- Divide the values and Subtract the exponent of the divisor from the exponent of the dividend.
- Units are divided.

Example:

$\frac{8 \times 10^{6}\ m}{2 \times 10^{3}\ s} = 4 \times 10^{3}\ m/s$

$\frac{8 \times 10^{6}\ kg}{2 \times 10^{-2}\ m^{3}} = 4 \times 10^{8}\ kg/m^{3}$

Practice:

1\. a) 2.0×10^{-6}m + 3.0×10^{-7}m

2.0×10^{-6}m
+ 0.30×10^{-6}m
2.3×10^{-6} m

b) 2.0×10^{6}m + 3.0×10^{7} ← 1 dec

0.20×10^{7}m + 3.0×10^{7}m
= 3.2×10^{7}m

2\. a) 3.04×10^{2}g - 4×10^{0}g

304 g - 4g
= 300g
= 3.00×10^{2}g

* Need sci. not. to show it is exactly 300g (3 s.f.)

b) 3×10^{-2} g - 2×10^{-3}g

0.03 g ← nearest hundredth
- 0.002 g
0.028g
= 0.03g ← nearest hundredth (1 s.f.) or 3×10^{-2}g

3. a) (2×10^{4}m)(4×10^{8}m)

= 8×10^{12} m^2

b) (6×10^{-4}m)(2×10^{-8}m)

= 12×10^{-12} m^2
= 1.2×10^{-11} m^2

4. a) $\dfrac{6 \times 10^{8}\ kg}{2 \times 10^{4}\ m^3}$

= 3×10^{4} kg/m^3

b) $\dfrac{6 \times 10^{-5}\ m}{3 \times 10^{3}\ s}$

= 2×10^{-8} m/s

5. a) $\dfrac{(3 \times 10^{4}\ kg)(4\times10^{4} m)}{6 \times 10^{4}\ s}$

= 2×10^{4} kg·m/s

b) $\dfrac{(2.5 \times 10^{6}\ kg)(6\times10^{4} m)}{5 \times 10^{-2}\ s^2}$

= 3×10^{12} kg·m/s^2

Metric System

- Systeme International d'Units (SI)
- Developed in France in 1795
- Convenient, based on powers of 10
- Fundamental/base units used worldwide:

Length	-	metre (m)
Mass	-	Kilogram (kg) *
Time	-	Seconds (s)

Prefixes

- Used to change SI unites by powers of ten.

Prefix	Symbol	Fractions
pico	p	10^{-12} or 1/1 000 000 000 000
nano	n	10^{-9} or 1/1 000 000 000
micro	μ	10^{-6} or 1/1 000 000
milli	m	10^{-3} or 1/1 000
centi	c	10^{-2} or 1/100
deci	d	10^{-1} or 1/10
		Multiples
decka	da	10^{1} or 10
hector	h	10^{2} or 100
kilo	k	10^{3} or 1 000
mega	M	10^{6} or 1 000 000
giga	G	10^{9} or 1 000 000 000
tera	T	10^{12} or 1 000 000 000 000

Multiples Units

- Larger than the base unit (i.e., km, Mg)

How do we convert 452 g to kg?

$$452\cancel{g} \times \frac{1\ kg}{10^3\ \cancel{g}} = \boxed{0.452\ kg}$$

How do we convert 5.3 kg into g?

$$5.3\ \cancel{kg} \times \frac{1000g}{1\ \cancel{kg}} = \boxed{5300g}$$

* Put units of conversion factor in first, with unit being cancelled on bottom.

* Put the "1" with the unit with the prefix

* The power of 10 conversion goes with the base unit.

Fractional Units

- Smaller than the base unit (i.e., cm, mL)

How do we convert 500 nm to m?

$$500nm \times \frac{10^{-9}\ m}{1\ nm} = 5 \times 10^{-7}\ m$$

How do we convert 0.005 m into nm?

$$0.005\ \cancel{m} \times \frac{1\ nm}{10^{-9}\ \cancel{m}} = 5 \times 10^{6}\ nm$$

Practice:

Convert each of the following length measurements to its equivalent in meters.

