What Are Two Pence Coins Made Of?

There are no more experimental measurements required for this exercise. You should refer to your data from the previous experiment 'The Density of Two Pence Coins'. This exercise looks at the treatment of experimental uncertainties. **The theory below is important for ALL experiments and needs to be known for the practical assessment.**

Theory of Experimental Uncertainties

Absolute Uncertainties

The absolute uncertainty in a value will be the larger of:

- The uncertainty resulting from the precision of the instrument.
- Half the range of values obtained ((biggest – smallest) ÷2)

If all the values are the same, then there is still an uncertainty that depends on the precision of the instrument. If the value is from a single **reading** (e.g. from a digital scale) then the uncertainty is ± ½ of the smallest division. A **measurement** (e.g. of length) is taken as the difference between 2 readings, and so the uncertainty is twice that for a reading, i.e. ± the smallest division.

Percentage Uncertainties

The percentage uncertainty is given by:

$$\% \text{ uncertainty} = \frac{\text{uncertainty}}{\text{average value}} \times 100$$

Combining Uncertainties

You can only find a total absolute uncertainty in the **same quantity**. For example, in measuring a difference in length you take a reading from two points on the scale, so the total uncertainty is 2 × half the instrument sensitivity, i.e. the instrument sensitivity.

To find the total uncertainty in a result found from several quantities you add the **% uncertainties**, taking into account the number of times each quantity was used in the calculation.

For example, Volume of a cylinder = $\pi r^2 h = \frac{\pi d^2 h}{4}$ so d occurs twice and h occurs once.

% Uncertainty in volume = 2 × % uncertainty in d + % uncertainty in h

Percentage Differences

To calculate the % difference between an experimental result and the standard (expected) value use:

$$\% \text{ difference} = \frac{\text{difference between the 2 values}}{\text{standard value}} \times 100$$

To calculate the % difference between two experimental results, where neither is a standard value use:

$$\% \text{ difference} = \frac{\text{difference between the 2 values}}{\text{average of the 2 values}} \times 100$$

Analysis

Please ensure that you include the answers to the following:

- State the (absolute) uncertainty in your value for the thickness of the coin, h.

  This will either be the smallest division on the micrometer if the readings were all identical or it will be half the range of values obtained ((biggest – smallest) ÷2)

- Calculate the percentage experimental uncertainty in your value for h using:

  $$\% \text{ uncertainty} = \frac{\text{uncertainty}}{\text{value of h}} \times 100$$

- In measuring the diameter of the 2p coins, explain why it is better to measure across all of the coins rather than measuring them individually.
- State the (absolute) uncertainty in your value for the measurement of 5d. This will be the smallest division on the rule as it is calculated from two separate distance measurements that each have an uncertainty of half the smallest division.
- Calculate the percentage experimental uncertainty in your value for 5d using:

  $$\% \text{ uncertainty} = \frac{\text{uncertainty}}{\text{value of 5d}} \times 100$$

  NB – **very important** – the uncertainty relates to what was measured (5d), not what is calculated (d).

  The percentage uncertainty in d is the same as the percentage uncertainty in 5d, so by measuring 5d we reduce the percentage uncertainty in d to 1/5 of that for a single coin.

- Work out the total percentage experimental uncertainty for the volume value you calculated.

  (% Uncertainty in volume = 2 × % uncertainty in d + % uncertainty in h)

- State the (absolute) uncertainty in your value for distance x (2 measurements made).
- Calculate the percentage experimental uncertainty in your value for distance x using:

  $$\% \text{ uncertainty} = \frac{\text{uncertainty}}{\text{value of x}} \times 100$$

- State the (absolute) uncertainty in your value for distance y (2 measurements made).
- Calculate the percentage experimental uncertainty in your value for distance for y using:

  $$\% \text{ uncertainty} = \frac{\text{uncertainty}}{\text{value of y}} \times 100$$

- Work out the total percentage experimental uncertainty for the mass value you calculated.

  $m_{coin} \times x = m_{mass} \times y$ the masses can be taken as 100% accurate
  x occurs once and y occurs once

  % uncertainty in mass = % uncertainty in x + % uncertainty in y

- Calculate the % difference between the two values of coin mass you obtained in the experiment. Neither is a standard value so they can only be compared to each other. First find the average of the two values

  Then use

  $$\% \text{ difference} = \frac{\text{difference between the 2 values}}{\text{average of the 2 values}} \times 100$$

- Work out the total percentage experimental uncertainty for the density value you calculated in the previous experiment

  $$\text{Density} = \frac{\text{mass}}{\text{Volume}}$$ so mass and volume each occur once

  % uncertainty in density = % uncertainty in mass + % uncertainty in volume

- Work out the maximum and minimum values your density value lies between. State this range of values.

- Metals and alloys which could be used to make the coin are listed in the table below.
- Identify which of them, if any, lie in the range of density values that you obtained. If none of them do then state that.
- Hence suggest which, if any, is the **most** likely to be the major component of the coins according to **your** results.

Metal	**Density/kgm^{-3}**
Copper	8930
Brass	8500
Mild steel	7860

Conclusion

State the metal, if any, the coins could be mostly made of according to **your** results.