Wallace Hall Academy

CfE Higher Physics

Unit 0 – Uncertainties, Open ended questions and Skills Notes

Name ___________________

Uncertainties

Uncertainties

All experiments have uncertainties associated with them. It is not that something was wrong with the experiment, it is just that it is impossible to measure all values accurately and precisely.

Mean

To increase the reliability of an experiment it is often useful to calculate the mean. The mean can be calculated as shown below.

$$\textbf{mean} = \frac{\textbf{sum of all values}}{\textbf{number of values}}$$

Approximate random uncertainty (aru) in the mean

The aru allows us to determine how spread out the values which calculated the mean were. The bigger the aru, the bigger the spread in values which created it.

$$\textbf{aru} = \frac{\textbf{max. value} - \textbf{min. value}}{\textbf{number of values}}$$

Percentage uncertainty in the mean

In order to compare uncertainties between different measurements (e.g. Voltage and current) it is useful to convert them into percentages.

$$\textbf{percentage uncertainty} = \textbf{100 x} \frac{\textbf{approximate random uncertainty}}{\textbf{mean}}$$

<u>Example:</u>
A pupil records the following Voltages; 6.23 V, 6.39 V, 6.33 V, 6.31 V, 6.24 V, 6.27 V, 6.35 V, 6.23 V.

a. Calculate the mean Voltage.
b. Calculate the aru in the mean.
c. Calculate the percentage uncertainty.

<u>Solution:</u>

Absolute uncertainties

Uncertainties in measured values can be carried forward to calculate uncertainties in calculate values as an absolute uncertainty. When doing so it is necessary to **carry forward the biggest percentage uncertainty in the measured values.**

Example:
Sharon measure the time it takes another John to run across the classroom. She measures the time it takes him 8 times and the length of the room 6 times as shown below.

Time (s)	3.4 s	3.4 s	3.1 s	3.6 s	3.9 s	3.1 s	3.8 s	3.2 s
Distance (m)	4.12 m	4.13 m	4.12 m	4.14 m	4.13 m	4.15 m		

a. Calculate the mean time and mean distance.
b. Calculate the aru in the mean for time and distance.
c. Calculate the percentage uncertainty in time and distance.
d. Calculate John’s average velocity.
e. Calculate the absolute uncertainty in John’s average velocity.

Solution:

Types of uncertainty

Random uncertainty

A random uncertainty has already been covered in page 2 of this booklet and was referred to as the approximate random uncertainty (aru). This can be reduced by repeating measurements.

Systematic uncertainty

A systematic uncertainty appears equally in all measurements and can indicate poor experimental technique. For example if you were to measure a distance from the edge of a ruler rather than from the 0 cm point you would add 5 or 6 mm to all of your readings. Systematic uncertainties usually results in a straight line graph missing the origin.

Reading uncertainty

A reading uncertainty refers to how accurately a scale can be read.

Digital scale = ± 1 of the smallest division

Analogue scale = ± ½ of the smallest division

The uncertainties are different for analogue and digital scales as with a digital scale you have no way of telling how close a reading is to a specific value but with an analogue scale you can estimate it, hence its uncertainty is less.

Example: Calculate the reading uncertainty and the percentage uncertainty for the readings shown below.

Digital scale, 5.02 V   Analogue scale, 3.25 m   Digital scale, 4.3 A

Solution:

Calibration uncertainty

A calibration uncertainty is a property of the equipment you are using and there isn't much you can do about it except take note. The manufacturer will usually specify what the value of the calibration uncertainty is.

Open ended questions

Open ended questions

In your exam at the end of the year there will be two open ended questions worth 3 marks each. They will make a statement or show you a picture and ask you to discuss them using 'your knowledge of Physics'. They are marked holistically with no correct answer and you will be awarded marks based on the quality of your response.

3 marks for showing a very good understanding of the Physics involved
2 marks for showing good understanding of the Physics involved
1 mark for showing some understanding of the Physics involved
0 marks for showing limited understanding of the Physics involved

In truth there is no point stressing about these questions as the vast majority of pupils will pick up either 1 or 2 marks and your revision time would be much better spent practising the rest of the content of the course as this will help your base knowledge when answering open ended questions.

The following technique should be used when answering open ended questions.

1. Identify the topic area which relates to the question you have been asked.
2. Refer back to the question when writing your answer.
3. Include diagrams or equations where suitable.
4. Write **<u>at least one</u>** thing you know about which relates to the topic.
5. You can leave the open ended questions to the end.

<u>Example:</u>
A student holds a ball at rest then allows it to fall. The ball accelerates freely to the ground.