1. 3.0 cm

$3.0 cm \times \frac{10^{-2} m}{1 cm} = 3.0 \times 10^{-2} m$

or 0.030 m

2. 83.2 pm

$83.2 pm \times \frac{10^{-12} m}{1 pm} = 8.32 \times 10^{-11} m$

3. 5.2 km

$5.2 km \times \frac{1000 m}{1 km} = 5200 m$

4. 0.426 Mm

$0.426 Mm \times \frac{10^{6} m}{1 Mm} = 4.26 \times 10^{5} m$

4. 24.3 mm

$24.3 mm \times \frac{10^{-3} m}{1 mm} = 2.43 \times 10^{-2} m$

or 0.0243 m

6. 5000 nm

$5000 nm \times \frac{10^{-9} m}{1 nm} = 5 \times 10^{-6} m$

Convert each of the following mass measurements to its equivalent in kilograms.

1. 293 g

$293 \cancel{g} \times \frac{1 kg}{1000 \cancel{g}} = 0.293 kg$

2. 207 μg

$207 \mu g \times \frac{10^{-6} g}{1 \mu g} \times \frac{1 kg}{10^{3} g} = 2.07 \times 10^{-7} kg$

3. 82.3 Mg

$82.3 \cancel{Mg} \times \frac{10^{6} \cancel{g}}{1 \cancel{Mg}} \times \frac{1 kg}{10^{3} \cancel{g}} = 8.23 \times 10^{4} kg$

4. 426 mg

$426 mg \times \frac{10^{-3} g}{1 mg} \times \frac{1 kg}{10^{3} g} = 4.26 \times 10^{-4} kg$

5. 2.4 ng

$2.4 \cancel{ng} \times \frac{10^{-9} \cancel{g}}{1 \cancel{ng}} \times \frac{1 kg}{10^{3} \cancel{g}} = 2.4 \times 10^{-12} kg$

6. 54.4 dg

$54.4 dg \times \frac{10^{-1} g}{1 dg} \times \frac{1 kg}{10^{3} g} = 5.44 \times 10^{-3} kg$

Derived Units

- A derived unit is composed of more than one unit or units with exponents.
- Conversions require cancellations in two directions

Convert 90 km/h into m/s:

$$90.0\,\frac{\cancel{km}}{\cancel{h}} \times \frac{1000\,m}{1\,\cancel{km}} \times \frac{1\,\cancel{h}}{3600\,s} = 25.0\ m/s$$

Convert 0.25 m³ to cm³:

$$0.25\,m^3 \times \left(\frac{1\,cm}{10^{-2}\,m}\right)^3 = 0.25\,\cancel{m^3} \times \left(\frac{1\,cm^3}{10^{-6}\,\cancel{m^3}}\right) = 2.5 \times 10^5\ cm^3$$

Practice:

1. Convert 25 m/s to km/h:

$$25\,\frac{\cancel{m}}{\cancel{s}} \times \frac{1\,km}{1000\,\cancel{m}} \times \frac{3600\,\cancel{s}}{1\,h}$$
$$= 90\ km/h \quad (9.0 \times 10^1\ km/h)$$

2. Convert 85 km/h to m/s:

$$85\,\frac{\cancel{km}}{\cancel{h}} \times \frac{1000\,m}{1\,\cancel{km}} \times \frac{1\,\cancel{h}}{3600\,s}$$
$$= 24\ m/s$$

3. Convert 15 000 mm² to m².

$$15000\,\cancel{mm^2} \times \left(\frac{10^{-3}\,m}{1\,mm}\right)^2$$
$$= 0.015\ m^2 \text{ or } 1.5 \times 10^{-2}\ m^2$$

4. Convert 5.0 m³ into cm³.

$$5.0\,\cancel{m^3} \times \left(\frac{1\,cm}{10^{-2}\,\cancel{m}}\right)^3$$
$$= 5.0 \times 10^6\ cm^3$$

5. Convert 25 km/min to m/s

$$25\,\frac{\cancel{km}}{\cancel{min}} \times \frac{1000\,m}{1\,\cancel{km}} \times \frac{1\,\cancel{min}}{60\,s}$$
$$= 4.2 \times 10^2\ m/s$$

6. Convert 1.352 km/h to mm/s

$$1.352\,\frac{\cancel{km}}{\cancel{h}} \times \frac{10^3\,\cancel{m}}{1\,\cancel{km}} \times \frac{1\,mm}{10^{-3}\,\cancel{m}} \times \frac{1\,\cancel{h}}{3600\,s}$$
$$= 375.6\ mm/s$$

CHALLENGE: (note: 1 mile = 1.6km and 1 in = 2.5cm)

7. Convert 22 miles to km

$$22\,\cancel{mi} \times \frac{1.6\,km}{1\,\cancel{mi}}$$
$$= 35\ km$$

8. Convert 2ft 9in to cm

$$2\,\cancel{ft} \times \frac{12\,in}{\cancel{ft}} = 24\ in.$$
$$24\,in + 9\,in = 33\,in$$
$$33\,\cancel{in} \times \frac{2.5\,cm}{1\,\cancel{in}} = 83\,cm$$

Graphing

Independent variable

- The one whose values the experimenter chooses and changes (manipulated variable);
- Plotted on the horizontal axis.

  i.e., the experimenter chooses the time at which to record the distance a toy car has travelled.

