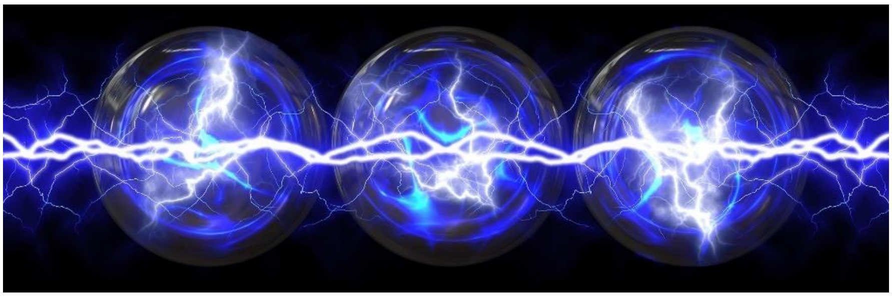
Physics A-Level

Bridging Opportunities:



All images: Pixabay.com

This booklet is designed to guide you through some key ideas and topics that would be very useful to complete before you start the course and will help you get a "real feel" for some differences between A level and GCSE Physics. The work is broadly broken down into 3 sections.

- Activity on Uncertainty. [Slice of bread and ruler required]
- Rearranging Common Physics Equations.
- A Research Project

Uncertainties

Uncertainties are a big part of the A-level course. One classroom saying is that "There is one certainty, and that is there is certain to be uncertainty questions in the exams!". It really isn't too difficult provided you think about what you are measuring and the tools resolution you are using.

Before you try this home-based activity, please watch this "short-science" video… It is 21 minutes long, but it is very good!

https://www.youtube.com/watch?v=ul3e-HXAeZA

Now we are going to put these ideas into practice.

Uncertainty in a Slice of Bread:

You need to have a ruler with a 1 mm resolution, this means 1mm is the gap between the smallest divisions. You need to measure the thickness of a slice of bread to the nearest mm. The reading you have recorded is in fact within a tolerance of ±1mm. The "±" symbol is used to show what we call the absolute uncertainty. It is the range in which the true value must reside. If you measured 5mm then your best estimate is 5mm, but there is a ±1mm uncertainty in that measurement so we write: 5 ±1mm. This means the true value could actually be anywhere between 4mm and 6mm. People often get very confused about this as surely you can measure to a tolerance of ±½ mm with a ruler? Well, yes, but what about the other end of the ruler? That also has a ±½ mm uncertainty, making a ±1 mm absolute uncertainty in the measurement overall.

Activity 1: Single readings

Action:

Use the mm scale on the ruler to take a single depth measurement along one side of the bread. Record the best estimate in the box. Due to the resolution of the ruler the absolute uncertainty of the measurement is ±1mm.

Depth (mm)		
Best estimate	±	Absolute uncertainty
	±	

Calculation:

Calculate the percentage uncertainty in this single reading using:

$$\%Uncertainty = \frac{\pm\, absolute\ uncertainty}{reading\ (best\ estimate)} \times 100\%$$

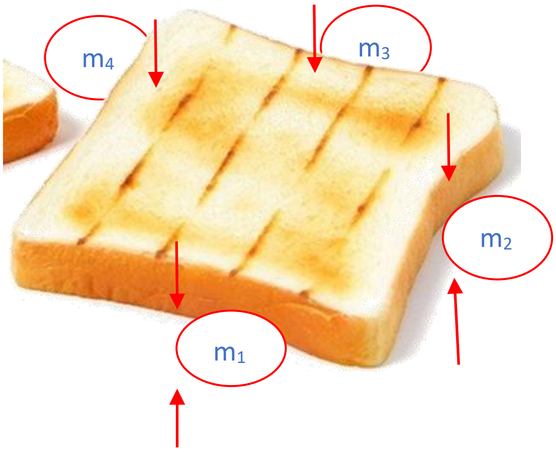
% Uncertainty

Activity 2: multiple readings

Action:

Make 4 measurements of the bread on each side of the slice. Record each one.

dimension	Value(mm)
m_1	
m_2	
m_3	
m_4	



Calculation:

Best Estimate (mm)	
Range (mm)	
½ Range (mm)	
Absolute uncertainty (mm)	±
Percentage uncertainty %	

- Take the average of the 4 measurements m_1, m_2, m_3, m_4. This value becomes your new "Best estimate".
- Calculate the range of your readings, the range is the smallest value subtracted from the largest.
- Calculate half of the range, this is now your absolute uncertainty in the depth of this single slice.
- Calculate the percentage uncertainty in the reading using the equation in activity 1, record in the table.
- Complete the expression below to show the measurement of the best estimate and absolute uncertainty in the depth of the slice.

