Teaching ideas for Topic 1: *Physics and physical measurement*

Questions

A number of worksheets are provided for this Topic:

- support questions examine the very basic concepts of the syllabus
- extended questions delve deeper and are equivalent to exam level questions.

Teaching ideas

This is the topic that is usually taught at the beginning of the course. It covers the basis techniques that appear throughout the course as well as error analysis, which is crucial for internal assessment.

- It is important that students learn the different rules for propagating errors under the operations of (1) addition and subtraction and (2) multiplication, division, roots and powers. It is not worth explaining the rules since at this stage as students have not yet studied any calculus. The rules are only approximate anyway.
- For addition and subtraction we add the absolute uncertainties to get the absolute uncertainty in the result.
- For multiplication, division, roots and powers we add the fractional uncertainties to get the fractional uncertainty.
- At this stage give lots of examples of the rules from past exam questions.
- Stress that, according to the IB, uncertainties are quoted to 1 significant figure only.
- Stress that to find the slope (gradient) of a straight line, two points on the line as far from each other as possible must be selected.
- Stress that, according to the IB, a 'line' may be straight or curved.
- Consider the more difficult problem of $a = 5.24 \pm 0.04$ mm and $b = 2.37 \pm 0.05$ mm. What is the dimensionless number $c = \frac{a}{b} + 1$ and what is its uncertainty? Most students will calculate $c = \frac{5.24}{2.37} + 1 = 3.21097$ correctly. The fractional error in $\frac{a}{b}$ is $\frac{0.04}{5.24} + \frac{0.05}{2.37} = 0.02873$ so the error in $\frac{a}{b}$ is $0.02873 \times 2.21097 = 0.06$, hence $c = 3.21 \pm 0.06$. Most students will give 0.09 as the uncertainty in c because they will multiply the fractional uncertainty in $\frac{a}{b}$ by 3.21097. It is interesting how many students get this wrong – so it is worth pointing out.
- If there are two quantities to remember for the exam these are the diameter of an atom (typical answer is 10^{-10} m) and the diameter of a nucleus (typical answer is 10^{-15} m). All other numbers used for estimates (masses of apples and oranges, times between heartbeats, etc.) should be common sense.
- It is absolutely crucial that students understand how to add and subtract vectors since this is a skill that will be used throughout the course. Vector subtraction usually takes a bit longer to master.

Practical activities/ICT

- The classic film about powers of 10 is a must see and is narrated by the legendary Philip Morrison. It is available in many places, including here: http://www.powersof10.com/film

Common problems

- Many students who are able to calculate the fractional error in a quantity correctly then have trouble taking the extra step to find the absolute uncertainty.

Theory of knowledge (TOK)

- Science is based on measurements that are uncertain. Controlling the uncertainty in each measurement by devising experimental methods that ensure small uncertainties is the basis of good experimental practice.
- Even though a result calculated from an experiment is uncertain it does not mean that it is not useful. Extending this a bit, knowledge of uncertainties allows one (by the use of statistics) to infer the confidence level at which a particular claim may be taken to be true.