The student notes that before release the momentum of the ball is zero but after release it has a momentum. The student concludes that this shows that the law of conservation of momentum is not always obeyed.

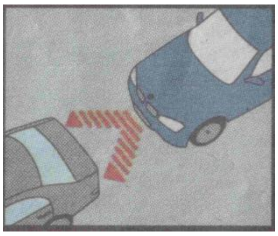
Use your knowledge of physics to comment on the pupils' conclusion.

<u>Solution:</u>

Example:

On 1 April, a car manufacturer placed an advertisement for a new system that could be fitted to cars and was called ‘Magnetic Tow Technology’. It was of course an April Fool – the system does not exist.

‘The system locks on to the car in front using an enhanced magnetic beam. Once you are attached, you are free to turn off your engine. The vehicle in front will do the pulling without noticing any changes.’



Use your knowledge of Physics to suggest how you can tell that the advertisement is an April Fool.

Solution:

Example:

A beam of green light and a beam of red light are shone onto a screen.

A student states that a beam of green light will *always* produce a greater irradiance on the screen than the beam of red light.

Use your knowledge of Physics to comment on this statement.

Solution:

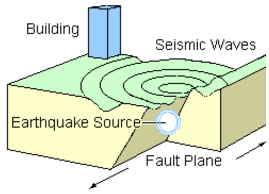
Skills

Skills questions generally come in two types.

1. You will be presented with some Physics notes on an area of Physics not in the Higher course, usually from Advanced Higher, and will be asked questions on it. Enough information will always be given in the questions to allow you to do this.
2. You will be presented with some experimental data on an area of Physics and will be asked to plot some data or interpret a graph which has already been drawn. This may also involve calculating the gradient of a line or determining an equation.

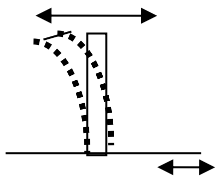
Example:

An extract from a student's investigation diary is shown.



Investigation – Preventing damage from earthquakes.

We found on the web that most of the energy of seismic waves from earthquakes is from waves close to a certain frequency. We carried out an experiment to find how the amplitude of vibration of the top of a building depended on the frequency of vibration of the ground. We used a flexible model of a building which was stuck to a horizontal plate that we vibrated at different frequencies.



Here are the results.

Vibration frequency (Hz)	Amplitude of vibration (mm)
0.5	18
1.0	32
1.5	48
2.0	49
2.5	34
3.0	10

The student has taken six sets of readings and used the results to reach a conclusion.

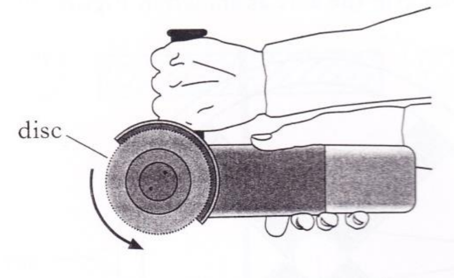
(a) Sketch a graph of the results.
(b) Using the information from your sketch graph write a conclusion for the experiment.
(c) Suggest two improvements that the student could have made to the collection of data for this investigation.
(d) Suggest any changes or extensions to the experiment that would make it more useful in determining the effect of earthquakes on buildings.

Solution:

Example:

The angular velocity of an object describes how many revolutions it completes per second. The angular acceleration of an object describes how many revolutions per second its angular velocity increase by per second. This is true for any object in rotational motion.

A grinder is used for cutting paving slabs.
The grinder has a motor and a disc with an abrasive edge as shown.



The motor is switched on and the disc reaches a maximum angular velocity of 600 revolutions per minute in a time of 5 s.

a. Calculate the maximum angular velocity of the disc in revolution per second.

b. Calculate the angular acceleration of the disc.

c. The first disc is replaced with a second much heavier disc. Explain what effect you think this would have on the angular acceleration.

Solution:

Analysis of straight line graphs

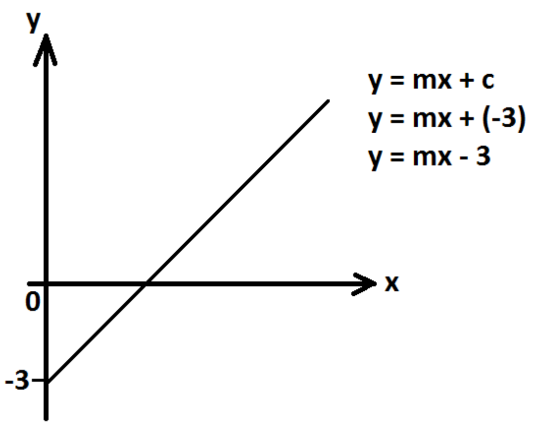
The equation for all straight line graphs is something you will have seen in Maths before.

