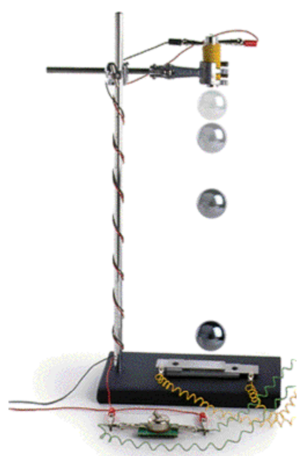
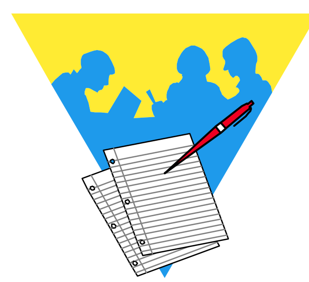
Teaching a Laboratory Section





I. Problem-Solving Labs in Operation

Introduction

The purpose of the UMn problem-solving labs is to provide students with practice and coaching in a logical, organized problem solving process. In other words, the purpose of the labs is the *same* as the purpose of the discussion sessions.

Instructions for problem-solving labs are different from the instructions for other labs with different purposes. A comparison of problem-solving labs with traditional verification and inquiry labs is shown in Figure 1 on the next page. You will not find a detailed discussion of the principles explored by the lab; you will not find any algebraic derivations of the equation to be used in the lab; and you will not find step-by-step instructions telling the students what to do. Instead, our labs allow students to practice solving problems (making decisions) based on the physics presented in the other parts of the class: the discussion sections, the lecture, and the text.

The student lab manuals are divided into about 6-7 two-to-three-week units called *labs*. The manual also includes an equipment appendix and technique appendices. The labs themselves are comprised of an introduction page and several lab problems. ***Notice that we do not do experiments in our laboratory.*** The lab problems are similar to the ones found at the end of a textbook chapter or on a quiz. Students solve the assigned lab problems(s) **before** the lab session. During the lab session, students collect data to check their solutions. Typically, it takes students less than an hour to check their solution for one lab problem (if they have done their homework). They should analyze all the data and reach a conclusion in class before starting to check their solution for the next assigned problem.

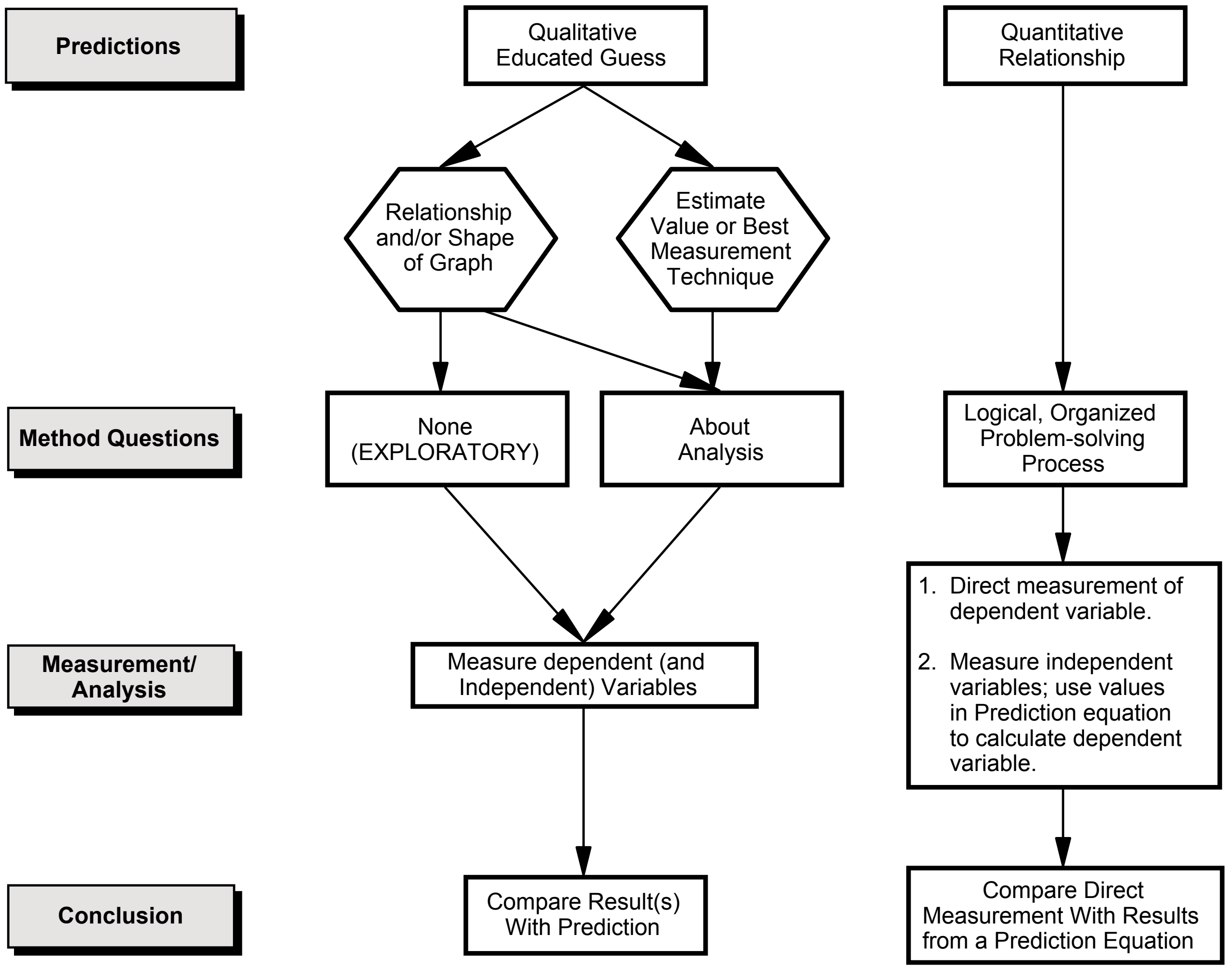
Each problem is broken down into sections that represent the processes expert researchers use in a laboratory. The sections are: introduction to the problem, description of the equipment, a prediction of the outcome, method questions, exploration, measurement, analysis and conclusion. Each lab problem begins with a brief description of the context in which the problem arises. The equipment is then described in enough detail to allow the students to predict the outcome of the problem. Students answer and turn into you the questions in the next two sections (*Prediction* and *Method Questions*) **before** they come into lab (see the Grading section on pages 71-72).

