Making Sense of Data: hints and ideas

Moderator's comments:

The Making Sense of Data task provides an opportunity for candidates to demonstrate their skills in handling data from an experiment and relate the outcome to the physics of the experiment. For this reason it is essential that candidates have a good set of data to work with and that they know how the experiment was actually carried out. Whilst it is not essential for every candidate to do the experiment, they should see some data being collected so that they are in a position to comment on the reliability of the data and relate the data to the physics of the experiment.

It is helpful to choose a task that allows some differentiation, allowing able candidates to show their strengths, whilst at the same time allowing access to the data to weaker candidates.
It was apparent that in some centres too much direction had been provided to candidates, leaving little scope for them to use their initiative and independence in choosing what to plot and how to interpret the outcomes. [I do not recommend an experiment that is closed, such as 'measuring g' or 'measuring h'.]
Candidates should be encouraged to look critically at the data they have before they take averages or plot graphs. Often the candidate did not identify 'rogue' values, leading to inappropriate mean values, which they then had difficulty in explaining.

An area of weakness amongst some candidates was in the presentation of graphs. It was pleasing to see that many candidates used ICT very competently, however some candidates allowed it to rule. Some graphs were rather small or labeled incompletely. In most cases it is better to hand draw a line after points have been plotted by the software. Awareness of the source of the data allows the best line of best fit to be drawn, and demonstrates real understanding of the data. The ease with which software can generate graphs leads to inappropriate graphs being plotted. For instance, a graph of gravitational potential energy against height unsurprisingly yields a straight line when the values for gravitational potential energy are derived from mgh.

Some experiments which have yielded high marks for good students include:

- Solar cell response to varying light intensity and varying load
- Motion of a trolley down a rough inclined plane
- Falling paper cones
- Muzzle velocity and range of marbles from a marble launcher
- Trajectory of a tennis ball
- Motion of a ball down a curtain track
- Standing waves in an air column
- Launching an air track glider with a elastic band catapult
- Motion of a ball bearing down a runway
- Resonances on a stretched string
- Resonances in a tube of air

Ideas posted on CAPT

1) We discovered that a 35mm film can just fit inside the plastic waste pipe used to connect sinks to the drain. The pipe can be arranged horizontally in a clamp and the film can is blown to produce projectile motion (a la monkey and hunter). We generated some data for range at different muzzle velocities and then repeated the experiment for different starting heights. The weaker pupils managed to verify that range was proportional to muzzle velocity at constant height by plotting the data given. Stronger candidates were able to spot the problem that there were no common muzzle velocities for each of the different heights (because it is hard to accurately control how hard you blow). This meant that they had to extract secondary data by reading off points from the range vs velocity family of lines in order to plot range vs height. If they did this they could easily see the squared relationship and explain why this should be so.
I think this is a great experiment for giving the weakest a chance to do something meaningful and the most able a real challenge. [Mary Whitehouse]

2) Ipswich School, Suffolk have Data Analysis information available to students via the web. goto http://www.ipswich.suffolk.sch.uk/physics

3) Using a demo is fine, but you need to have one where the students have a lot of scope in what sort of data analysis they do. The problem with the led one is there is effectively only one graph they can do, so you won't get the discrimination. At Tasker Milward School, my colleague Pete (he does this bit in chapters 8/9, it's his idea) does a light-gate measurement of speed of a trolley rolling down a ramp (students can measure the slope), with students timing the time between the start point and the place where the speed is measured, moving the measurement point progressively further down the slope, with an appropriate number of repeats.
This allows lots of scope for poor students just to plot graphs of the time and speed, while good students can go into energy considerations, and /or working out frictional forces.
[John Miller, Tasker Milward V C School]

4) A word of warning about 'trolley on a ramp' data tasks - I moderated a depressingly large number of these last year and many weaker pupils confused 'time taken to go down the slope' with 'time taken to pass through the light gate' and 'average speed down the slope' with 'instantaneous speed at the light gate'. This seriously affected their marks for section B.
I have always provided three different data sets –
1. resistance of a wire (very easy stuff - I warn them that they are unlikely to score much above 30 with it but that is exactly what some of them want)
2. spectrum of mercury (see below)
3. trolley down a ramp - then shown them how all three experiments could be done to get the data, given them some time to play with the kit and then asked them to choose.
They are fairly realistic by this stage of the year and so far no disasters.
[Jules Hoult while at Oakham School (Now Felsted)]

5) Last year we launched an air track glider using stretched elastic.
The students were able to obtain their own force-extension graphs for the elastic and to relate the data (e.g. area under the curve) to the kinetic energy of the glider as measure via light gates. It gave them plenty to do and ensures that they had some 'ownership' of at least some of the data.
[Tony Reeves Christ College Brecon]

6) Last year we used a motion sensor to measure a bouncing ball. This was done as a demo. We found that this gave quite a lot of scope for students to do a variety of tasks in analysis. Some used the distance measurements to calculate velocity and then onto acceleration or distance from the area under the graph. Others measured velocity before and after the bounce and look at loss of kinetic energy during the bounce and compared it to the subsequent height reached. It also leads onto some useful evaluations of the experimental technique with sampling rates etc.
[Keith Orchard, Wells Cathedral School]

7) If students have done Question 210S (Using Diffraction Gratings), then the following data set from the mercury spectrum sets them a reasonable challenge (some other comments about Q210S are also given below):

The data was taken using a 400-lines/mm grating.
A spectrometer was set up and students taken through how the data was taken.