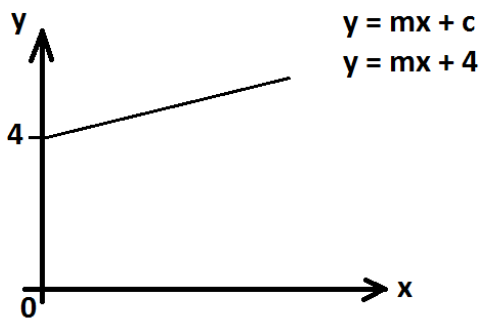
$$y = mx + c$$

where,
y is the quantity on the y-axis
x is the quantity on the x-axis
m is the gradient of the straight line
and c is the y-intercept (where the straight line crosses the y-axis)

Proportional

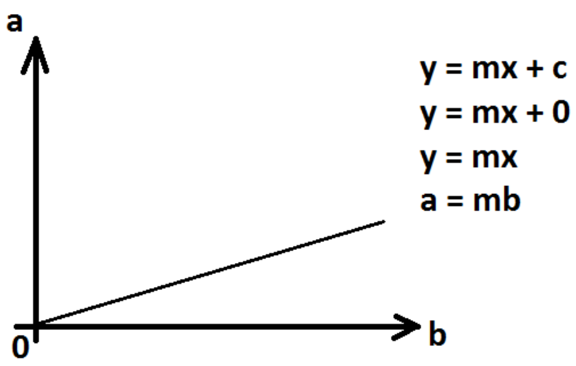
The following graphs show y being proportional to x but it is still important to mention c in the straight line equation as the y intercept (c) is not 0.

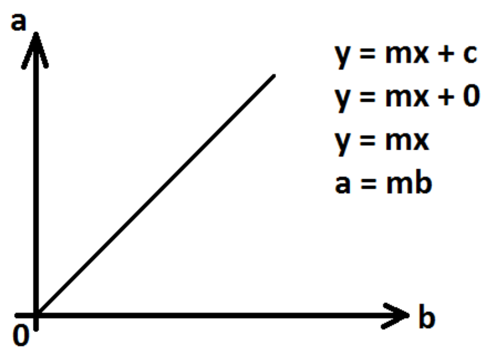




Directly Proportional

The following graphs show "a" being <u>directly</u> proportional to "b" as the y-intercept is zero.

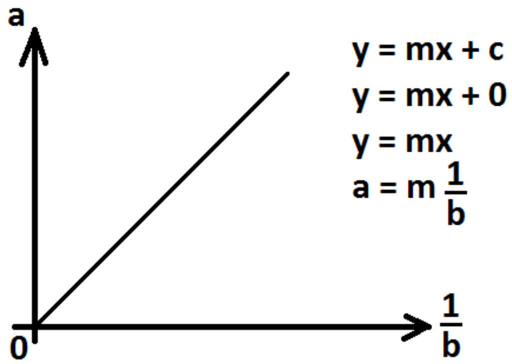




You may look at both these graphs and be confused because the equations are the same. However, the second graph has a steeper line so its gradient (m) is a larger number than that in the first graph.

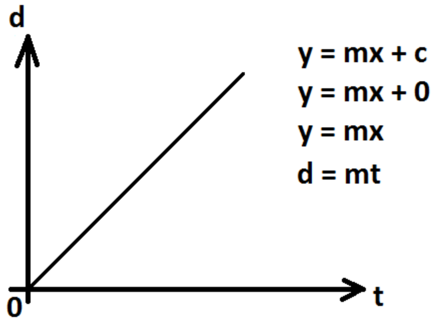
Inversely Proportional

The following graph shows "a" being directly proportional to the inverse of "b" as the y intercept is zero. **We say a is inversely proportional to b.**



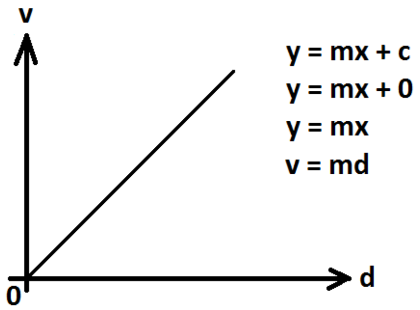
Physics Examples of Directly Proportional

Travelling at Constant Speed



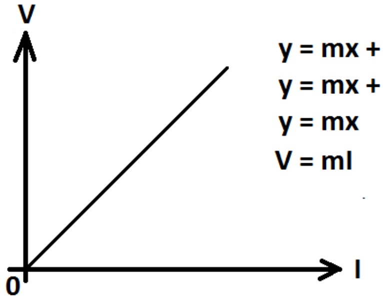
From the last line of the equation - "distance covered is directly proportional to the travelling time". In the above example the gradient would be equal to velocity as d = vt.