Dependent variable

- Responding variable;
- Changes as a result of a change in the other variable;
- Plotted on the vertical axis.

  i.e., The distance a toy car travels increases as time increases.

Plotting Graphs

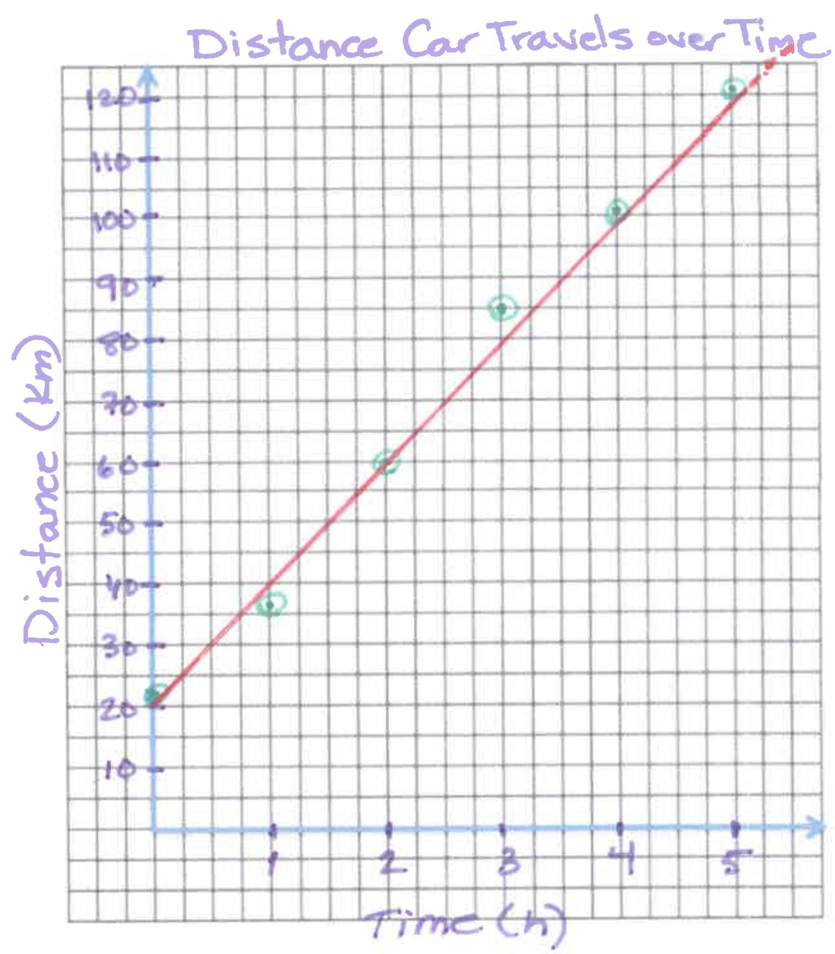
1. Independent variable is placed on the horizontal axis and the dependent variable is placed on the vertical axis.

2. Determine the range of data and spread the scale as widely as possible. Number and label each axis and put a title on top of the page (dependent-independent).

3. Plot each data point and mark it in pencil. Draw a small circle around each dot, and then draw the best straight line or smooth curved line that passes as many points as possible.

Example: The distance a car travels over time is recorded in the table below. Plot the data on the graph.

