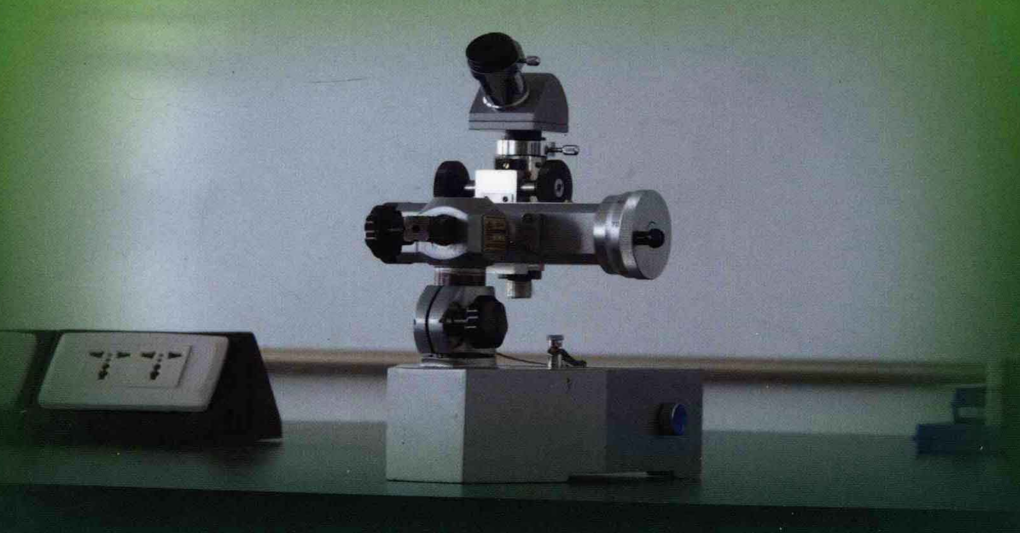
医学教育改革系列教材

# Experiments of Pre-medical Physics

*Chief Editor* Zhicheng Liu



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# Experiments of Pre-medical Physics

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# Foreword

Global developments in medicine and health shape trends in medical education. And in China education reform has become an important focus as the country strives to meet the basic requirements for developing a medical education system that meets international standards. Significant medical developments abroad are now being incorporated into the education of both domestic and international medical students in China, which includes students from Hong Kong, Macao and Taiwan that are taught through mandarin Chinese as well as students from a variety of other regions that are taught through the English language. This latter group creates higher demands for both schools and teachers.

Unfortunately there is no consensus as to how to improve the level and quality of education for these students or even as to which English language materials should be used. Some teachers prefer to directly use original English language materials, while others make use of Chinese medical textbooks with the help of English language medical notes. The lack of consensus has emerged from the lack of English language medical textbooks based on the characteristics of modern medical education in China.

In fact, most Chinese teachers involved in medical education have already attained an adequate level of English language usage. However, English language medical textbooks that reflect the culture of the teachers would in fact make it easier for these teachers to complete the task at hand and would improve the level and quality of medical education for international students. In addition, these texts could be used to improve the English language level of the medical students taught in Chinese. This is the purpose behind the compilation and publishing of this set of English language medical education textbooks.

The editors in chief are mainly experts in medicine from Capital Medical University (CCMU). The editorial board members are mainly teachers of a variety of subjects from CCMU. In addition, teachers with rich teaching experience in other medical schools are also called upon to help create this set of textbooks. And finally some excellent scholars are invited to participate as final arbiters for some of the materials.

The total package of English medical education textbooks includes 63 books. Each textbook conforms to five standards according to their grounding in science; adherence to a system; basic theory, concepts and skills elucidated; simplicity and practicality. This has enabled the creation of a series of English language textbooks that adheres to the characteristics and customs of Chinese medical education. The complete set of textbooks conforms to an overall design and uniform style in regards to covers, colors, and graphics. Each chapter contains learning objectives, core concepts, an introduction, a body, a summary, questions and references that together serve as a scaffold for both teachers and students.

The complete set of English language medical education textbooks is designed for teaching overseas undergraduate clinical medicine students (six years), and can also serve as reference textbooks for bilingual teaching and learning for 5-year, 7-year and 8-year programs in clinical medicine.

We would like to thank the chief arbiters, chief editors and general editors for their arduous labor in the writing of each chapter. We would also like to acknowledge all the contributors. Finally, we would like to acknowledge Higher Education Press. They have all provided valuable support during the many weekends and evening hours of work that were necessary for completing this endeavor.

