THE SECOND YEAR LABORATORY

PHY230/231 Experimental Physics I and II

1) Introduction

Welcome to the Second Year Laboratory, - which will provide an introduction to more sophisticated and detailed experiments than those of the First Year. The accent will be on understanding the experiments, performing them correctly and accurately interpreting the results.

It will involve using a **Laboratory Diary** and completing all the observations and the data analysis **in the Laboratory itself**. You must then ask a demonstrator to sign your Laboratory Diary containing your data and analysis before starting your write-up. Until this point the Laboratory Diary must stay in the lab.

You will undertake three experiments (each will take on average 4 sessions to complete) and be assessed on all three of these on the basis of an **Experimental Report**. The Experimental Report is the basic form of scientific communication, which is described in Section 7 below. It should explain the purpose, methods and results of an experiment clearly and concisely to a non-specialist, scientific reader. Such a report can also form the template for a Poster or Oral Presentation.

The first experiment will be assessed by a **4 page written Report and the Laboratory Diary**; the second by a **defended Poster** and the third experiment by an **Oral Presentation**. The last two must also be supported by the **Laboratory Diary** in case the results are in error.

Remember that these Laboratory sessions in the first and second Semester are both **complete and separate modules PHY230 and PHY231**. **They must be passed** in order to gain the appropriate number of credits. The marking of these Modules will be done progressively throughout the two Semesters, with the three Reports submitted according to strict timetables for handing in completed work.

In the second Semester, the timetable and the general running of the Laboratories for Module PHY231 will be similar to the scheme used in the first Semester for Module PHY230. **This is intentional** and it allows single honours physics students to have a greater exposure to a wider range of different experiments and techniques before they start project work in the third (and fourth) years.

The Laboratory will be supervised by Dr Paganis together with Drs Buckley and Mc Milan - plus a team of postgraduate demonstrators and Mr Webb acting as the Laboratory Technician.

2) The organisation of the Second Year laboratory

In Week 1 attendance **is compulsory** at an **Introductory Talk** for PHY230 in LT7 on **Monday 27th September 2010 at 3.00 p.m** and at introductory talks on Experimental Uncertainties and Presentation Skills on **Friday 1st October 2010 at 2.00 p.m**, in LT7**.** Attendance **is compulsory** at an **Introductory Talk** for PHY231 on **Monday 7th February 2011 at 2.00 p.m** and talks on Experimental Uncertainties and Presentation Skills on **Friday 11th February 2011 at 2.00 p.m.** The requirements, assessment and details of the Second Year Laboratory will be explained in these sessions. You will be asked to read through the material which has been prepared on the organisation of the Laboratory. **You must sign the first attendance list** and this will be used **to indicate that you have read and understand what you are required to do**.

The class lists will be finalised in these sessions and you can choose your partner (as most of the experiments are undertaken working in pairs). The class will be divided into two groups, each of which will spend three laboratory sessions performing each experiment, followed by one session analysing data for each experiment in the computing laboratory. Experiments can be booked via the 2nd year website (http://www.shef.ac.uk/physics/teaching-resources/second-year) up to 1 week before the start of the experiment. Lab-scripts can also be downloaded in pdf format from this page.

The Laboratory will be open on **Mondays and Fridays** from **2.00 to 5.00 p.m**. In case of difficulties with an experiment, you are welcome to come in to the Laboratory on other days, providing you have asked permission of one of the Staff demonstrators and the Laboratory Technician knows of your presence (this is a general requirement for the Health and Safety at Work regulations).
You must ask a demonstrator to **sign and date your Attendance Sheet** at the end of each session you attend the Laboratory. This is Departmental policy, but your regular attendance in the Laboratories is most important for these Modules which are effectively, continuously assessed. **Poor attendance will not be tolerated!**

You will find all the information and material relevant to the two Modules PHY230 and PHY231 at http://www.shef.ac.uk/physics/teaching-resources/second-year. You should use a hard-bound Laboratory Diary (normally this should be the same as your 1st Year Lab Diary) in which all your work must be recorded (see below for details). The **requirements** for the Modules PHY230 and PHY231 in the first and second Semesters of the Second Year Laboratory are to complete three different Laboratory experiments in the Semester; to submit the completed Reports on time and to have them assessed. The total mark will be out of 100 and the pass mark will be 40.

