Case Studies: Quality of Measurement, Questions, Data Handling, Practice, accuracy, uncertainty, Calculating with Uncertainties

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Very often, the best way to improve a measurement is to identify the largest source of uncertainty, and take steps to reduce that uncertainty. Thus we have chosen to limit the analysis of uncertainties of measurement to:

 identifying and estimating the most important source of uncertainty in a measurement.

 This can be estimated in several ways:

 from the resolution of the instrument concerned; for example, the readout of a digital instrument ought not to be trusted to better than plus or minus 0.5 of the last digit

 from the stability of the instrument, or by making deliberate small changes in conditions (a light tap on the bench, maybe) that might anyway occur, to see what difference they make

 from the range of a few repeated measurements.

What is the uncertainty of the result?

In each question you should:

 determine the largest percentage uncertainty in the data given

 calculate a final result, giving it to a sensible number of significant figures

 give an estimate of the overall uncertainty, expressed as an absolute value and as a percentage.

In estimating uncertainties:

 use common sense to think about handling uncertainty

 always err on the cautious side: round uncertainty estimates up, not down

 do not automatically add up percentage uncertainties; this would only be right if variations in one quantity were related to variations in another

 remember that uncertainty estimates are themselves very uncertain: always estimate them to one significant figure.

Consult your formula sheet for the relationships required and for the meaning of symbols.

1. In measuring the Young modulus of a rubber band in its initial region of linear strain, the following measurements were taken.

*F* = 0.5 N ± 1% *A* = 4.0 mm2 ± 3% *x* = 0.0080 ± 0.0005 m *L* = 0.1450 ± 0.0005 m

Calculate the Young modulus and its uncertainty.

2. To measure the breaking stress and breaking strain in copper wire, the following measurements were taken at the breaking point.

*F* = 11.5 N ± 1% *d* = 0.31 ± 0.01 mm *x* = 0.655 ± 0.002 m *L* = 1.500 ± 0.002 m

 Calculate the breaking stress and the breaking strain  with uncertainty estimates.

3. In measuring the resistivity of a doped semiconductor chip, the following measurements were taken. The current

 was passed through the chip parallel to its length dimension.

*V* = 2.40 ± 0.01 V *I* = 40.0 ± 0.1 mA width = 5.10 ± 0.01 mm thickness = 1.05 ± 0.01 mm

length = 10.20 ± 0.01 mm

Calculate the resistivity of the doped semi-conducting material with an uncertainty estimate.

4. In measuring the electrical conductivity of copper, the following measurements were taken on a very thin wire

specimen.

*V* = 0.500 ± 0.001 V *I* = 0.146 ± 0.001 A *d* = 0.16 ± 0.01 mm *L* = 4.00 ± 0.01 m

Calculate the conductivity of the copper with an uncertainty estimate.

5. Satisfy yourself by a simple arithmetic check that an uncertainty of ± 4% in a measured resistivity of a material

 gives about the same % uncertainty in the value of the conductivity of the same material.