SCIENTIFIC SKILLS

Standard Units and measurement practises - Applies to all areas of study

- **Standard units (SI) are units that all measurements should be based on.** There is one type of unit for each type of measurement

Quantity	Unit name	Symbol
Time	second	s
Length	metre	m
Mass	kilogram	kg
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

- These standard units can be combined to form new ways of measuring things:
- When these units are being used for measurement, they also follow a special naming process based on the size of the measurement compared to the base measurement unit

Symbol	p	n	µ	m	k	M	G
Prefix	pico	nano	micro	milli	kilo	mega	giga
Order of magnitude	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{3}	10^{6}	10^{9}

- **Measurements can be simplified using significant figures**
  - For example, 82,000,000 is 8.2×10^7 ← You count how far the decimal place has moved
- There are rules for converting measurements and calculations to significant figures
  - Leading zeros are never significant
  - All non-zero digits are always significant figures
  - Trailing zeros are surprisingly always significant - 213000 → 2.13000×10^5
  - Zeros between digits are obviously always significant
  - Scientific notation can be used for all numbers and it should be used to express numbers that have less significant figures to the left of the decimal point than the number of digits to the left of the decimal point (e.g. when the measurement is rounded to the nearest ten, hundred, thousand).
  - The result of a product or division should have the least number of sig figs used
  - The results of an addition or subtraction should have same no. of digits to the nearest right of the decimal point as the measurement used in the calculation with the fewest significant numbers to the right of the decimal point

GOOD to answer to correct no. sig figs in exam, do NOT round during the question, USE exactly what you put in the answer box for part b), c)... of the question

Experimental Analysis - Applies to all areas of study

Experiments are based around **carrying out an aim** and **proving a hypothesis**

Validity refers to whether an experiment measures what it claims to measure.

- Determined by **Accuracy** - Closeness of the data values to their true/specific value
    - % Variation between [Experimental] and [Actual] values is a scalar quantity, no $\pm$ needed
    - An experiment is accurate if the measured value is less than the 'uncertainty' away from the actual value
- If constants are changed the experiment becomes invalid

Reliability is whether the experiment was repeated under controlled conditions and whether trial results were consistent.

- Determined by **Precision** - Closeness of the data values to each other
- An experiment is reliable if the line of best fit passes through all the error bars
- Repeatability: The measured data is in close agreeance when tested independently under identical conditions (same lab, same operator, same apparatus).
- Reproducibility: The measured data is in close agreeance when treated independently under different conditions (different lab, different operator, different apparatus).

Experimental **error** is also important when analysing an experiment

- **Random error causes one measurement to differ slightly from the next.**
    - **It comes from unpredictable changes during an experiment.**
    - **LOOK HARD for fluctuations** in what should be linear results in a data table, then that variable/corresponding measurement technique is a source of random error
    - **Decreases precision**
    - **Repetition or modification of the experiment may reduce it**
    - E.G. Not drying to constant mass in a gravimetric analysis: You don't know how much water has evaporated and therefore it has affected the result randomly
- **Systematic error always affects measurements the same amount OR by the same proportion, provided that a reading is taken the same way each time.**
    - **It is predictable, and comes from poor experimental design**
    - **Decreases accuracy**
    - **Repetition does not reduce it**
    - **Systematic uncertainty** is measured in terms of the limitations of the equipment used - Equal to the ½ of the lowest measurement increment used
        - If weights were measured to be 0.345kg, 0.450kg and 0.659kg, then the uncertainty would be $\pm$0.0005kg
        - If times were measured to be 1s, 2s and 2.4s, and velocities were calculated based off of these times, then the uncertainty would be $\pm$0.05s (and $\pm$0.05m/s because m/s was calculated from s)

- The impact of uncertainty can be decreased by taking <u>larger measurements of other variables</u>
- Relative uncertainty is the size of the uncertainty as a %of the measured value
  - E.G. (1.2±0.05)cm has a relative uncertainty of (±0.05/1.2)*100= ±4.17% but (20.3±0.05)cm has a relative uncertainty of (±0.05/20.3)*100 = ±0.25%
  - This means that taking larger measurements can decrease relative uncertainty
- Uncertainty adds up: If you are taking a measurement of a quantity larger than your measuring device can measure at once (e.g. measuring a table with a ruler, measuring a tonne of material with kitchen scales) then the <u>total uncertainty</u> is equal to the uncertainty of the measuring instrument multiplied by the amount of times you used that instrument

Experimental **improvements** are based around improving validity, reliability, accuracy.

NOTE: DO NOT SPEND TOO LONG ON GRAPHS!!! - THEY CAN EASILY SUCK TIME

PRACTICAL SKILL: Including an estimate of error

Measured/calculated data (*dependent variable*) often contains uncertainty e.g.