*President of Capital Medical University*
*Director of English Textbook Compiling Commission*
*Zhaofeng Lu*
*August 1st, 2011*

# Preface

The book is written primarily for the first year of pre-medical students. We provide a systematic but brief introduction to the knowledge of measurement data analysis, which includes uncertainty estimation, significant figures and scientific notation. The emphasis of this book is on the training of basic measurements, such as the measurements of length, speed, temperature and voltage, and experimental skills, such as correct recording of data, focusing of a telescope, operation of an oscilloscope, circuit connection, finding the relation between two sets of data, and so on. Although most details necessary on the procedures of the experiments are given, this book can not be used as a substitute for carrying out actual experiments. Besides, it is encouraged that students conduct experiments by themselves and carry out data analysis independently, even if, in some cases, cooperation is required. The best way to learn from experimental physics is to do it, instead of watching it as a stander-by.

*Zhicheng Liu*
*June, 2012*

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# Introduction to Physics Experiments

After reading this chapter, you should know answers to the following questions:

1) What are the general purposes of physics experiments?
2) What rules should you observe during the experiments?
3) How to design an eligible experimental report?

## 1. General objectives of physics experiments

Physics experiments are the most basic scientific experiments, which ushered the dawning of modern science. As a would-be physician, you need to have a basic training in physics experiments. They play the following roles in your way to be a doctor. First, they make you familiar with the basic knowledge of experimentation, e. g. , the correct presentation of measurement result, the difference between direct measurement and indirect measurement.

Second, through the experiments, you can improve experimental skills and understand some experimental methods, which include: summarizing the key points of the principles underlying each experiment by reading relevant materials and instructions for use; the proper use of some basic experimental instruments such as oscilloscope, vernier caliper, micrometer caliper; measurement of basic physical quantities, e. g. , length, time and temperature; and operational skills, such as the tuning of telescope, recording and processing data correctly, analyzing results with graphs and models, and designing lab reports.

Last but not least, you should learn through the experiments to respect and accept facts, even if they looked undesirable, i. e. , they were not what you had expected. In scientific experiments, unexpected result sometimes implies great discovery. For example, the unexpected result of the measurement of light speed lead to the awareness of the failure of classical physics and hence the theory of special relativity, which is one of the fundamental theories of modern physics. However, when unexpected results emerge, you should analyze them carefully in order to reveal the underlying cause.

## 2. Disciplinary rules in doing experiment

When conducting an experiment in the lab, you should observe the following rules:

1) Do not make noise and chat in the lab. If necessary, you may discuss with your partner in low voice. When you need instructor's help, you could raise your hand.

2) Prepare the lab report before class by making necessary forms in order to fill in with the data to be recorded. You can copy the data forms from the experiment notes if they are available.

3) Check if there are all necessary apparatuses for your experiment. Should you find that they are not complete, report to the instructor immediately.

4) Disassembling the instruments or detaching parts of the instruments is forbidden.

5) In case of fault conditions with regard to the apparatuses, report to the instructor immediately (If power supply is used in the experiment, switch off the power first).

6) After finishing an experiment, ask the instructor to check the data for you. Be sure to recover the instruments to their original states after your data has been confirmed by the instructor, and only then is your experiment finished. You may switch off the power and reset the instruments afterwards.

7) Leave the laboratory only after you have filled the 'experiment register', in which you should sign your name.

## 3. General procedure of the experiments

In general, there are 3 steps in performing a physics experiment.

**(1) Previewing**

Before the class, you are supposed to preview the scheduled experiment by reading this book carefully. You should design the experimental report (which includes the title, the objectives, and main apparatuses of the experiment, and forms for recording data) as the outcome of this step during which you are supposed to understand the principles of the experiment and to envision the procedure for conducting the experiment.

**(2) Experimenting**

This is the actual step of conducting the experiment, which involves preparation, adjusting, observation and recording.

Preparation: you should check if the apparatuses are intact and ready prior to the experiment. In addition, you need to record the No. of the set of instruments you use, listen carefully to explanations by the instructor, read relevant manual, if necessary.

Adjusting: you should adjust and calibrate the apparatuses with care according to the instructions given by the instructor and the notes.

Observing and recording data: you should be patient and not to avoid troubles (e. g, reduce the number of repetition times required).