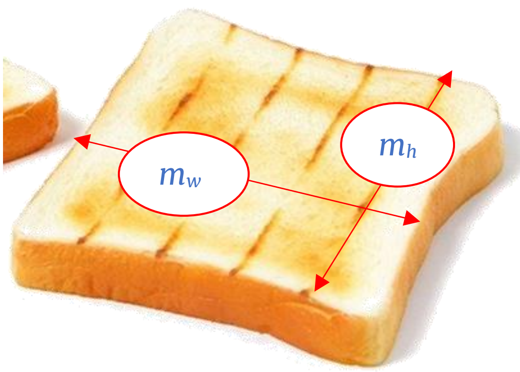
The depth of the slice = best estimate ± absolute uncertainty

depth of slice = ………………… ± ……………………

Activity 3: uncertainties in Areas

Action:

Now we are going to work out the uncertainty in the surface area of one side of the bread.



- Measure the slice of bread at three points across its width m_w and height m_h.
- Record them in the table.

Reading	m_w	m_h
1		
2		
3		
average		

Best estimate of area

……………… mm²

Calculation:

- Take the average width and height, these become the best estimates for both height and width.
  - Multiply the averages together to get the area. The best estimate for the height multiplied by the best estimate for the width, unsurprisingly becomes the best estimate for the area. But what is the uncertainty in this area?
- Note: you do have to assume the slice is a rectangular!

Activity 4: Uncertainty in your Area

Now work out the ranges of values from the 3 readings in activity 3 on page 3 for both width and height. Complete these equations:

$$Absolute\ uncertainty\ in\ width = \frac{Range_{(width)}}{2} = \qquad \pm\ \_\_\_\_\_\_\_\_\_\_\_\_$$

$$Absolute\ uncertainty\ in\ height = \frac{Range_{(height)}}{2} = \qquad \pm\ \_\_\_\_\_\_\_\_\_\_\_\_$$

This now means you could find the highest (best estimate + uncertainty) and lowest (best estimate – uncertainty) values for both the width and height. When you multiple the largest width possible, by the largest height possible, then you will get the largest area possible. Alternatively, if you multiply the smallest width possible by the smallest height possible then you will get the smallest area possible. Now you can find the full range of values for the area of the slice of bread. This then means you could half the range and that becomes your absolute uncertainty in the area. Look through the worked example below:

A worked Example:

The best estimate and uncertainties:

Width=50mm±2mm

Height=80mm±4mm

The best estimate for the area is

50mm x 80mm=4000mm^2

The largest area could be:

52mm x 84mm = 4368mm^2

The smallest area could be:

48mm x 76mm = 3648mm^2

The range is therefore:

3648mm^2 to 4368mm^2 =720mm^2

The absolute uncertainty is half the range:

Absolute uncertainty= $\frac{720}{2} = \pm 360mm^2$

The best estimate of the area and the uncertainty of the slice is therefore:

4000 ± 360mm^2

Calculation

Your go now, follow the same steps shown on page 4 to work out the absolute uncertainty in the area for your slice of bread. Use your best estimates and uncertainties for your slice recorded in activity 4, page 4.

Your Answers:

The best estimate and uncertainties:

Width=______ mm ± _____mm

Height=______mm ± _____mm

The best estimate for the area is

_______mm x _____mm=_______mm^2

The largest area could be:

______mm x _____mm = _______mm^2

The smallest area could be:

______mm x _____mm = _______mm^2

The range is therefore:

______mm^2 to _______mm^2 =______mm^2

The absolute uncertainty is half the range:

Absolute uncertainty= $\frac{\quad}{\quad}$

$= \pm$ _______mm^2

The best estimate of the area and the uncertainty of your slice is therefore:

_____________ ± ____________mm^2

Activity 5: Converting Absolute uncertainty into Percentage uncertainty

Sometimes we must change absolute uncertainties into percentage uncertainties and combine them. Converting the absolute into percentage uncertainty is done using the following equation:

$$\begin{matrix}\%Percentage\ Uncertainty \\ Width\end{matrix} = \frac{\pm\ Absolute\ Uncertainty_{width}}{best\ estimate_{width}} \times 100\%$$

We will use this equation to work out the percentage uncertainties of the of the values used in the previous worked example.

