Studying Science

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[Tutors, I know you know how to study science, or you wouldn’t be a successful science student; however, sometimes we do things well without being fully conscious of how or why, and being conscious of how and why you are a good science student will help you to help your tutees. Feel free to share this handout with your tutees.]

Science has been called the "endless frontier," but for some students it seems just plain endless. There are endless lectures, endless textbooks, endless problems, and worst of all, endless labs. This chapter presents some techniques to help make science a little less intimidating and a little more exciting. It provides effective methods for…

• Learning from Lectures
• Reading a Science Textbook
• Working Scientific Problems
• Working in the Laboratory

In every subject that you study, including science, you must learn new terminology, facts, and ideas; then you must develop the ability to apply them to solve various types of problems. But studying science is different from studying other subjects. First, the terminology, facts, laws, and principles must be learned with extreme precision. And second, the problems are almost always quantitative; in fact, most ideas are stated in quantitative (mathematical) terms.

A good example is the definition of work, which is learned early in the study of physics:

The work $W$ done by a force of magnitude $F$ in moving a body through a distance $d$ in the direction of the force is $W = F \times d$.

Such a definition can cause several kinds of headaches for a student who isn't accustomed to precise and quantitative terms:

1. The definition is precise, and it must be learned and used precisely. What might seem like a minor rewording could change it to an incorrect (and thus useless) definition.
2. The definition contains several parts, and the reason for each part must be understood if the definition is to be understood.
3. The definition is quantitative. It makes use of a formula to define work, and that formula may be used to calculate work under certain conditions.
4. The student must learn what these conditions are, and how to take them into account when using the formula.
5. The word work is used in a different sense from the one we're used to. Some common words are given special meanings in the sciences, and the usual definition can get in the way of remembering the scientific definition.
The reason for all this precision is simple. The sciences deal with actual, measurable things. If these things are not described or computed precisely, then they are described or computed incorrectly.

So you need to learn the precise terminology, facts, and ideas when you study a science. But you should not try to learn a science as a collection of isolated facts. That would be an almost impossible task, and the isolated facts would have little meaning for you.

The way to learn science is to fit facts and principles together into groups, or clusters, in your memory. Within each science, the facts and principles are related to each other, to a much greater extent than in non-scientific subjects; so clustering should be easier. Actually, much of science is concerned with finding and explaining the relationships among various facts, concepts, and theories. Even our precise definition of work is really a relationship; it is given as a formula because the relationship is a precise one. Your textbook and teachers will be pointing out many more. Your job is to use these relationships to cluster the facts and ideas in your mind.

As you learn in this way, your knowledge of a few facts in a cluster will easily extend to new facts and ideas that you want to include in the same cluster. You will find yourself becoming more and more comfortable with science and its precision. You may begin to ask yourself questions about how new ideas fit in with old ones; and about the patterns that you find in both old and new facts; or about why a principle that you learned in one science course seems so much like a principle you learned in some other science course. Then you will really be learning science.

LEARNING FROM LECTURES

Remember that your objective is to learn (1) the facts and (2) their inter-relationships, and your ears and eyes must be alert to both. Take full, legible notes at lectures, paying particular attention to explanatory diagrams. And don't hesitate to ask questions if you cannot grasp a point after reviewing your lecture notes and reading your text.

Taking Lecture Notes

1. Take notes on ideas, not words. Do not try to get the lecture word for word. If you do, the words will get in the way of the ideas. The objective of taking notes is to have a record of the main ideas, so you can study them later in the privacy of your own room, for deeper understanding, for review, and in preparation for examinations.

2. Be systematic. Use the Cornell System of taking notes, as illustrated in Figure 21.1. Write your notes in the large right-hand column. Then, as soon as possible after each lecture, put your notes in order by filling in missing steps in the arguments, by detecting and correcting any errors, and by relating these new notes with the previous lecture's notes. Label each idea on the right with a key word, placed in the left-hand column.

3. Make master summary sheets. Periodically (to prepare for tests or at spaced intervals), reorganize your notes on separate sheets of paper, by clustering the ideas and details under main topics and categories. By constructing such summary sheets, you will be relating facts and ideas to each other and fixing them in your memory.
### Polarity of Magnets

- *Magnetism is stronger at ends than middle*
- *Like poles repel each other. Ex. 2 N poles when brought together fly apart when released. Same for 2 S poles*

### Experiment: Iron Filings

- *Experiment to show stronger ends*
  - *place bar magnet under glass*
  - *pour small iron filings on glass*
  - *tap glass and filings arrange selves showing lines of force*

### Theory of Magnetism

- *not sure what causes it*
- *believe: way molecules are arranged*

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**Asking Questions**

If you have difficulties in relating concepts, in solving assigned problems, or in completing lab experiments satisfactorily, there may be gaps in your understanding. In such cases, you should start asking question.

