# Experimental Physics 1 (PH100):
# How to work in the lab and read the lab manuals


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## 1 Learning outcomes

Experimental Physics 1 is a modern, lab-based physics course where all the SSE students will be exposed to a variety of techniques, concepts and skills in the experimental sciences. At the end of the course, the students will be able to do the following.

*Mathematical and physical*

1. Demonstrate a keen appreciation of physical quantities, their dimensions and units.
2. Perform simple statistical analysis of data including calculating means, mean squares and correlations.
3. Mathematically understand physical processes and corroborating them with linear, exponential, sinusoidal and polynomial models.
4. Accurately represent experimental data in the form of tables and graphs.
5. Understand errors, uncertainties and their propagation.
6. Demonstrate the ability to present an idea in the following equivalent forms:
   - equations and formulas
   - words
   - graphs
   - pictures
7. Develop an appreciation of energy, its myriad manifestations and inter-conversion.

*Engineering and practical*

1. Design simple experiments to test physical ideas.
2. Understand the significance of various kinds of materials (ceramics, plastics, metals, conductors, insulators) in the design of hardware.

3. Perform experiments safely.
4. Demonstrate the ability to work in teams.
5. Use locally available resources including materials and craftsmanship to build new projects.

# 2 Website

The course website is

`http://www.physlab.org`

You are responsible for visiting the website regularly, at least twice a week. Announcements and course information will be uploaded here. The website contains a list of experiments as well as the following supporting material.

1. Lab manuals
2. Matlab codes
3. Labview VI's (virtual instruments)
4. Further reading and references
5. Representative results and graphs
6. Supporting literature for the hardware

The website also displays the course time table, the lab allocation schedule, a brief history and philosophy and contact details for the lab staff.

Time table for Experimental Physics 1

| | |
|---|---|
| Week 2 | Error analysis |
| Week 3-4 | Mathematical computing |
| Weeks 6-15 | Experiments |

# 3 Mathematical computing

The laboratory course uses MATLAB as the computing environment. All students are expected to gain a minimum level of proficiency in MATLAB. For this purpose, we have dedicated one week to a lecture based demonstration of MATLAB followed by practice labs. The practice labs are conducted by the lab instructors.

## 4 Error analysis

Errors and uncertainties lie at the heart of experimental physics. A one week is devoted to a lecture based exercise on predicting and analyzing errors. Refer to the online time table for more details.

## 5 Data acquisition

Some of our experiments use data acquisition (DAQ) hardware and software. On the overall, students are expected to treat the DAQ systems as black boxes, although the more energetic and forward-looking students will be attracted towards a deeper understanding of DAQ. Furthermore, the experiment on Electronics, in fact, also serves as a veiled introduction to DAQ.

## 6 Our experiments

The Physlab at LUMS SSE has developed a set of 23 experiments along with associated 10 tasks for the freshmen students. These cover the following subject areas.

1. General Physics
2. Mechanics
3. Heat and Thermodynamics
4. Optics
5. Electricity and Magnetism
6. Electronics
7. Cryogens and Cryostats
8. Electromagnetic Induction and Magnetic Media
9. Fluid mechanics
10. Radioactivity

Students are required to perform at least six experiments, one experiment per week. Besides the general physics experiment, will work in pairs. The lab staff publishes an allocation schedule on the website. Students are not allowed to change the groupings and allocations.

## 7 Guidelines for practical work inside the Lab

The Experimental Physics 1 Lab is an intensive, high-enrollment and busy experimental environment. So following guidelines are aimed at enhancing the overall value of this course.

1. *Lab manual:* Students must actively read the lab manual before coming for the experiment (See the next Section). They are also required to bring the manual with them to the lab.

2. *Logging into the PC's:* The lab is equipped with personal computers fitted with DAQ hardware and MATLAB. Students Login with their individual username and password.

3. *Lab notebooks:* Each student *must* brings his/her notebook to the lab. This is a hard-bound notebook that will serve as a valuable reference in years to come. Note down the answers to all the queries (see next Section) in notebook. The demonstrators will mark and sign solutions only if they are presented in the proper notebook. Loose paper will not be entertained. Sample notebooks are available with the laboratory staff.

4. *Printing:* Printers are available in the lab. Students must plot graphs and paste them into notebooks. These printers must not be used for printing lab manuals, which are available online or can be purchased from *Gestetner Photocopier Centre* inside LUMS.