Time (h)	Distance (km)
0	22
1	36
2	60
3	85
4	101
5	121



Linear, Quadratic, and Inverse Relationships

Direct (Linear)

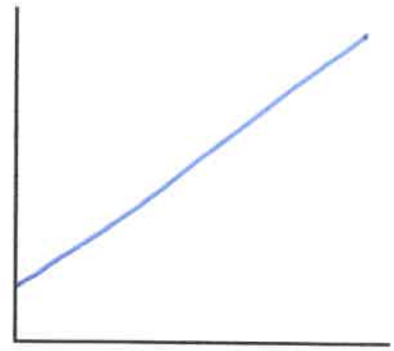
$y = mx + b$

b = y intercept

m = constant (slope)

y = rise

x = run



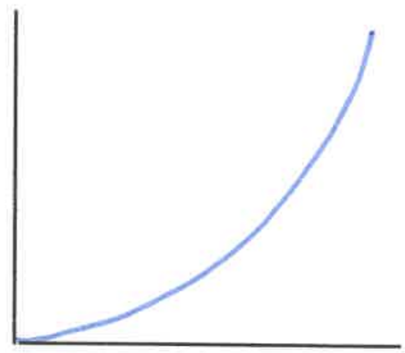
Exponential (parabolic)

$y = kx^z$

k = constant

y varies directly with the square of z

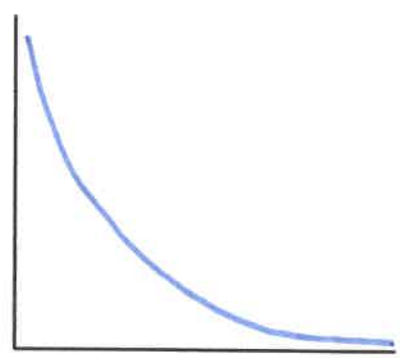
(as x increases, y increases more quickly)



Inverse (hyperbolic)

$xy = k$ or $y = \frac{k}{x}$

As x increases, y decreases



interpolation- finding values between measured points.

extrapolation- finding points beyond measured points.

- if graph is extended beyond plotted points, use a dotted line.

Manipulating Equations

$$(I)\,R = \frac{V}{\cancel{I}}\,(\cancel{I})$$

Therefore, $\cancel{I =}$ $IR = V$.

$\cancel{V =}$ or $\boxed{V = IR}$

$$\frac{I\cancel{R}}{\cancel{R}} = \frac{V}{R}$$

$$\boxed{I = \frac{V}{R}}$$

Solve for X:

$$(\cancel{X})\,\frac{Ay}{\cancel{X}} = \frac{cb}{S}\,(X)$$

$$Ay = \frac{cbX}{S}$$ 1) Multiply both sides by X.

$$\frac{X\cancel{cb}}{S\cancel{cb}} = \frac{Ay}{cb}$$ 2) Rearrange X on left side

$$(\cancel{S})\,\frac{X}{\cancel{S}} = \frac{Ay}{cb}\,(S)$$ 3) Divide both sides by cb.

$$X = \frac{AyS}{cb}$$ 4) Multiply by S.

Practice:

1. $y = mx + b$

a) Solve for x.

$mx + b = y$

$mx + \cancel{b} - \cancel{b} = y - b$

$\frac{\cancel{m}x}{\cancel{m}} = \frac{y-b}{m}$

$x = \frac{y-b}{m}$

b) Solve for b.

$mx + b = y$

$\cancel{mx - mx} + b = y - mx$

$b = y - mx$

2. Solve for v.

a) $d = vt$

$vt = d$

$\boxed{v = \frac{d}{t}}$

b) $t = \frac{d}{v}$

$tv = d$

$\boxed{v = \frac{d}{t}}$

c) $a = \frac{v^2}{2d}$

$v^2 = 2ad$

$\boxed{v = \pm\sqrt{2ad}}$

d) $\frac{v}{a} = \frac{b}{c}$

$vc = ab$

$\boxed{v = \frac{ab}{c}}$

3. Solve for E.

a) $f = \frac{E}{s}$

$fs = E$

$\boxed{E = fs}$

b) $m = \frac{2E}{v^2}$

$mv^2 = 2E$

$2E = mv^2$

$\boxed{E = \frac{mv^2}{2}}$

c) $\frac{E}{c^2} = m$

$\boxed{E = mc^2}$

4. Solve for a.

a) $v = v_o + at$

$v_o + at = v$

$at = v - v_o$

$\boxed{a = \frac{v - v_o}{t}}$

b) $v^2 = v_o^2 + ay$

$v_o^2 + ay = v^2$

$ay = v^2 - v_o^2$

$\boxed{a = \frac{v^2 - v_o^2}{y}}$

c) $v = \sqrt{2ad}$

$v^2 = 2ad$

$2ad = v^2$

$\boxed{a = \frac{v^2}{2d}}$