**Asking The Teacher At The Start Of The Class.** This usually is the best time to ask questions, because they have been considered carefully. Well-phrased questions about the previous lecture or the reading assignment can often be cleared up quickly. Moreover, something that presented difficulty for you probably did the same for other members of the class; your teacher may want to discuss it during the lecture.

Never worry about being the only student who doesn't understand, or about showing that you didn't grasp a particular idea. If you do, you will only be underestimating the teacher and yourself, misjudging the purpose of the course, and making it harder for the teacher to keep in touch with the class.

But don’t ask questions like "How do you do this problem?" Such a question may get you the answer to the problem, but it will be of little help to your understanding. Much better questions are, "Did I use the right strategy in attacking this problem? Are there other
strategies that I could have used?" This type of question will get you useful information—ideas that you can apply to a broad range of material.

**Interrupting A Lecture.** Don't be bashful; interrupt a lecture with a question if you need to. Often it is helpful for the whole class to have a lecture slowed down or brought to a halt for a while—especially if some point is obscure. But don’t interrupt too often, and make sure your question is an important one to you.

**Asking The Teacher Between Classes.** A good teacher's interest in his or her subject and students continues between classes in spite of many other duties. Most teachers enjoy a discussion with an individual student, because that is the most favorable teaching situation. But remember one thing: You must have done (or tried) the assignment and thought about the problems for yourself, before you ask for assistance. Private sessions between teacher and student should only supplement your own work. The major part of learning must be done by you alone.

**Asking Other Students.** Discussions with other students can be a great help. Friends learning a subject together share the same difficulties, and they need not hesitate to contradict each other. They can enlighten each other very effectively.

**READING A TEXTBOOK IN SCIENCE**

In some ways, studying a science textbook is like studying any other textbook. You should take notes using the Cornell format, review them using the recitation method, and from time to time make master summary sheets. However, there are also some special techniques that you should use to get the most out of a science textbook. For example, you should keep in mind the fact that science texts are packed with information. You must read them sentence by sentence, making sure you understand each sentence before going on to the next.

Here are four more techniques:

**Using Mental Visualization**

James Clerk Maxwell, a British mathematical physicist, recognized that different people, as they read and study science, mentally visualize or reconstruct concepts and ideas in their own personal ways. He believed that (1) the concepts and ideas of science can be lifted out of a textbook and placed in one's mind only by the process of mental visualization, and (2) different people have different ways and abilities to visualize, but, they all visualize to varying degrees.

Fortunately, most textbooks and articles in science are heavily illustrated with diagrams to aid the process of visualization. Learn to use the illustrations and text to complement one another. When there is no diagram to illustrate a process or idea, or if a given diagram doesn't work for you, then make your own.
Learning New Terms
A second important technique is learning new terms. You will find that your science textbooks are crowded with terms that are new to you. Since these terms stand for essential concepts, you must know precisely what they mean if you are to understand the subject matter. To help you pick them out, these important new terms are usually emphasized by italics or heavy type when they first occur and are specifically defined there or in a glossary at the end of the book. Give extra time and attention to the task of memorizing these terms and learning what they mean. Put them on 3 x 5 cards, and master them as you would any new vocabulary word.

An Important Tool: The Language of Measurement
Learn the language of scientific measurement. Most commonly used are the metric system and the Celsius and Fahrenheit temperature scales. Learn to think meaningfully in these quantities and measures, so that you will not be reading mere words and symbols.

For example, you should know that the word metric comes from meter, which is the principal unit of length in this system. The metric system was developed by French scientists in 1799 and is now used everywhere in the word for scientific work. Table 21.1 compares some metric units with English units of measurement.

You will want to know about the Celsius and Fahrenheit temperature scales, too. The thermometers for both look alike and have the same size tubes; both are filled with mercury, and the mercury rises and falls to the same levels. They differ in the way the scale is graduated. On the Celsius thermometer, the point at which water freezes is marked 0 (zero), while on the Fahrenheit thermometer it is marked 32. On the Celsius scale the boiling point is 100, while on the Fahrenheit it is 212.

On the Celsius thermometer, then, there are 100 equal spaces or degrees between the freezing and boiling points of water. On the Fahrenheit thermometer, there are 180 degrees between the freezing and boiling points. Thus,

* To change Celsius readings to Fahrenheit readings, multiply by 180/100 or 9/5, and then add 32.

* To change Fahrenheit readings to Celsius, subtract 32 and then multiply by 5/9.