5. *Dialogue with the demonstrators:* The experiments will be supervised by a team of lab demonstrators and instructors. The lab manuals are written to encourage dialogue. It is mandatory that you engage with the demonstrators in a meaningful two-way rapport. Never be shy of talking to your colleague or to the demonstrator. Intelligent conversations with the dialogists will help them assess your contribution to the experiment and furthermore, will contribute towards your overall grade.

6. *Role of the demonstrator:* The role of the demonstrator in the lab can be summarized in pointwise fashion.

   - Asking questions and injecting the experimenters with mental conflicts that will, hopefully, guide them towards a better understanding of the experiment.
   - Engaging the experimenters in a meaningful dialogue about the experiment.
   - Attesting and marking the experimental results as and when they become available.
   - Ensuring that experimenters follow all safety protocols.
   - Organizing mini-tutorials before the experiment for the initiated students.
   - Describing key features of the apparatus.
   - In general, holding everything together.

7. *The success and failure of experiments:* It is quite likely that during the course of lab work, some experiment might not work. Don't conceive this as a *failure* of the experiment. In real life, experiments seldom work in the first attempt. So as long as you can document what went wrong, and interpret the results, you will be fine. In fact, recognizing and interpreting procedural mistakes or limitations in the hardware makes you deserving of extra credit.

8. *Lab safety:* Lab safety is of paramount importance in this course. Our experiments present five kinds of hazards.

   - Intense light sources called lasers.
   - Hot surfaces approaching 400°C.
   - Lifting and transporting hot and heavy objects.
   - Large electric currents.
   - Low temperatures $-200$°C.

Sufficient engineering controls are in place to protect students against hazards. Personal protective equipment (laser goggles, thermal gloves, insulation gloves and footwear) are also provided as the next level of safety. It is unacceptable not to follow the rules and in case of intentional carelessness, lab demonstrators reserve the right to bar student's admission to the lab, to say the very least.

# 8 Lab Safety

1. Shoes are required at all times.
2. Food and drink are not permitted in the lab at any time.
3. Any tobacco use is forbidden in the lab at any time.
4. Do not come in the lab early unless the instructor is present.
5. Keep the windows in the laboratory rooms closed at all times.
6. Do not wear loose hair or clothing around moving equipment.
7. Do not place equipment in the aisle or loiter in the aisle.
8. Do not set equipment too close to the edge of the table.
9. Do not activate any circuit or apparatus until the instructor inspects it.
10. Only use lasers, projectile launchers, pendulums, etc., for the instructional purposes for which they were intended.
11. Never look directly into the beam of a laser or into the barrel of a projectile launcher.
12. All trash and waste materials should be disposed in the proper container. Do not pour chemicals into the laboratory sinks.
13. Never touch a possibly live circuit.
14. Do not short the electrical leads on any equipment.
15. Any equipment not in use should be turned off.
16. Do not take apart any apparatus or piece of equipment.
17. All damaged equipment and chemical spills should be immediately reported to the laboratory instructor.
18. Students should never handle liquid nitrogen.
19. Students should never be allowed to use a Van de Graff generator unless directly supervised by the lab instructor.
20. Never remove any computer components (especially the mouse or keyboard) unless the computer is turned off.
21. Do not move or jostle a computer while the CPU is turned on.
22. Do not place books or papers on the tops of computer monitors.

23. Do not shutdown the computers or monitors unless instructed to do so by the lab instructor.
24. Leave your lab station neat, clean and organized at the end of each lab period.
25. Instructors teaching the last lab of the day should turn off the power to the computers' monitors at the conclusion of the lab.
26. Instructors teaching the last lab of the week should properly power down each computer at the conclusion of the lab.
27. Ensure that all laboratory doors are locked and closed at the conclusion of each lab.
28. Do not press the Ground Fault Circuit Interrupters.

# 9 How to read the Lab manual

Each experiment comes with a Lab manual. As a pre-lab exercise, the student must read the *entire* lab manual (for the forthcoming experiment). These manuals are available from the website. They can either be downloaded and printed (on personal printers or printers located in the IST) or the consolidated booklet containing all lab manuals can be purchased from the Gestetner Photocopiers inside LUMS.

The manuals must be read **actively**, diligently and carefully. Students must have come across the phrase "to read between the lines". While reading our lab manuals, students must also develop the habit of "writing between the lines". It is assured that this is not an act of mutilation, but of love. Marking of manuals, taking notes, repeating the calculations and practicing derivations. Ask questions. Find answers. Take visuo-psychological leaps of imagination and make pictures, many, many pictures. Even try sketching the graphs. In this way, you may end up predicting the outcome even before the experiment[1].