The standard departmental policy on late-submission of work will be enforced.

3) The nature of the laboratory work

The Second Year Laboratory is an important link between the First Year, where there was a concentration on learning basic skills in experimental physics and the Third (and Fourth) years where project work become more important and where obviously the range of experimental techniques becomes more limited.

• the **three main aims** of the Second Year laboratory are,

to expose you to a wide range of more advanced experiments and,

to train you to work with a Laboratory Diary in the way that is adopted everywhere in University, Government and Industrial research and development laboratories***** and,

to develop your presentational skills in both written and oral presentations.

*(*****Note: Please understand, that even if you never want to work in a research or development laboratory in your future career, the Second Year Laboratory will nevertheless provide you with a training in the scientific method which is relevant to your third and fourth year projects. Some examples of completed Laboratory Diaries will be available from the laboratory records for you to inspect, so that you know what your own example should contain. If you have any doubt or uncertainty about what to do in an experiment or what to include/omit in the experimental report, please consult one of the Staff demonstrators.)*

The important aim of the practical work in the Second Year is to establish that the **Laboratory is the place where the experiments are undertaken and where the data are analysed and interpreted**. There will be no question of going home and "writing the lab diary up neatly" because all stages of the work should be undertaken in the Laboratory, where the proper facilities exist and the staff are present, to make this process as efficient as possible. Only the final report, summarising the contents of the lab-diary, may be written outside of the lab.

The **steps needed to successfully complete an experiment** are as follows;

a list of the experiments and a summary of each experiment are given in the web site.

The first experiment will be allocated by a demonstrator

there are normally 4 separate kits for each experiment so you and your partner will not be doing the experiment alone.

Later on, you and your partner can choose the second and subsequent experiments, subject to their availability.

Printed sheets which describe the experiment and its procedures are stored in two cabinets in the Second Year Laboratory close to the demonstrators' desk. You are welcome to look at these to help your decisions.

Note that there is an on-going programme of development of new experiments and improvements to existing ones in the laboratory. You may therefore, be invited to act as "guinea pigs" to try newly introduced experiments. In this case, the assessment of your results will be more lenient or sympathetic than for the normal well-established experiments. Your constructive comments (positive or negative) on ***any of the***

experiments are always welcome, as our aim is to have experiments which are straightforward to perform and give satisfactory results.

4) Guidelines for performing an experiment and recording the data.

• consider that the experiment is **a task that you have been allocated** which you must do **to the best of your ability**
• **start** by reading the Laboratory Sheet as many times as necessary for you **to understand completely what you are going to do.**
• **consult a demonstrator** at this stage, if you have any doubts ! Each staff and postgrad demonstrator will be responsible for 5 or 6 of the available experiments as displayed on the lists provided. Remember that the demonstrators are shared by a large number of students and on occasions there will inevitably be delays.

• **begin your Laboratory Diary** by writing a **short introductory paragraph** which describes **the aims of the experiment** in terms of the physics you are learning and the result you expect to obtain. Make a sketch of the main components, specifications and layout of the equipment. This should establish whether you have understood what you must do in the experiment.

• **every relevant detail of the experiment** must be written down **directly into your Laboratory Diary.** This will form the record of what you have done and in the event of problems, it will provide evidence of where you went wrong. This is why the Diary must be available each time you submit a Report.

Remember that the Laboratory Diary must contain sufficient information for you to **repeat the experiment under precisely the same conditions**, if you are asked to do so.

• before you start the actual measurements, **think about the quantities you are going to measure**, - how many different variables and how many data points you will record for each. You will then make the correct **tables of data** from the outset and your Diary will be correspondingly neater. Complete the work in a logical sequence and record all the relevant information and data. Write a brief description of how you performed the experiment.