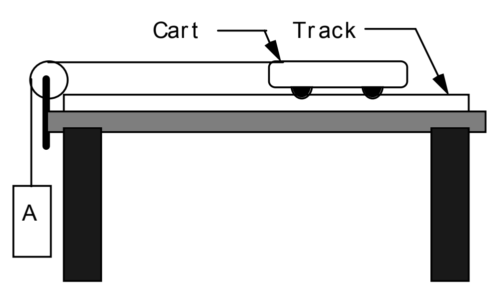
There are two different types of lab problems, as shown in Figure 1 (page 63). That is, the Prediction can be either a qualitative (educated guess) or a quantitative solution to the problem. There are two types of qualitative predictions. Students may be asked to predict a *relationship and/or the shape of a graph*. Problem of this type are called *Exploratory* lab problems. For example, for one exploratory lab problem students predict the brightness of each bulb in three different circuits. In another lab problem, students predict the shape of a velocity versus time graph of a cart rolling down and then up two inclined planes. In the second type of qualitative lab problem, students predict either the value(s) of a measurement, or which of two measurement techniques is best (most accurate). Qualitative lab problems are usually at the beginning of a lab topic.

Comparison of Different Types of Labs

Traditional Verification Labs	**U of Mn Problem-Solving Labs**	**Inductive or "Inquiry Labs**
Major Purpose: To illustrate, support what is being learned in the course and teach experimental techniques	**Major Purpose:** To illustrate, support a logical, organized problem-solving process	**Major Purpose:** To learn the process of doing science
Introduction: • Students are given quantity to compare with measurement. • Students are given theory and how to apply it to the lab. • Students are given the prediction (value measurement should yield).	**Introduction:** • Students are given a problem to solve. • Students must apply theory from text/lecture. • Students predict what their measurements should yield.	**Introduction:** • Students are given a question to answer. • Sometimes students are given related theory. • Sometimes students are asked for a prediction.
Methods: • Students are told *what* to measure. • Students are told *how* to make the measurements.	**Methods:** • Students are told *what* to measure. • Students decide in groups *how* to make the measurements (guided qualitative exploration).	**Methods:** • Students decide *what* to measure. • Students decide *how* to make the measurements (open-ended qualitative exploration).
Analysis: • Students usually given analysis technique(s). • Emphasis is on precision and experimental errors.	**Analysis:** • Students decide in groups details of analysis. • Emphasis is on concepts (quantitatively).	**Analysis:** • Students must determine analysis techniques. • Emphasis is on concepts (qualitatively).
Conclusion: Students determine how well their measurement matches the accepted value.	**Conclusion:** Students determine if their own ideas (prediction) match their measurement.	**Conclusion:** Students construct an hypothesis to explain their results.