ANGLE (degrees.MINUTES)	COLOUR
9.20	purple
10.00	blue
12.35	green
13.27	yellow
18.50	purple
20.26	blue
25.55	green
27.31	yellow
29.04	purple
31.28	blue
40.19	purple
40.50	green
43.54	yellow
44.13	blue
53.57	purple
60.39	blue
60.50	green
67.31	yellow
76.15	purple

Notes:

1. The data for the yellow line is the average for a doublet.

2. For the first two orders of diffraction the lines appear in "spectrum sequence", but thereafter overlaps occur – i.e. shorter wavelength lines from the next higher order intrude between longer wavelength lines from the previous order. So care needs to be taken assigning the correct order n to each line. Answers ought to draw attention to what is happening.

3. Up to six orders of diffraction are present.

4. Note that the angles are given in degrees and minutes, NOT degrees and decimal points of a degree. Not a huge error will result if decimal points of a degree are assumed, but the more astute students will take care how they compute the sin of the angles.

5. Students need to convert lines / mm into either line separation in metres or lines/metre depending on their method of analysis.

6. There are several ways to analyse the data using the grating formula d sin theta = n lambda. Best would be graphs of sin theta versus n for each colour. Slope = lambda/d. Hence lambda.

7. For reference: The data book vales for the mercury spectrum are:
purple = 404.7 nm
blue = 435.8 nm
green = 546.1 nm
yellow = 578.0 nm

Question 210S Using Diffraction Gratings - some comments

1. It is useful to get the students to draw a diagram of the experimental set up. It's not quite what they may assume. It's also worth setting up a spectrometer if you have one.

2. Measurements can be taken from the jpg images using the image cursor. The ruler in the picture is used to find the resolution of each image.
[Dr Rick Marshall]

3. Last year we took data about the force produced by rotating (toy) propellers. One of my upper sixth students had constructed the apparatus for his Investigation, so we hijacked it when he had finished. An electric motor was mounted on a square bit of MDF and suspended from the ceiling by threads at the corners attached to hooks in the ceiling. A horizontal thread over a pulley was used to make this arrangement lift 10g slotted masses and a rheostat was used to vary the speed of the propeller. We took results of force as a function of speed of rotation (measured using a stroboscope) for propellers of different lengths. This afforded plenty of opportunity for log-log graphs to establish empirical formulae and certainly allowed treatment of errors. Nobody failed to get somewhere with the data and no-one managed to analyse the whole lot, so I reckon the exercise was successful.
[Ralph Holmes Langley School Norwich]

We have used a similar experiment but connected the fan directly to an electronic mass balance. It works nicely.
[Tony Reeves, Christ College Brecon]

4. Mount a solder remover (solder-sucker) firmly on an inclined plane and fire marbles as projectiles from any angle at the press of the button. Our plane is 0 to 45 deg. and is very heavy (so low recoil) and by changing the "sucker" investigate spring constant (and initial energy) - which "should" be constant for each shot with a given spring.
Variables are then, 1 angle - 2 range - 3 calculate initial v 4 - relate to energy 5 - mass of marble.
The device has older staff recalling "The Golden Shot."

Each time you load the marble you can tell the students about "Bernie the Bolt." Masses of data are generated. Each shot takes only seconds. Put some benches together and use carbon paper on the landing strip. Gentle applause can be given if landing dots are very close. It's a throwing event in miniature.
[Michael Moylan Park Lane College]

5. Crater data - ball bearings dropped into flour - all data in cms

drop height 20cm   a   b   c   d
diameter   1.1   1.7   2.1   2.7
depth   0.6   0.4   0.6   1.2   1.6
ejecta   3.2   3.5   4.3   4.7   5.5

drop height 40cm
diameter   1.1   1.8   2.1   2.7
depth   1.5   1.6   2.3   2.0   2.6
ejecta   3.2   5.0   5.8   6.8   6.9

drop height 60cm
dia   1.2   2.3   2.5   3.1   3.5
dep   2.0   2.3   3.1   2.8   3.1
ej   3.8   4.7   5.2   5.9   8.1

BALLS   DIA cm   0.6   1.3   1.5   2.1   2.3
mass g   1.9   3.1   10.2   9.4   14.1

6. Have you tried timing the fall of various sizes of paper pastry cases? You can get different sizes and I included coffee filters. They reach terminal velocity very quickly, which can be examined, and you can stack them to increase their weight, but not the area (significantly).
I found that this provided an excellent vehicle for data collection, dropping them from about 2.5 metres. The apparatus required is also simple and readily available in numbers. There were interesting discussions about the area (is it surface area, or area presented by the base?) and many of my students found the relevant equation relating weight to drag. Thanks to M. Brimbicombe for suggesting this activity many years ago in SSR
[Russell Wallington, UCLES]

7. We have used data obtained by measuring the velocity (light gate) of a mass when dropped from a range of heights above the gate (20 - 920 mm)
This has worked well; a variety of things can be done with the data (find g, investigate GPE = KE, look for air resistance to name a few)
However, although we use a set of data obtained by the staff, we make sure everyone has a good go at collecting some results. Without this "hands on" experience doing justice to some of the criteria isn't easy (particularly wrt errors) This limits the usefulness of a data bank I fear, though one could be useful for practice runs on the data manipulation (if you have time for practices)
[Keith Davies]