You must abide by the following rules when recording data.

1) Write in the experimental report with pen only. This eliminates the temptation to erase what you have written because you think you have made a mistake. *Do not erase anything you have written in your experimental report*. If you think you've made a mistake, cross out with one line what you have just written (so it is still readable) and re-write the correct number near or following it. The reason you should not erase *anything* in your report is that occasionally what you thought was a mistake turns out to be correct. You do not want to lose original information. Some people may say that this policy makes the experimental report messy, but a 'messy' experimental report is not a bad experimental report. Of course, you must be able to read and identify data in your report. A neat experimental report is usually contrived and artificial. Real experimental reports are not perfect and beautiful records of your experimental work; they are written logs of what you have done *while you are doing it*! As such they may not always have beautiful appearance. These remarks, however, should not be interpreted as to mean that a sloppy report is desirable. Your report must be a clear, readable, chronological 'diary' of tasks performed in the lab.

2) Scratch paper is absolutely not allowed. That includes any loose papers in your experimental report. Loose or scratch paper of any kind will be thrown away by your instructor as soon as they are spotted and any work done on these will be lost. *This rule will be strictly enforced*! This ensures all original data, calculations and ideas be included chronologically so that nothing is lost. The idea that you take the original data on a piece of scrap paper and later transfer it to your report to make it neat is wrong, since it allows for mistakes to be made during that data transfer.

**(3) Reporting**

After you have collected all data required (be careful! You must understand what data should be acquired after previewing the experiment, and they should be reflected in your experimental report design. If you skipped something, your experiment would fail), you should ask your instructor to check your data. In some cases, it is advised that you ask them to check your data after you finish collecting the first set of data. After the data is ratified, finish the data analysis according to the requirement given in the experiment notes.

Sign your name on the experimental report, and then reset the apparatuses, fill in the experiment register. If the data analysis can be finished in the class, you can submit your experimental report to the instructor before leaving the laboratory. However, generally the data analysis is finished after class, and you must submit the experimental report in next experiment class, i. e. , at the same time next week.

## 4. The experimental report

As the primary form in which experiment data and results are preserved and the means by which you show your understanding of your experiment and get credit for your effort, experimental report is the final conclusion to the experiment. The report needs to be self-contained and complete. The main way the instructor will know what you did and how you performed your task is through your success in communicating those facts in your report.

The report is a written, self-contained document and should be handed in as such, not torn from a notebook. It should be on standard paper of experimental report, and if you were able to type it, you could. It is obviously to your advantage that it is easy to read as well as legible.

**Note**: *You and your partner must submit separate reports*. The first five sections (see below) may be identical with the single joint proposal you and your partner have agreed upon; however, any changes in apparatus and procedure that were made during the experiment itself should be in your own words. As stated above, and reemphasized here, each partner must have an independent experimental report with a record of the experiment progress and the data. But the data numbers should be identical! Never leave the laboratory without a complete set of data in your own experimental report. Each partner must be prepared to complete the analysis independently once the data acquisition is finished. Besides, your presentation of the *Results* and your *Discussion & Conclusion* should finally be done independently in your own words-not a Xerox or computer copy. You and your partner, however, can collaborate on the calculations and analysis of the data to any degree you both wish, and discussion with your partner of the results is welcome, as an important part of the collaboration.

You are advised to follow the format below exactly, for it is a general practice in organizing a scientific report. All sections except the discussion should be brief. It should take a lot longer to decide what to say than to write it down, and you should make it concise and clear.

A experimental report consists 6 parts: 'Objectives', 'Instruments', 'Principle & theory', 'Procedure', 'Data, calculations and results', and 'Discussion and conclusion', as described below.

**(1) Objectives**

This should be one or a couple of sentences, short and specific.

**(2) Instruments**

A couple of sentences, telling what system you worked with, what things had to be measured to achieve the objective, and what instruments or techniques were employed for those measurements. You should make complete list of all pieces of equipment and supplies needed. To make sure it is complete, imagine yourself going through the entire experiment, and make a note of every item you see yourself handling.

**(3) Principle & theory**

The purpose of this section is to state the principle upon which the method is based. Usually, you should include a schematic block diagram to make the explanation, and sometimes, mathematical formulas should also be given to make this part concise and clear.

Furthermore, your 'theory' must contain clear definitions of all symbols in its equations, relating them exactly to your apparatus and your measured numbers, as well as relating the final result of the experiment to the readings. Typically, 250～500 words are appropriate for this part.

