Edexcel Physics A-level

Topic 1: Working as a Physicist

Notes

1 - Working as a physicist

1.1 - SI Units

SI units are the fundamental units which are used alongside the base SI quantities. They are made up of:

Quantity	Unit
Mass	Kilogram (kg)
Length	Metre (m)
Time	Second (s)
Current	Ampere (A)
Temperature	Kelvin (K)
Amount of substance	Mole (mol)
Luminous intensity (brightness of light)	Candela (cd)

Derived quantities are any quantities which are not included in the table above. Any other quantities that you may come across, such as **force**, have been derived from the quantities above. The SI units of quantities can be **derived** using their equation, e.g. F = ma.
For example, to find the SI units of force (F) multiply the SI units of mass and acceleration:
kg x m s^{-2} = kgm s^{-2} Which is the SI unit of force, also known as N.

Below are the **prefixes** which could be added before any of the above SI units:

Name	Symbol	Multiplier
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}
Femto	f	10^{-15}

Some examples:

6pF (picofarads) is **6 x 10^{-12} F**

9GΩ (gigaohms) is **9 x 10^{9} Ω**

10μm (micrometres) is **10 x 10^{-6} m**

1.3 - Estimation

Estimation is a skill physicists must use in order to approximate the values of physical quantities, in order to make comparisons, or to check if a value they've calculated is reasonable.

You can find an **estimate** by rounding your values up or down, as appropriate, and carrying out any calculation as you would normally do.

1.4 - Limitation of physical measurements

Random errors affect precision, meaning they cause differences in measurements which causes a spread about the mean. You **cannot** get rid of all random errors.
An example of random error is electronic noise in the circuit of an electrical instrument.

To reduce random errors:

- Take **at least 3 repeats** and calculate a **mean**, this method also allows anomalies to be identified.
- Use **computers/data loggers/cameras** to reduce human error and enable smaller intervals.
- Use **appropriate equipment**, e.g a micrometer has higher resolution (0.1 mm) than a ruler (1 mm).

Systematic errors affect accuracy and occur due to the apparatus or faults in the experimental method. Systematic errors cause all results to be too high or too low by the same amount each time.
An example is a balance that isn't zeroed correctly (zero error) or reading a scale at a different angle (this is a parallax error).

To reduce systematic error:

- **Calibrate** apparatus by measuring a known value (e.g. weigh 1 kg on a mass balance), if the reading is inaccurate then the systematic error is easily identified.
- In radiation experiments correct for background radiation by measuring it beforehand and excluding it from final results.
- Read the meniscus (the central curve on the surface of a liquid) at eye level (to reduce parallax error) and use controls in experiments.

The **uncertainty** of a measurement is the bounds in which the accurate value can be expected to lie e.g. 20°C ± 2°C , the true value could be within 18-22°C

Absolute Uncertainty - uncertainty given as a fixed quantity e.g. 7 ± 0.6 V
Percentage Uncertainty - uncertainty as a percentage of the measurement e.g. $7 \pm 8.6\%$ V

To reduce percentage uncertainty, you can measure larger quantities.

Resolution and Uncertainty

Readings are when one value is found e.g. reading a thermometer, measurements are when the difference between 2 readings is found, e.g. a ruler (as both the starting point and end point are judged).

The **uncertainty in a reading** is ± half the smallest division,

e.g. for a thermometer the smallest division is 1°C so the uncertainty is ±0.5°C.

The **uncertainty in a measurement** is at least ±1 smallest division,

e.g. a ruler must include **both** the uncertainty for the start and end value, as each end has ±0.5mm, they are added so the uncertainty in the measurement is ±1mm.

Digital readings and given values will either have the uncertainty quoted or assumed to be ± the last significant digit e.g. 3.2 ± 0.1 V, the **resolution** of an instrument affects its uncertainty.

For **repeated data** the uncertainty is half the range (largest - smallest value), show as mean ± $\frac{range}{2}$.

You can reduce uncertainty by fixing one end of a ruler as only the uncertainty in one reading is included. You can also reduce uncertainty by measuring multiple instances,
e.g. to find the time for 1 swing of a pendulum by measuring the time for 10 giving e.g. 6.2 ± 0.1 s, the time for 1 swing is 0.62 ± 0.01s (the uncertainty is also divided by 10).

Uncertainties should be given to the **same number of significant figures** as the data.

Combining uncertainties

Adding / subtracting data - Add absolute uncertainties

E.g. A thermometer with an uncertainty of $\pm$0.5 K shows the temperature of water falling from 298$\pm$0.5 K to 273$\pm$0.5K, what is the difference in temperature?

298-273 = 25K 0.5 + 0.5 = 1K (add absolute uncertainties) difference = 25$\pm$1 K

Multiplying / dividing data - Add percentage uncertainties

E.g. a force of 91$\pm$3 N is applied to a mass of 7$\pm$0.2 kg, what is the acceleration of the mass?

a=F/m =91/7 = 13ms^{-2} percentage uncertainty= $\frac{uncertainty}{value} \times 100$

Work out % uncertainties $\frac{3}{91} \times 100 + \frac{0.2}{7} \times 100$ = 3.3% + 2.9% add % uncertainties
= 6.2%

So a = 13$\pm$6.2% ms^{-2} 6.2% of 13 is 0.8

a = 13$\pm$0.8 ms^{-2}

Raising to a power - Multiply percentage uncertainty by power

E.g. the radius of a circle is 5 ± 0.3 cm, what is the percentage uncertainty in the area of the circle?

Area = π x 25 = 78.5 cm^2

Area = π r^2

% uncertainty in radius = $\frac{0.3}{5} \times 100$ = 6%   % uncertainty in area = 6 x 2 (2 is the power from r^2)

= 12%

78.5 $\pm$ 12% cm^2

1.6 - Applications and implications of science

An **application** of science is a use of scientific knowledge in order to carry out a specific action, an example of an application of science is developing a medical treatment, or carrying out further research based on prior knowledge.

A radiation procedure, designed as a treatment for cancer, is an example of an application of science, and bears associated **benefits**:

- Used as a treatment for cancer so it can potentially save lives.

And **risks**:

- Accidents may occur as it is a new technology, causing injury or even death.

It is important to note that all applications of science will have their own associated **benefits and risks**.

An **implication** of science is a direct or implied consequence of the knowledge of a particular concept. There are many different types of implications such as:

- **Commercial** - concerning money
- **Legal** - concerning the law
- **Ethical** - concerning moral principles
- **Social** - concerning society

For example, a **legal implication** of a project which aims to map the human genome is the question of whether DNA sequences can have copyright protection and an **ethical implication** could be, how should the information learned from this project be used.

1.7 - Role of scientific community in validating new knowledge

Knowledge and understanding of any scientific concept **changes** over time in accordance to the **experimental evidence** gathered by the scientific community. However, these pieces of experimental evidence must first be **published** to allow them to be **peer-reviewed** by the community to become **validated**, and eventually accepted.

1.8 - How society uses science to inform decision making

There are many aspects of society in which science is used to **inform decision making**, for example science is used in:

- **Policy-making** - to ensure that government policies are as beneficial to society as possible
- **Criminal justice system -** evidence is analysed scientifically in order to provide information about how a crime was carried out
- **Everyday life** - our scientific knowledge of a healthy lifestyle may inform the choices we make on a daily basis, e.g. walking to school instead taking the bus in order to get some exercise.