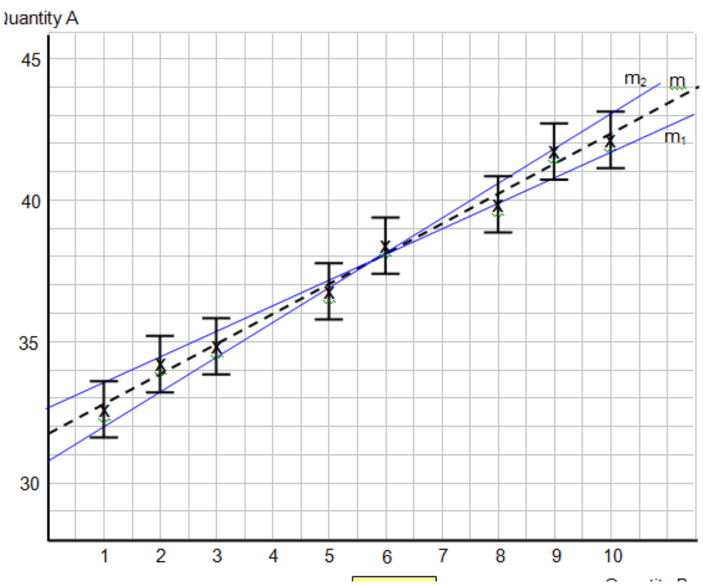
Average I_U (A): 0.80±0.02, 1.80±0.30, 3.03±0.30, 4.70±0.40

When dependent variables with uncertainty are plotted against independent variables, error bars are used to represent the uncertainty of the measured/calculated data E.G:

Let the x-axis be F_M (N) and the y-axis be I_U (A)

To find **an estimate of error for relationship I_u vs F_M**:

- **Line of best fit**: line that is closest to each point (here m)
- **M_{MAX}**: Line that goes through the bottom of the first error bar and the top of the last error bar (here m_2)
- **M_{MIN}**: Line that goes through the top of first error bar and bottom of last error bar (m_1)



Gradients (examples only):

Line = 5, M_{MAX} = 6, M_{MIN} = 4.5

Therefore the relationship **I_u vs F_M** is the **<u>greatest difference</u> between relationship (gradient) and either max or min error**, here it is 5±1 because 6 is further from 5 than 4.5, UNCERTAINTY = 20%

TO USE THIS IN A CALCULATION: Find B, field strength

$F = nBIL \rightarrow F/I = (\text{gradient})^{-1} = nBL$ thus 0.2 = 1*0.02*B, therefore B = 1

BUT uncertainty is 5±1 **[a 20% difference]** thus B = 1±(1*0.20) = 1±0.2 T

FIELDS

All fields are vector quantities - they have a magnitude and direction
Non-uniform fields are fields with diverging field lines around a point (gravity), while uniform fields are fields with parallel lines (electric+magnetic fields can be uniform)

Gravitational fields - UNIT 3 AOS 1

- Gravity is a force that exists throughout the universe. It acts between any two bodies, and is inversely proportional to the square of the distance between the two objects
- **Gravitational Force is the force between any two objects (force acting on each object caused by the other object) - Represented by F (Newtons)**
  - E.G. A space shuttle is orbiting earth (mass $6.0*10^{24}$kg, radius $6.4*10^{6}$m) at an altitude of 600km. Find the force due to gravity on a 75kg astronaut.
  - $r = 600km*10^3+6.4*10^6 = 7.0*10^6m$
  - $F = (6.67*10^{-11})*(6.0*10^{24})*75/(7.0*10^6)^2 = 613N$

$$g = \frac{GM}{r^2},\ F = \frac{GMm}{r^2}$$

G is the universal gravitational constant ($6.67*10^{-11}Nm^2/kg^2$), M is the mass of the central/larger body, m is the mass of the smaller/orbiting body, r is the **distance** between the **centre of each mass**

- The inverse relationship between gravity and distance, there are a number of formulas that can be obtained from this basic gravitational formula

$$\frac{r_F^3}{T_F^2} = \frac{r_I^3}{T_I^2},\ \frac{F_F}{F_I} = \frac{r_I^2}{r_F^2}$$

F_B and F_A are the gravitational forces acting on an object **before and after** a change in orbital height/radius, r_B and r_A are the orbital radiuses of a body **before and after**
This formula only works when the same two bodies are used (e.g. earth and one satellite changing orbit)

- Furthermore, because of the fact that objects are presumed in VCE physics to orbit bodies in circular orbits, gravitational force = centripetal force

$$a/g = \frac{v^2}{r} = \frac{GM}{r^2} = \frac{4\pi^2 r}{T^2},\ F_g = \frac{mv^2}{r} = \frac{4m\pi^2 r}{T^2}$$

- E.G. A small satellite orbits Mars. It has a kinetic energy of $3.0*10^{10}$J and is at a constant distance of $8.0*10^7$m from the centre of Mars. What is the weight of the satellite at this height?
  - Weight (F_G) = mg = mv^2/r for orbital motion = $2*(½mv^2)/r$ = 2*KE/r
  - $=2*(3.0*10^{10})/(8.0*10^7) = 750N$

T.M.J Tutoring
Perseverance Drives Success