Keeping Your Lab Diary

1. What is the purpose of a lab diary?

Working scientists need to keep a detailed record of what they are doing, for a number of reasons:

- as a working record of an experiment in progress (for example, noting down actions which may have a bearing on the final result, lists of items that cannot be dealt with now, but will have to be considered later, details of the reasoning that led you to choose one way of doing something over another which might seem just as good);
- to ensure that good ideas or technical points are not forgotten, but can be looked up and re-used (since the same type of problem may come up again in a different context);
- to track down problems if things do not go according to plan (for example, if your results do not agree with a colleague's, your lab diary may show that you used slightly different experimental techniques);
- as evidence that the work was done (for example, if the award of a patent is contested by another company).

This makes keeping a good lab diary an important part of scientific practice, and therefore something which we should encourage you to do in your undergraduate laboratory work. In any case, the above reasons for keeping a lab diary apply to the astronomy lab just as much as they do to a working research lab: most assignments last more than a week, so you need a working record; techniques such as line fitting and calculating the error on an average will recur in different exercises; your results may not agree with the textbook, so you may need to track down an error; and we will assess your work on the basis of the evidence provided by your lab diary.

2. What should your lab diary look like?

Your lab diary should be a book, not a loose-leaf folder (it is a general rule that vital items fall out of loose-leaf folders and get lost!). The most convenient type of book is the "laboratory notebook" style with alternating pages of graph paper and lined paper, obtainable from the Student Union shop. Now that many people do all their plotting with computers, a simple lined-paper notebook might be OK, but graph paper is still useful for diagrams, plots that are difficult to make on computers (e.g. plots with spectral class along one axis – Excel does not really understand scales that run OBAFGKM!), plots that are too simple to be worth writing a spreadsheet for (e.g. simple histograms), etc.

If you do have plots made on computer, *fix them permanently into your book* (glue, staple or sellotape them to the appropriate page), and *make sure they are properly labelled.* Anonymous graphs on loose sheets will get lost, or you will forget what they refer to. Remember that a lab diary is supposed to be a *permanent record* of your work (you may well see some of your lab demonstrators referring to their lab diaries from four years ago when they try to help you with a problem).

Since your lab diary will be used for assessment, it is important that it is legibly written and logically laid out. It's OK to cross things out, as long as the organisation of the material is still clear enough for someone else to follow. It is useful to number the pages, and keep an up-to-date table of contents at the front (laboratory notebooks generally provide a table of contents page). Remember to put your name on your book!

3. What should be in a lab diary?

Your lab diary should make it possible for you, or another reader, to reconstruct *precisely* what you did when you carried out the work, what decisions you made in the process, and what reasoning lay behind those decisions. Therefore, it should contain:

- *the date, and the title of the assignment*
  These are obviously needed so that you can find the record later if you need it!

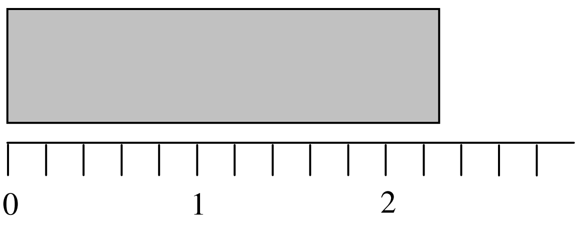
- *a brief introductory paragraph summarising the nature and purpose of the assignment*
  Read all the way through the script, work out what you are being asked to do and why, and summarise this in a short introduction. This will ensure that you start the assignment with a clear picture of what you are trying to do. If, after reading the script, you are still not sure of the point of the assignment, ask a demonstrator.

- *descriptions of points of procedure not specified in the lab script, with explanation*
  For example, if the lab script said "measure the diameter several times", your lab diary should specify how many times you measured it, and what measuring instrument you used (ruler, vernier callipers, etc.). This information may be needed to confirm your error estimates and understand any discrepancies (if you used a ruler while your colleague used callipers, your measurement errors will obviously be different). You should also explain *why* you did what you did: for example, you may have felt that the dominant error in measuring the diameter was in locating the edge of the image precisely, and therefore there was no point in using callipers instead of a ruler.

