Accuracy, Precision and Uncertainties

Precision

- How close your results are to each other
- How repeatable they are
- The number of decimal places or significant figures that an instrument can measure

Accuracy

- How close your results are to the true value of what you are measuring

Example 1

- The actual temperature of a classroom is 18.5°C

- A digital thermometer measures it to be 12.231°C

  - is this accurate or precise?

It is very precise because it gives a value to 5 significant figures, but it is not very accurate because it is a long way from the true temperature

Example 2

- The actual temperature of a classroom is 18.5°C

- A digital thermometer measures it to be 19°C

    - is this accurate or precise?

It is accurate because it gives a value close to the actual value, but it is not very precise because it only reads to two significant figures

Random errors

- Human errors e.g. reaction time when using a stopwatch or parallax errors when reading a graduated scale
- Unpredictable environmental changes e.g. wind blowing during an outdoor experiment to measure the speed of sound
- Random errors can be reduced by repeating the experiment and averaging your results
- Random errors mainly affect precision

Systematic errors

- Equipment errors e.g. digital scales being incorrectly zeroed or a thermometer that consistently reads 3°C too high
- Systematic errors can be reduced by replacing equipment, calibrating equipment or using multiple sets of equipment to compare readings
- Systematic errors mainly affect accuracy

Summary questions 1

Please write your answers in your books and attempt these questions without looking back at the previous slides. Spend 5 minutes on this.

1. Describe the difference between accuracy and precision

2. Describe the difference between random and systematic errors and give an example of each

Summary questions 1 - answers

Who would like to share their answers with the class?

Percentage difference

- The percentage difference is a simple calculation to compare the value obtained in an experiment to its true value
- It gives an idea of how accurate your result is

$$\% \; difference = \frac{|experimental\ value\ - true\ value|}{true\ value} \times 100\ \%$$

- The vertical bars mean take the ‘modulus’ (absolute value) – so you ignore the minus sign if the numerator is negative
- A rule of thumb is that if your % difference is less than 10% then your experimental result is fairly accurate

Example 1

- An experiment to measure the time taken to travel a certain distance gives a reading of 11.8 s. The true time taken is 10.3 s. Calculate the percentage difference and comment on the accuracy of the experiment.

$\% \, difference = \frac{|11.8-10.3|}{10.3} \times 100 \, \%$ = 14.6 %

It is not a very accurate experiment because the % difference is greater than 10 %.

Example 2

- An experiment to measure the density of steel gives a value of 7895 kgm^{-3}. The true value is 8050 kgm^{-3}. Calculate the percentage difference and comment on the accuracy of the experiment.

$$\%\, difference = \frac{|7895 - 8050|}{8050} \times 100\ \% = 1.9\ \%$$

It is a very accurate experiment because the % difference is much less than 10 %.

Summary questions 2

Please write your answers in your book and attempt these questions without looking back at the previous slides. Spend 5 minutes on this.

1. An experiment to measure the temperature of an aluminium block gives a result of 94.2°C. The true value is 81.8°C. Calculate the percentage difference and comment on the accuracy of the experiment.

2. An experiment to measure the mass of a copper block gives a result of 1.01 kg. The true value is 1.06 kg. Calculate the percentage difference and comment on the accuracy of the experiment.

Summary questions 2 - answers

Question 1

$\% \; difference = \frac{|94.2-81.8|}{81.8} \times 100 \; \%$ = 15.2 %

It is not a very accurate experiment because the % difference is greater than 10 %.

Summary questions 2 - answers

Question 2

$$\% \, difference = \frac{|1.01 - 1.06|}{1.06} \times 100\ \% = 4.7\ \%$$

It is an accurate experiment because the % difference is less than 10 %.

Absolute uncertainties

- These are expressed as ± the smallest increment that your instrument or measuring device can measure.
- For example a stopwatch that can measure to 0.1 s has an absolute uncertainty of ± 0.1 s.
- So, if this stopwatch gives a reading of 5.0 s it should really be quoted as 5.0 s ± 0.1 s.
- This means that the range of true values is 4.9 s to 5.1 s.

Percentage uncertainties

- These are the absolute uncertainties expressed as a percentage of the measured value
- So, for the stopwatch that produces a reading of 5.0 s ± 0.1 s, the percentage uncertainty is:

$$\frac{0.1}{5.0} \times 100 = 2\ \%$$

Absolute and Percentage uncertainties

- It is important to note that the absolute uncertainty is fixed as it is directly related to the resolution (how small the measuring increments are) of the measuring device.

- Percentage uncertainty can be reduced however, by increasing the range of your measured value.