Worked Example:

Width=50mm±2mm

Height=80mm±4mm

$$\%\ uncertainty_{width} = \frac{2}{50} \times 100\% = 4\%$$

$$\%\ uncertainty_{height} = \frac{4}{80} \times 100\% = 5\%$$

Calculation:

Now you complete the table below using your best estimates and absolute uncertainties in the width and height from activity 4 page4.

Your Answers

Width=................ mm ±................mm

Height=................ mm ±..............mm

$$\%\ uncertainty_{width} = \frac{}{} \times 100\% = \_\_\_\_\_\_\%$$

$$\%\ uncertainty_{height} = \frac{}{} \times 100\% = \_\_\_\_\_\_\_\_\%$$

Activity 6: Combining Percentage Uncertainties

We will now combine these percentage answers to find the overall uncertainty in the Area. Follow the worked example below showing how to combine them.

Worked example (using dimensions from previous worked examples)

Percentage uncertainty of our slice = %uncertainty of width + %uncertainty of height

Percentage uncertainty of slice = 4% + 5% = 9%

Uncertainty in the area is therefore 9% of the best estimate: 9% of 4000mm^2

If you wanted to find the absolute uncertainty of the area from this percentage, it is simply:

Absolute uncertainty = Best estimate x $\frac{9}{100}$ = 4000mm^2 x 0.09 = ±360mm^2....

Phew the same answer!...

The uncertainty in the area is therefore either 9% or ±360 mm^2

Calculation

Now you work out the percentage uncertainty in the area of your slice by combining the percentages you calculated in activity 5, page 6.

Your Answers (using your measured dimensions)

Percentage uncertainty of our slice = %uncertainty of width + %uncertainty of height

Percentage uncertainty of slice = ______% + _____% = _______%

Uncertainty in the area is therefore ______% of the best estimate: ______% of _______mm^2

If you wanted to find the absolute uncertainty of the area from this percentage, it is simply:

Absolute uncertainty = Best estimate x $\frac{}{}$ = _________mm^2 x ______ = ± ________mm^2....

Hopefully, the same answer?_________

The uncertainty in the area is therefore either ________% or ±_________ mm^2

General Rules for Combining Uncertainty:

In 90% of cases you will need to combine values that they themselves will have an associated uncertainty.

Rules for combining percentage uncertainties:

dividing, multiplying or raising to the power

- If you multiply two values which have associated uncertainties, then you add the percentage uncertainties together.
- If you divide two values which have associated uncertainties, then you add the percentage uncertainties together.
- If you raise a value "r" which has an associated uncertainty to the power "n", then you add the uncertainties "n" times e.g.

  Example If "r" has an associate percentage of 3% then:

  $\%r^2 = \%r + \%r$ or simply $2 \times \%r = 6\%$

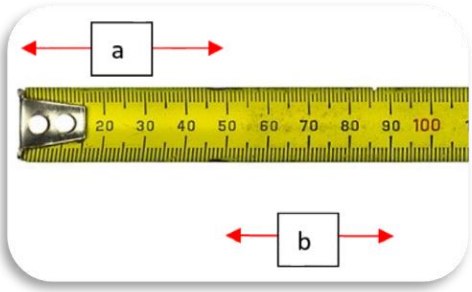
  $\%r^3 = \%r + \%r + \%r$ or simply $3 \times \%r = 9\%$

Adding and Subtracting Uncertainties

Rules for

Adding and Subtracting:

- If you add or subtract values that have associated uncertainties, it must be done in terms of absolute uncertainties.



Example: if a=50±2mm and b=40±3mm

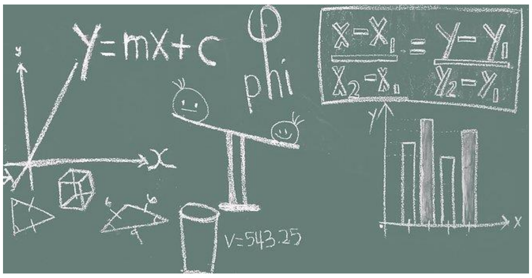
- Value "a" has an associated uncertainty of ±2mm and value "b" has uncertainty of ±3mm.
- The best estimate and uncertainty of a + b = (50 ±2mm) +(40 ±3mm) = 90 ± 5 mm

But surprisingly also…

- The best estimate and uncertainty of a - b = (50 ±2mm) +(40 ±3mm) = 10 ± 5 mm

Summary of Uncertainty work:

Although uncertainty can be reduced by using high resolution or high precision equipment it is always present. This activity was just a basic introduction and there is far more to learn. The more we use these techniques in lessons the better you will get. Do not panic if there are sections of this you just don't get, but having an early introduction to the ideas of uncertainty is very useful.