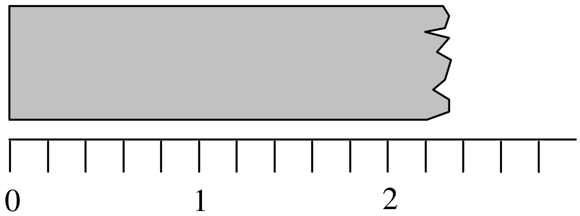
- *notes about any aspect of the procedure that worried you, or any decisions you made*
  Sometimes you may find that the lab script does not specify what to do in a particular case: for example, if you are told to group stars into their luminosity classes, denoted by the Roman numerals I to V, what do you do with a star that has the intermediate class II-III? In other cases, you may be worried about the data themselves: perhaps one image of a binary star system is of particularly poor quality, so your measurement of the separation of the two stars is unreliable. In such cases, the important thing is to *make a decision* about what to do, and *write that decision down*. You might decide to count all intermediate-class stars as belonging to the first class (II) or to the second class (III), you might allocate half a star to class II and half to class III, you might count them separately, or you might omit them from the count altogether. All these options are reasonable, but each will result in a different total count – so you need to write down what you chose to do. In the second example, you may decide to include that point with a large error bar, or you may decide that it is so unreliable you are better off omitting it altogether: in either case, you need to write a note explaining what you did, and why, so that if the demonstrator says, "What happened to the 1954 point?", you have an answer.

- *tables of the measurements* ***you actually made****, not just the derived physical quantities*
  For example, you might measure a length on a photographic image in mm, convert to arc seconds using a measured or calculated conversion factor, and then put this into a formula to derive the mass of a planet. You need to write down the original length, the conversion factor, and the converted value, as well as the final mass. This is critical in finding and correcting mistakes: for example, if you mistyped or miscalculated the conversion factor, it will be much easier to correct the problem if you have written down the original lengths. It is also important in getting your error estimates right: the fundamental source of the uncertainty is, after all, the precision of the original measurement.

- *estimates of the uncertainty of measured quantities,* ***and the reasoning that led to them***
  It is not enough just to say "±0.5 mm": you need to *justify* this estimate. If the dominant uncertainty is the accuracy with which you can read your ruler, are you *sure* you can't do better than ±0.5 mm? In the picture, the ruler is marked every 0.2 units, but we can see that the edge of the grey block is slightly less than halfway between 2.2 and 2.4: we might estimate its length as 2.28±0.02. This is much more realistic than simply rounding to the nearest scale division and saying 2.2±0.1.



  If the dominant uncertainty is *not* the accuracy with which you can read your measuring instrument (and ideally it shouldn't be – if it is, try to find a more accurate instrument!), then you should explain what it is: for example, in this picture the irregular edge of the block is the dominant uncertainty.



If you have made repeated measurements, you may have calculated your error statistically (as the standard error of the mean), rather than trying to estimate it from first principles. If this is the case, then say so, and note the number of measurements that you averaged (the standard error of 10 measurements is more reliable than the standard error of 4).

- *any graphs used to analyse the data, and the results obtained from them*
  If you use Excel for graphical analysis, make sure that your plots are glued, stapled or sellotaped into your book – don't leave them lying around loose. Make sure graphs have axis labels, including units, and a title. It is useful to number graphs so that you can refer to them. If the relevant quantity is derived from the gradient of the graph, make sure that the gradient is quoted, together with its uncertainty and its units (the linest function in Excel will give you the gradient and intercept of a line with their uncertainties).
- *any necessary diagrams, definitions of symbols, etc.*
  You do not want to return to the book a week or two later and discover that you have forgotten whether *r* refers to the radius of the planet or the radius of its orbit!
- *the sources of any constants or standard values that you looked up*
  If you found the mass of Jupiter from Allen's *Astrophysical Quantities*, then say so (don't just say "book value"). The accepted values of some quantities do change over time, so an old book may have an out-of-date number, or you might have confused the units (many astronomy reference books use cgs units instead of SI). It is much easier to fix such problems if you have noted your source.

You do *not* need to copy out all the material in the lab script, since both you and the demonstrator will have a copy of this, but it is sensible to copy out anything that you need to refer to or use in calculations, such as an equation or a diagram.

In general, if you have any doubts about whether something should be included or not, put it in: it is much better to have included something you didn't need than to have left out something vital.

4. How will your lab diary be assessed?

You should take about a session and a half to complete each assignment. When you think you have finished one, take your lab diary to a demonstrator. He or she will go through the assignment with you, asking questions if anything is not clear and filling out a checklist like the one attached to these guidelines. The demonstrator will explain any points where he or she feels your account is incorrect or incomplete, and will ask you questions about anything that is not clear. Finally, you will be given a mark out of 5, based on the checklist. *You will not be allowed to start a new assignment until the previous one has been marked*: this rule is intended to prevent you from losing marks by repeating mistakes.

If there is something seriously wrong, such as a fundamental error in the calculation, and *if you have time*, the demonstrator may ask you to fix the problem and come back to be re-marked. This is for your benefit: you will get a much better mark as a result, and you should also learn how to do whatever it was that you got wrong. But the demonstrator will only do this if it will not put you at risk of not completing the three assignments you are expected to do for each module: gaining an extra mark in assignment 2 is not a good bargain if it means you never get round to assignment 3. For this reason, it is best to complete your assignments on schedule, or if possible ahead of schedule.