• **results and analysis** this can be one section or two. The results should be presented in a tabular and graphical form where appropriate. Complete the data analysis with the aid of the facilities available in the Laboratory. When plotting graphs make sure you show the experimental data points clearly and include error bars where necessary. Include an analysis of the errors in your measurements and in the final result. There is an EXCEL spreadsheet available on the laboratory website for this purpose (http://www.shef.ac.uk/content/1/c6/04/20/03/chisquare_v1.xls). Justify your estimates of the errors and show the techniques used to derive them. A discussion of errors and Tables of useful formulae and the values of common physical constants is given in the following pages. Note that there is a strong emphasis on correct treatment and presentation of experimental uncertainties in the second year lab. The **compulsory lectures** on Experimental Uncertainties in the first weeks of semesters 1 and 2 will help you to understand what is required. NB **Poor treatment of uncertainties will result in poor marks!**

• **conclusions** finally draw your own conclusions from the work you have undertaken. If you have measured a standard quantity compare it with the values found in the literature and discuss any disagreements.

5) The Three Experimental Reports - what is to be submitted and how will it be marked?

The **first Experimental Report** each Semester will each be a **4 page written Report and Laboratory Diary** - which must include the cover sheet and the written **Report** which is a **summary of the whole experiment** condensed into 4 pages, according to the instructions given below, together with your Laboratory Diary completed following the instructions above.

The **second Experimental Report** will be presented as a **Poster** which you will be asked **to explain/defend orally** supported by the Laboratory Diary to resolve any potential problems**. The poster must be made either using powerpoint and printing using the university printing services (preferred), or handmade by gluing printed figures on a carton. The 2nd year lab cannot provide an area for making the poster, so any handmade posters must be produced outside the laboratory areas.**

The **third Experimental Report** will be an **oral presentation** with appropriate audio-visual aids and your Laboratory Diary must also be available

Because of this emphasis on Poster and Oral Presentation, attendance is compulsory at a short presentation, (normally given by Dr Cartwright) in week 1 of each Semester which **explains how to make a poster and how to give an oral presentation**. Generally, the poster and the oral presentation can both be based on the same general format as the written Report which is described in section 7 below. Issues such as using large fonts and bullet points instead of large paragraphs of text will be covered in Dr Cartwright's presentation.

No facilities (glue, card, space) will be provided to produce the posters. However there is a scanner in the Laboratory that can be used. There is also a digital camera and colour printers and one colour photograph per experiment can be made. A multi-media projector is also available to test/prepare PowerPoint presentations.

Computing Facilities available in the Second Year Laboratory

Everyone is strongly recommended to use computers as much as possible, especially for analysis of data and for word-processing. As well as the PC's which are directly interfaced to certain experiments, there are PC's in the Second Year Laboratory which are connected to the University Network with all the usual facilities available. They also have the package OFFICE XP installed on their hard drives, which includes EXCEL, with which you will plot graphs and analyse your data. The Media Room E39 will be pre-booked for the exclusive use of 2nd Year students on the days set aside for the preparation and presentation of posters and oral submissions, as shown on the timetable.

How will the Reports be marked?

The most important criterion to ensure good marks for the three Reports, is to obtain realistic value(s) for the quantities under investigation. If, for example, you get a value of $n = 10$ for the refractive index of water (instead of $n = 1.333$) or a value of the wavelengths of the sodium yellow lines that lies outside the visible spectrum, you will obviously never get a good mark for that experiment. Errors on that scale can not be glossed over irrespective of

how well the work is presented. However, for less disastrous measurements, some balance will be made between the experimental values and the presentation according to aims of the Laboratory set out in Section 3.

Thus the general scheme will be.

First Report	Laboratory Diary 50%	4 page Report 50%
Second Report	Defended poster	
	Experimental results 50%	Presentation 50%
Third Report	Oral presentation	
	Experimental results 50%	Presentation 50%

The experimental reports will be marked exclusively by Staff demonstrators. The marking of each element of the above will be on a 0-100 scale, using ***the normal degree classifications to give a broad outline***, *e.g*.

	>80	A piece of work of distinction
I	> 70	A first class effort worthy of a high mark.
II/1	60 - 69	A second class effort but still of good quality.
II/2	50 - 59	Second class work, possibly deficient in some areas.
III	44 - 49	A third class effort, which clearly deserves a lower mark.
P	39 - 43	Work that is only worthy of a bare pass.
F	0 - 38	A performance which has failed to address the experiment.