You are also required to bring a copy of the manual to the lab.

The lab manuals are divided into the following sections.

1. *General introduction:* This is a prelude to the experiment. It gets you started.
2. *Keywords:* This is a listing of the main concepts and hardware used in the experiment. The purpose of this vocabulary is to provide you with a distilled extract of terms that you can quickly look up in a standard textbook, a reference book or on Google.
3. *Approximate performance time:* This is self-explanatory. Our experiments are long, but it is imperative that you do not rush through them. But do not proceed at zero speed.
4. *Conceptual objectives:* The learning outcomes of the experiment are described in the "conceptual objectives" section. These are the "take-home lessons" from the experiment. A few years down the line, you may forget the precise details of the practical exercise, but I expect you to fully assimilate the conceptual objectives. These skills and concepts will become a part of your academic personality, running in your bloodstreams.

[1] If you want to know more about active, thoughtful and two-way reading habits, consult the book "How to read a book?" (1940) by Mortimer Adler.

5. *Experimental objectives:* This is a concise statement of the goal of the experiment, such as "this experiment determines the optical activity of sucrose solution".

6. *Theoretical introduction:* The section titled "theoretical introduction" summarizes the background theory required for a complete understanding of the experiment. Whenever you are in a state of confusion or a yearning to know for more, consult either the References at the end of the lab manual or your favourite textbook such as *Physics for Engineers and Scientists* (H. C. Ohanian).

There are two kinds of activities, that we call **queries**, imbedded in the manuals. These queries are colour coded.

The lab manuals also contain questions or problems that you must solve at home, before coming to the lab. You will not be assessed on these queries, but your complete understanding of the experiment *does* depend on successfully tackling them. The query question is activity-based, and can only be addressed inside the lab. These queries are based on the experiment, the apparatus or the data acquired therefrom. Your overall assessment and grading will depend on how you approach these queries.

1. *General introduction:* As the name implies, this section describes the hardware used in the experiment. I have tried to put in photographs where possible. The aim is to help you *visualize* and draw mental pictures of the experiment. The sources of the equipment are also mentioned and helps give a flavour of what it takes to build teaching equipment.

2. *Experimental method:* This section forms the crux of the manual. It takes you through the experiment, step by step and query by query. On the day of the experiment, you will spend almost all of your time forging through this part of the manual.

3. *Experience questions:* This is a list of nudge questions. Ponder over these questions in your free time. The physics lab staff will be happy to discuss these points with you.

4. *Idea experiments:* The poet William Blake once remarked,

   I will not reason and compare,<br>
   My business is to create.

   We strongly feel that creation is the best form of comprehension, more so as it applies to physics. Students should get involved in creating new experiments. The best of these will serve as model experiments for the forthcoming years. So, if anyone of you has the fondness and the passion for building new setups, please get in touch with Physlab team. In this very spirit, the present section includes a list of representative "idea experiments".

5. *References:* The lab manual concludes with the bibliography. All research articles mentioned in this section can also be downloaded from the website. The books listed in the bibliography are all available in the LUMS Library.

# 10 Grading and assessment

The lab demonstrators are responsible for the overall grading. At the end of the course, students will be ranked into the following categories.

| | |
|---|---|
| 10 | Exceptional |
| 9 | Very Good |
| 8 | Good |
| 7 | Average |
| 6 | Poor |
| 5 | Very Poor |

We have prepared an individualized marking sheet for each experiment. The marking premises are largely determined by the "conceptual objectives" mentioned in the lab manual. These outcomes are quantified through verbal discussion. For example, if one of the learning outcomes is "understanding how errors propagate", the corresponding quantifiable discussion would be, "how did you find the error in the spring constant, given the uncertainty in the measurement of displacement?" Some sample marking premises for one of our experiments, are reproduced below,

- Understanding of theory
- Procedural understanding
- Uncertainties and Propagation
- Significant figures + Units
- Quality of lab notebook
- Curve fitting and Linearization
- Plotting and Presentation
- Results interpretation
- MATLAB and LabVIEW Skills
- Extra Work and Proposals

The overall grade will be assigned after compiling all the six marking sheets for the student. Note that in order to fail the course, you need to be extremely non-serious or miss out on two or more lab sessions.