<table>
<thead>
<tr>
<th>Metric System</th>
<th>English System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilometer</td>
<td>Mile = 1.609 kilometer</td>
</tr>
<tr>
<td>= 0.621 mile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yard = 0.9144 meter</td>
</tr>
<tr>
<td>Meter</td>
<td>Foot = 0.3048 meter</td>
</tr>
<tr>
<td>= 1.093 yards</td>
<td>Inch = 0.0254 meter</td>
</tr>
<tr>
<td>= 3,281 feet</td>
<td></td>
</tr>
<tr>
<td>= 39,370 inches</td>
<td></td>
</tr>
<tr>
<td>Unit</td>
<td>Conversion Factor</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Gram</td>
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</tr>
<tr>
<td></td>
<td>0.0648 grams</td>
</tr>
<tr>
<td></td>
<td>0.032 troy ounce</td>
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<tr>
<td></td>
<td>31.1 grams</td>
</tr>
<tr>
<td></td>
<td>0.0352 avoirdupois ounce</td>
</tr>
<tr>
<td></td>
<td>28.35 grams</td>
</tr>
<tr>
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<tr>
<td></td>
<td>453.6 grams</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>0.907 metric ton</td>
</tr>
<tr>
<td>Carat</td>
<td>3.08 grains</td>
</tr>
</tbody>
</table>

Using Study Guides
Study guides accompany the textbooks for many science courses. These guides can be very valuable in mastering scientific subject matter.

One type of guide uses what is called a programmed approach. In this approach, a section of the guide containing sentence-completion questions corresponds to each section of the textbook. The questions help you evaluate what you've learned and what you still need to review. They also help you rehearse for real examinations on which you'll be graded. In addition, there is a brief summary of each chapter and a list of chapter objectives. The value of the summary is self-evident. The objectives are a ready-made-self-test that you can use to make sure you've learned the important concepts in the chapter.

A second type of study guide contains the following, for each textbook chapter: an overview, chapter objectives, an expanded chapter outline, student study objectives, a vocabulary checklist, and self-tests. When you are using this type of guide, you should read the text chapter before attending the lecture on that chapter. Then, after the lecture, read the overview, objectives, and outline in the guide, and summarize the chapter in your own words. Check through the student study objectives, and write out any answers that are called for. Next, make sure you can define all the terms in the vocabulary checklist. Finally, take the self-tests to check that you have mastered the chapter. And don’t forget to use the study guide along with your notes when you review for an examination.

A Final Word
Different sciences call for different attacks and emphases in your reading. Generally, biology and geology place relatively heavy emphasis on key terms and definitions; physics and astronomy, on measurement and mathematics; biology and chemistry, on manipulation; and physics and chemistry, on visualization. Make sure you adapt your study methods accordingly.

WORKING SCIENTIFIC PROBLEMS
The Value of Practice
You should never skip an assigned practice problem. The most successful way to solve a problem on a test is to remember how you solved a similar problem previously. When you first attempt a new kind of problem, it is natural to be hesitant, to make false starts, to be temporarily stumped—to waste time. But as you work more problems of the same kind, you learn to do them more quickly and surely. Besides, each problem usually has some feature that is not present in previous ones. So you gradually build up the ability to attack a wider and wider range of problem types.

Complex problems are usually solved in many simple steps. If these steps are so familiar that they are automatic, you can concentrate on how they fit together in the problem. Then you can proceed from start to finish without confusion. But if each step presents difficulty, you'll get so involved in the details that you won't find the right path to the solution.

In studying a science, therefore, you should really do more than only the assigned problems. If your own textbook does not have many extras, look for problems in other books on the same subject. Use a study guide. Or, best of all, try to make up appropriate problems for yourself. Making up good ones is harder than solving them, but it is an excellent exercise—particularly for two students who are studying together. If you do this, try to imagine the problems your teacher will make for your tests.

Doing New Types of Problems
If you do your assignments faithfully, you should come across new and unfamiliar problems only in your homework. A recommended approach to such problems is as follows:

1. Don't start doing problems until you have studied your lecture and textbook notes.
2. Make a list of what is given in the problem, and what is to be found.
3. Try to develop a chain of logical steps leading either forward from the known quantities to the one you have to find, or backward from the unknown to the given quantities. If necessary, work from both ends to the middle, until you find a logical connection.
4. Express these logical steps in the form of equations.
5. Combine the equations and solve them for the unknown.
6. Check your answer by determining whether it is reasonable in magnitude. If you are unsure, substitute the answer into the original relations, and see whether it fits consistently.

Answering Discussion Questions
Discussion questions appear occasionally in quizzes and examinations. Before you answer one, try to understand the purpose and point of view of the person asking the question. Learn to put yourself mentally in his or her place. Ask yourself how the question is related to the subjects that were recently discussed in class or in your reading assignments, and what principles it is intended to bring out. If you can visualize the question within your clusters of facts and ideas, you should know how you want to
answer it. All that remains is to express your answer in clear language, using the technical words accurately.