**(4) Procedure**

Write a step-by-step list of things to be done, from start to finish. However, it is not desirable to be too specific (i. e., to write everything conceivable down, say, 'turn the knob clockwise'). Usually, simple titles of the steps involved would be sufficient. **Note:** You should leave some space between the lines here. If your actual work differs from the procedure you have devised, you should modify it accordingly. Diagrams, appropriately labeled, illustrating your apparatus and method, are recommended here.

**(5) Data, calculations, and results**

Usually you need to make a couple of data forms for recording data according to the instructions given in the book. Be sure that measured numbers are identified with the symbols defined under '*theory.*' In addition, you should leave sufficient space to allow for correction to mistakes. **Note:** you should pay special attention to the unit of variable used in the data form, make sure to make proper conversion of unit when the unit on the meter is different from that used in the data form.

You make use of your *data* in conjunction with the *theory* to produce your *results*. You need not work out all the arithmetic steps in the report, but you should include enough explanation to make clear how you arrive at the results quoted below the data forms. A detailed sample calculation will usually do this. However, the arithmetic steps of simple statistical calculations such as those of mean value, sum, and standard deviation, are not required. These statistics can be sometimes included in the data form together with the record of readings. In addition, you should make a detailed calculation on the uncertainty of the result if required.

After the calculations, state your final results, simply and clearly. These should obviously refer back to the *objective*, and will usually be expressed in the form of numbers or graphs obtained in the *calculations* section. **Note on graphs:** draw your graph always on coordinate paper if it is drawn manually; you could draw the graph while the data is being taken, point by point, so measuring errors and blunders can be easily detected before you stop taking data. For better quality graphs drawn after the data taking, use a computer if available. All quality hand-drawn graphs should occupy at least half of one full page. Create your data points with a sharp pencil. Never 'connect the dots' on your graph one point to the next! Draw a visually best fit line through the data points using a ruler if a linear relationship is expected. Remember that the 'best fit' line may not intersect even one data point.

**(6) Discussion & conclusion**

It is your final review of the experiment, and three aspects could be addressed on. ① Uncertainty analysis(if required): what are the rationales for the uncertainties of the input quantities, what sources of uncertainties have you considered, why some of them are negligible in your calculation of the uncertainty of the result? ② Significance of results: In light of your uncertainty analysis, does your result agree with the theory or the reference value? If there were significant disagreement, what would be the most probable reason? Your discussion may, at your option, extend beyond this basic consideration into subjective matters: what the experiment shows, what defects the methodology has, why you did or did not enjoy it. ③ Recommendations (optional): unexpected problems you encountered, and what you would suggest to improve the experiment if it were to be done again.

More about a experimental report

A successful report would allow the reader to duplicate the basic experiment; it is by the contents of this report that your results can be checked and confirmed.

You may read a sample experimental report given in next Chapter.

# Introduction to Data Analysis

After reading this chapter, you should know the answers to the following questions:

1) What is uncertainty of an experiment?

2) What is error?

3) What is the property of error distribution?

4) What is Type A estimate of uncertainty?

5) What is Type B estimate of uncertainty?

6) How to calculate the standard deviation of a set of measurements obtained under the same condition?

7) How to estimate the uncertainty of an experiment? How dose it relate to confidence level?

8) What is significant figure?

9) What is scientific notation?

10) What is the best way to manifest a relationship between two sets of data?

11) How should you state the result of your measurement?

The data analysis of a measurement is roughly classified as quantitative and semi-quantitative. In quantitative analysis, we use uncertainty and confidence level to express the quality of the measurement, whereas in semi-quantitative analysis, we just calculate the direct result and express the uncertainty in a self-evident manner with significant figures, which give a mere estimation of the uncertainty. In all scientific experiments, quantitative data analysis should be performed following strict rules. However, semi-quantitative analysis generally gives us immediate and intuitive impression about the result.

## 1. Significant figures

A *significant figure* is a digit in a number representing a quantity, other than a leading or trailing zero introduced *only* to mark the decimal place position. For example, the zero in 0.23 is NOT a significant figure, and the zero in 120 can either be or not be a significant figure(see Example 3 below), while every digit in 1.020 is a significant figure. The meaningful digit in a number furthest to the right is called the *least significant digit*.

Significant figures allow a quick and casual approximation of the final