Transposing Equations

You will need to be able to change the subject of equations. Here is some practice in transposing equations using some Physics equations you will become familiar with over the A-level course. Here is an example. The technique which works for any equation is that if you something to one side of the equation to get rid of something, then you must do the same to the other, that's it! In this example I multiply both sides by "d" and simplify. Then divide both sides by "A" and simplify.

Example: find ε_o in this equation:

$$C = \frac{\epsilon_0 A}{d}$$

$$multiply\ both\ sides\ by\ "d"$$

$$Cd = \frac{\epsilon_0 Ad}{d} \quad therefore \quad Cd = \epsilon_0 A$$

$$divide\ both\ sides\ by\ "A" \quad \frac{Cd}{A} = \frac{\epsilon_0 A}{A}$$

$$\frac{Cd}{A} = \epsilon_0 \quad therefore \quad \epsilon_0 = \frac{Cd}{A}$$

A nice way to start, this topic is to watch this video. It is a little slow, but it is a good introduction and reinforces the example above.

https://www.youtube.com/watch?v=Sa_Xwpun1zE

You may know how to do this already, in which case go straight to the questions on the next page. The video tackles more difficult problems towards the end.

Calculations:

Question 1:

$F = ma$ $\quad$ *make m the subject*

Question 2:

$v = u + at$ $\quad$ *make u the subject*

Question 3:

$v^2 = u^2 + 2as$ $\quad$ *make a the subject*

Question 4:

$R = \frac{\rho L}{A}$ $\quad$ *make ρ the subject*

Question 5:

$s = \frac{1}{2}at^2$ $\quad$ *make t the subject*

Question 6:

$F = \frac{Qq}{4\pi\epsilon_0 r^2}$ $\quad$ *make r the subject*

A Mini-research Project:

“The Current Wars”

Tesla versus Edison :

There is a lot of media attention given to the battle of minds involving these two great scientists. There has even been a Hollywood movie made about this conflict called the “The Current Wars”, it is available to view on several of the online streaming services, although this is not essential to completing this task, you may find it interesting if you already have access to these services.

Your task is to investigate the scientific background of this “war”. Electricity is a physics concept that once the foundations are firm, the understanding is far less challenging. Various models of electricity enable us to make these foundations firm. This research should allow you to develop a better understanding in two very important concepts that we cover at A-level. The first being energy transfers and currents in circuits and the second the relationship between current and magnetism in applications such as transformers. Your project report should be written to include as many of these aspects as possible:

- A brief historic background of each scientist.
- The arguments and tactics used by each to convince others that their view of either AC or DC were correct.
- The science behind a DC current at electron level.
- The science behind an AC current at electron level.
- The reason why we transmit electrical energy at extremely high voltages.
- The role transformers had in the outcome of this debate and the science behind them.
- Other ideas Tesla had i.e. power without wires.

Some Resources that may help are, but there are many, many others:

https://www.newscientist.com/article/2211368-the-real-history-of-electricity-is-more-gripping-than-the-current-war/

https://www.livescience.com/46739-tesla-vs-edison-comparison.html

Further Preparation.

A PDF booklet is produced by OCR to support students with developing maths skills that are commonly used in Physics. I really don't expect you to know everything in this booklet when you start the course, it is however a great resource and ideally you should be "familiar", with its contents so that you know where the information can be found if you need it.

https://www.ocr.org.uk/Images/295471-mathematical-skills-handbook.pdf

The following are key sections I would like you to read through before you start :

Page 8	M0.2	Recognise and use expressions in decimal and standard form.
Page 14	M1.1	Use an appropriate amount of significant figures
Page 18-19	M1.5	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers. **This reinforces our slices of bread activity.**
Page 21-22	M2.2	Change the subject of the equation, including non-linear equations
Page 23	M2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities.
Page 35	M3.3	Understand that y=mx+c represents a linear relationship.
Page 36	M3.5	Calculate rate of change from a linear graph
Page 37	M3.6	Draw and use the slope of a tangent as a measure of a rate of change

Course Textbook:

We study OCR Physics A. In my opinion the course textbook is extremely good. I have provided a link to the OUP website page, just so you know what it looks like. You can of course buy it wherever you like. It is possible to buy this book as two separate books, one covering "year 1 and AS" and one for "year 2", this does usually end-up being a more expensive way to purchase exactly the same information though.

https://global.oup.com/education/product/9780198352181

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