Hubble's Law



"Recessional velocity is directly proportional to the distance from Earth". In the above example the gradient would be equal to the Hubble constant as $v = H_0d$.

Ohm's Law



$y = mx + c$

$y = mx + 0$

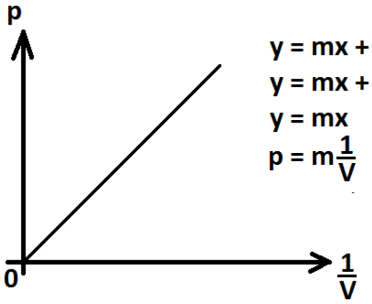
$y = mx$

$V = mI$

"Voltage is directly proportional to the current". In the above example

Physics Examples of Inversely Proportional

Gas Laws - Boyle's Law



$y = mx + c$

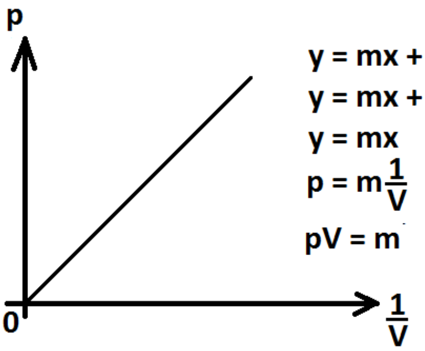
$y = mx + 0$

$y = mx$

$p = m\frac{1}{V}$

"Pressure is inversely proportional to volume (when temperature is constant)"

Think of a balloon filled with air. The balloon starts to be compressed. As the volume decreases, 1/V would increase and the pressure inside the balloon would increase too. The graph shows the pressure increasing as the inverse of V (meaning 1/V) increases.



$y = mx + c$

$y = mx + 0$

$y = mx$

$p = m\frac{1}{V}$

$pV = m$

➡

$pV = m$

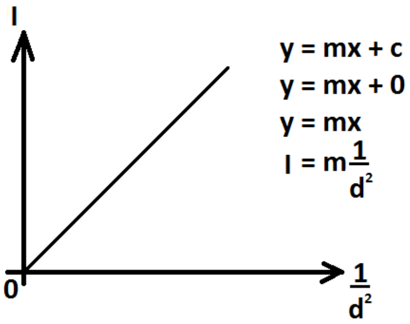
m = a constant number

pV = constant

$p_1V_1 = p_2V_2$ = constant

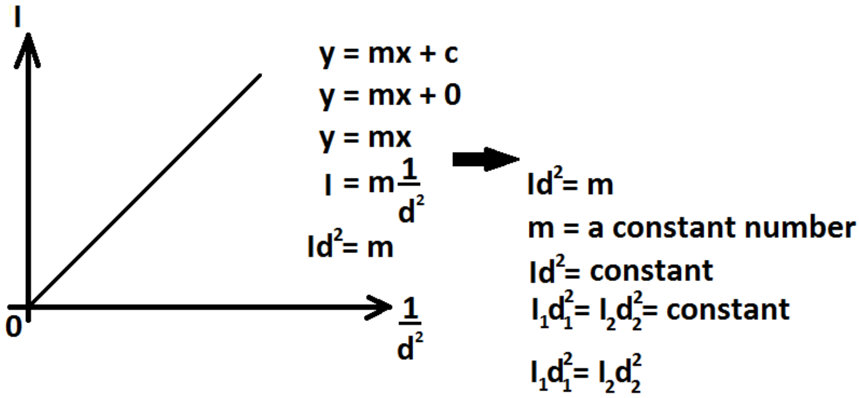
$p_1V_1 = p_2V_2$

Intensity of Light vs. Distance^2 - Inverse Square Law



"Intensity of light is inversely proportional to distance (from the light source) squared"

This is why you can look down your street at a distant street lamp easily without hurting your eyes, but can't look directly at the "big light" in your home.



$d = vt$ $v = H_o d$ $V=IR$ $p_1V_1 = p_2V_2$ $I_1d_1^2 = I_2d_2^2$

All of these are equations you can find on your Higher/National 5 Physics equation sheet. They all came from graphs and the graphs were produced from experimental results.

It's important not just to think of equations as something you pin numbers into. They stand for something and they are all relevant to the universe we live in.