Practice is needed to become skillful in answering discussion questions. This skill can be developed by taking part in discussions with your friends; by participating in classroom discussions; and by paying careful attention to your writing skills. Usually, the problems are not in the grammar, but in the vocabulary, in logic, and in ordering the steps in an argument.

WORKING IN THE LABORATORY

Here are some hints on good attitudes and habits for the laboratory work:

1. Do not trust your memory. Write down everything you think may be pertinent. Some things that you observe in the laboratory may seem to be clear at the time that there is no point in writing them down. But memory fades; if an experiment is not completely written up when it is performed, you may not be able to recall important items.

2. Make a permanent record of your observations. Keep a full record of your calculations, observations, and results in a special notebook; don't ever write anything down on separate scraps of paper—not even your arithmetical calculations. If you make mistakes, cross them out and go on from there, but keep everything as part of your complete record. Start your record of each experiment or laboratory session on a new page, headed with the date. This will give you a permanent log of all your data and your thinking, regarding every problem on which you have worked—the raw materials for your final report.

3. Organize the recorded data. Arrange the data so that they will be clear and fully labeled for later reference. The few extra minutes you spend to make neat and orderly records during the lab period will save you time that you might later have to spend deciphering sloppy notes.

4. Do not trust yourself or the apparatus too much. It is unwise to record a lot of untested numbers, dismantle the apparatus, and leave the laboratory before knowing whether your data are of any use. It is much better to do at least an approximate analysis (including rough graphs) of the date while they are being taken. Such a check will give you a chance to detect anything that is going wrong, in time do something about it—such as readjusting the apparatus, checking or repeating an observation, or asking your instructor for assistance.

5. Baby the apparatus. Poor performance in a laboratory is often due to carelessness, but it may also be the result of an uncooperative attitude: being too ready to say the apparatus doesn't work, or to believe it is limited in capability. The trick is to regard the apparatus as your friend, not your opponent. Treat it tenderly, and coax out of it all the accuracy it is capable of. Make notes of its limitations. And watch the apparatus like a hawk for signs of strange behavior. No real equipment is quite like the ideal version pictured in a textbook or laboratory manual; each piece of apparatus has an individual personality.

6. Keep the purpose of the experiment in mind. This can save you much wasted effort, and keep you from overlooking the main point of the lab work.

7. Write up your reports clearly, legibly, and concisely, in the proper form. The writing style should be impersonal; in technical reports it is customary to use the passive voice.
The usual laboratory report contains as many of the following items as apply:
* Purpose (object): A statement explaining what the problem is.
* Theory: the background for the problem and the justification for your method of attack.
* Apparatus (equipment, materials): A listing and brief description of the essential apparatus, often including a sketch of the apparatus
* Results: A summary of your findings and an assessment of their accuracy, showing how your results succeed or fail in resolving the problem

Above all in writing a report, remember that your purpose is to make your findings understandable to a reader. Make full use of your writing skills.

**SUMMARY**

*How is learning science different from learning other subjects?*
There are two differences. First, the terms, facts, and principles must be learned precisely. Second, the facts and problems are quantitative in nature.

*What is "learning in clusters"?*
Briefly, it is finding the relations among various pieces of information and then grouping the information in your mind according to those relations. It makes remembering much easier.

*How can we improve our notetaking in science lectures?*
There are three ways. First, concentrate on the ideas that are being presented, rather than on the words themselves. Second, use the Cornell System, which allows for you to take, review, recite, and consolidate your notes more easily. Convert your notes into master summary sheets as part of your studying.

*What's the best time to ask a question in class?*
At the beginning of the lecture. Questions asked at this time are usually well thought out. And the instructor may want to make use of them in class discussion.

*What is a mental visualization?*
This is the way most of us understand abstract concepts, whether we realize it or not. With mental visualization you create a picture in your mind's eye. As soon as you do, the concept becomes easier to see and remember.

*What is the best way to solve a test problem?*
Remember how you solved it before. This recall requires experience, and the only way you can get experience is with plenty of practice. Work out all the assigned problems, and then look for some more to work on.

*How should I handle a type of problem that I've never faced?*
Be logical and systematic about it. First, figure out just what you need to find. Then try to plot a logical course from the given quantities to the unknown quantities, or vice versa.
Once you have plotted this course, convert it into one or more equations and solve them.

*What's the key to answering discussion questions?*
Figure out just what sort of answer the question requires. Then try to connect it with your clusters of learned facts and principles. Once you've made the connection, write out your answer in clear, precise language.

*What is the object of the seven hints for doing lab work?*
It's the same objective you have in writing lab reports: to make sure you have all the information or data you need, in a logical and legible form, to communicate your lab results clearly and precisely.