Absolute and Percentage uncertainties

- As seen previously, if the stopwatch is used to measure 5 s, the percentage uncertainty is:

$$\frac{0.1}{5.0} \times 100 = 2\ \%$$

- If the same stopwatch is used to measure 50 s, the percentage uncertainty is:

$$\frac{0.1}{50} \times 100 = 0.2\ \%$$

Absolute and Percentage uncertainties

- This is why in an experiment you want your measured range to be as large as possible – because it reduces the % uncertainty in your result.
- For example measuring the period of a pendulum oscillation by timing over multiple swings rather than just one swing

Absolute and Percentage uncertainties

- At A Level, you need to be able to calculate the percentage uncertainty of a quantity derived from a formula - for example, the percentage uncertainty in speed from measured values of distance and time.

- To work out the percentage uncertainty of a quantity derived from a formula, the uncertainties from the measured values MUST BE EXPRESSED AS PERCENTAGE UNCERTAINTIES FIRST – this is usually the first step in these questions.

- If the measured quantities in the formula are being multiplied or divided YOU ALWAYS ADD THE PERCENTAGE UNCERTAINTIES.

- If you have a squared (or cubed) quantity then you ADD the uncertainties just the same as if it were any other two quantities being multiplied together – TAKE CARE HERE, MANY A LEVEL PUPILS LOSE MARKS WITH THIS.

Example 1

A runner runs in a race. The distance is measured as 250 m ± 1 m and the time is measured as 31 s ± 0.1 s. Calculate the percentage uncertainty in their average speed.

Step 1: Work out the percentage uncertainties of distance and time

Distance = 1/250 x 100 = 0.40 %

Time = 0.1/31 x 100 = 0.32 %

Step 2: Look at the formula for average speed: average speed = distance/time

Distance and time are divided – this means that to calculate the % uncertainty in speed, you ADD the % uncertainties in distance and time.

Step 3: Percentage uncertainty in average speed = 0.40 + 0.32 = 0.72%

Example 2

A car's mass is measured as 1200 kg ± 25 kg and its velocity is measured as 18 m/s ± 1 m/s. Calculate the percentage uncertainty in the car's momentum.

Step 1: Work out the percentage uncertainties of mass and velocity

Mass = 25/1200 x 100 = 2.08 %

Velocity = 1/18 x 100 = 5.56 %

Step 2: Look at the formula for momentum: momentum = mass x velocity

Mass and velocity are multiplied – this means that to calculate the % uncertainty in momentum, you ADD the % uncertainties in mass and velocity.

Step 3: Percentage uncertainty in momentum = 2.08 + 5.56 = 7.64%

Example 3

The length of a cube's edge measures 40 cm ± 2 cm. It's mass measures 5 kg ± 0.15 kg. Calculate the percentage uncertainty in its density.

Step 1: Work out the percentage uncertainties of length and mass

Length = 2/40 x 100 = 5.0 %

Mass = 0.15/5 x 100 = 3.0 %

Step 2: Look at the formula for density: density = mass / volume

Step 3: Look at the formula for volume: volume = length^3

Mass and volume are divided – this means that to calculate the % uncertainty in density, you ADD the % uncertainties in mass and volume. To calculate the % uncertainty in volume, you need to ADD the % uncertainties in length THREE TIMES BECAUSE IT IS CUBED.

Step 4: Percentage uncertainty in density = 3.0 + 5.0 + 5.0 + 5.0 = <u>18.0 %</u>

Summary questions 3

Please write your answers in your book and attempt these questions without looking back at the previous slides. Spend 10 minutes on this.

1. A cyclist travels 3500 m ± 60 m in a time of 1200 s ± 30 s. Calculate the percentage uncertainty in their average speed.

2. An object with a mass of 80 kg ± 2 kg travels with a velocity of 250 m/s ± 5 m/s. Calculate the percentage uncertainty in its kinetic energy.

Summary questions 3 - answers

Question 1

A cyclist travels a distance of 3500 m ± 60 m in a time of 1200 s ± 30 s. Calculate the percentage uncertainty in their average speed.

Step 1: Work out the percentage uncertainties of distance and time

Distance = 60/3500 x 100 = 1.7 %

Time = 30/1200 x 100 = 2.5 %

Step 2: Look at the formula for average speed: average speed = distance/time

Step 3: Percentage uncertainty in average speed = 1.7 + 2.5 = 4.2 %

Summary questions 3 - answers

Question 2

An object with a mass of 80 kg ± 2 kg travels with a velocity of 250 m/s ± 5 m/s.
Calculate the percentage uncertainty in its kinetic energy.

Step 1: Work out the percentage uncertainties of mass and velocity

Mass = 2/80 x 100 = 2.5 %

Velocity = 5/250 x 100 = 2.0 %

Step 2: Look at the formula for kinetic energy: kinetic energy = 0.5 x mass x velocity^2

Step 3: Percentage uncertainty in kinetic energy = 2.5 + 2.0 + 2.0= 6.5 %

The end