This has been found to give the best uniformity between the assessments of the different Staff demonstrators, especially since the classifications are universally well understood. So, if for example, a Report is judged to be "***of an average II/1 standard***", it will get a mark close to 65 while one judged to be " ***a good II/2***" will get a mark around 57-58.

What is needed to get good marks for the Experimental results?
good careful measurements; good numerical results; quoted to the correct precision, with errors and units; comparison with accepted values.

What is needed to get good marks for the presentation?
good, clear and concise presentation; well structured; good coverage of all the relevant points; free from errors;

Remember, if you are in any doubt about any of the points raised above, please consult with a staff demonstrator

N.B. The marks in Modules PHY230 and PHY231 have been uniformly good in recent years and the majority of the class has obtained First or II/1 classifications in the Modules. This incidentally, confirms a well-known feature of laboratory work, that is quite hard to obtain the very highest marks for a ***perfect*** experiment but conversely very low marks are rare under these conditions of continuous assessment and supervision

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6) What is the structure of a good Laboratory Diary?

It will normally contain,

(i) **Title** and date(s) clearly indicated.

(ii) **Introductory paragraph**, aims clearly and correctly set out; brief description of the task

(iii) **Experimental method** explanation of the method and of any special [points

(iv) **Measurements**, good quality, carefully made, clearly listed
Data tables well laid out with proper headings and units
Graphs well presented with proper axes scales, units etc

(v) **Data analysis,** clearly presented good numerical values quoted to the correct precision, errors and units

(vi) **Summary and conclusions,** comparison with accepted values, brief discussion of any discrepancies, brief conclusions

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7) What is the structure of a good experimental report?

It will normally contain,

(i) The **Title** should be brief (typically 5–15 words) but informative.

(ii) The **Abstract** is a paragraph (50–150 words) summarising the purpose, method and principal results of the experiment. It is usually easiest to write the abstract last!

(iii) The **Introduction** describes the purpose and scientific context of the experiment, and should be fairly short, - typically not more than about 20% of the total length of the report.

(iv) Most experiments set out to test a theory, or rely on theory for their interpretation, so the **Theory** section gives the mathematical background and defines any specialist terms before the description of the experiment itself.

(v) **Experimental Method** This section describes how the experiment was performed; the equipment used; the measurements made; any special precautions and should normally include a labelled diagram of the apparatus.

(vi) The **Analysis** section should explain how the raw data is converted into the desired physical quantities and the final results. Particular points to note are:

- data should be presented graphically if possible (it is easier to assimilate);
- data presented graphically does not need to be duplicated in tabulated form
- long tables of data *can* always be presented as an appendix;
- numerical values must be presented with their uncertainty/error, rounded to the appropriate number of decimal places (*e.g.* 12.34±0.16 s, 5.7±0.3 mm).

(vii) The **Discussion** section should start with a summary of the results obtained, compared to the accepted values or theoretical predictions. Any discrepancies between the two should be discussed with a proper scientific assessment of the experimental uncertainties or errors. Suggestions for improvements to the apparatus or technique can also be included in this section. The **Conclusion** section can summarise whether the aims of the experiment have been achieved, what has been learnt from the results, and whether they fit into any broader context. These two sections are often combined into **Discussion and Conclusions**.

(ix) In the **Acknowledgments** anyone who has helped particularly in the experiment or the report can be mentioned.

(x) There are two standard forms of **References**
"……..the astronomical unit is 1.4960×10^{11} m (Carroll and Ostlie, 1996)*……"

where the entry in the list of references is
B.W. Carroll and D.A. Ostlie, *Modern Astrophysics*, Addison Wesley, 1996

or "……..the astronomical unit is 1.4960×10^{11} m [1]……"

and the items in the reference list are obviously numbered [1]…to…[n].

**n.b.* one author is usually written in the text as (Smith, 1996), two authors as (Smith and Jones, 1996) and three or more as (Smith *et al,* 1996) and all of the "*et al*" should be given in the reference list.