Figure 1. Types of Laboratory Problems





The majority of the lab problems, however, are quantitative. For example, the question in one lab problem is: What is the velocity of the car after being pulled for a known distance? Students model this problem with the equipment shown at right. The prediction for this problem is: Calculate the cart's velocity after object A has hit the floor, as a function of the mass of the object A, the mass of the cart, and the distance object A falls. The variable on the left side of a prediction equation (e.g., velocity) is called the dependent variable. The variables on the right side of a prediction equation (e.g., mass of the object A, the mass of the cart, and the distance object A falls) are the independent variables.

The *Methods Questions* are designed to coach students through a logical, organized problem-solving process to arrive at their prediction. Although the *Prediction* section comes before the *Methods Questions*, the Methods Questions should be completed before the students make the prediction. The *Prediction* section is first so that the students will know the purpose of the *Methods Questions*. Students tend to do things in the order presented, so they will have to be reminded to do the *Methods Question*s first to solve the problem. Of course, if a student can solve the prediction in a logical and organized manner, the *Methods Questions* serve as a check of their knowledge leading to that prediction.

Typically, the `introduction to each lab session` will begin when you ask the members of each group to arrive at a consensus about one or two of the *Method Questions*. You will know which Methods Question(s*)* to have students discuss and put on the board from your examination of the answers your students turned in before lab Make sure to give an explicit time limit for this group discussion: usually this should take no more than 5 - 10 minutes. At the end of the group discussion time, have one representative from each group put their answers to the specified the *Methods Question(s)* they have just discussed on the board. This can help reinforce that it is possible to get the "right" answer for the wrong reasons.

Then conduct a class discussion comparing and contrasting these answers. Remember that the purpose of the introduction is to get students to make an intellectual commitment to the physics of the lab. ***The discussion need not arrive at the correct answers to the questions. If there is unresolved disagreement, wait to resolve it in the closing discussion, after they have completed checking their solution to the laboratory problem.***

The `Exploration` section encourages the students to become familiar with the apparatus so they will understand the range over which valid measurements can be made. This is perhaps the most important section of the laboratory and the one that students tend to skip. Don't let them. This is where they develop a "feel" for the real world that is a crucial guide in solving problems. This is also where students can qualitatively test their preconceptions about the physical process occurring. Give students a lot of encouragement to explore with the equipment. You and I know this is the essence of physics, but many students view it as a "waste of time." The outcome of the *Exploration* should be an organized plan for making the measurement.

The `Measurement` section asks the students to make the measurements needed to check their prediction. Here students need encouragement to pay attention to their measurements **as they take them**. They should be able to tell if their measurements "make sense" and why. If the measurements don't make sense to them, this is an ideal coaching moment. Either they have a misconception of physics or a misconception of the measurement process. In either case, you should work with them to set them straight.

In the `Analysis` section, students process their data so that they can interpret their results in the *Conclusions* section. When students analyze their data by finding a function to represent the data, it is important that they understand the meaning of the constants in that function. By using some calculus and/or making measurements on the computer screen, students should be able to predict those constants reasonably precisely. Do not let your students get into the random guessing mode. This wastes a lot of time and eliminates some of the learning built into the lab. It is especially important that they should be able to tell you the units of those constants for the particular situation.

In the `Conclusion` section, the students should reflect on their results and observations while *solving and checking* the laboratory problem. This gives many students a great deal of difficulty, especially at the beginning of the course. Make sure they write an outline of the conclusions for the problem **before** going on to the next problem. The conclusion should include a corrected, logical and organized solution to the prediction question.

The conclusion should also go back to the original "realistic" problem and state a definite solution. Finally, the conclusion should address the validity of the prediction and the measurement. Students love to give "human error" as a reason for a discrepancy. This is not an acceptable reason. Human error should always be corrected before a report is written.

When most of the students have collected the data and at least begun discussing their conclusion, conduct a `whole class discussion.` This discussion will be different for different types of problems. We will discuss leading discussion in the Orientation and the seminars.

NOTES:

II. Rationale for Problem Solving Labs

What goals do these labs address?

There are many possible reasons for doing a physics laboratory. For example, a lab could allow students to:

- confront their preconceptions of how the world works;
- practice their problem solving skills;
- learn how to use equipment;
- learn how to design an experiment;
- observe an event that does not have an easy explanation, so they realize new knowledge is needed;
- gain an appreciation of the difficulty and joy of doing and interpreting an experiment;
- experience what real scientists do; and
- have fun by doing something more active than sitting and listening.

It is impossible to satisfy all of these goals with a single laboratory design. Because this course follows the traditional structure of learning physics through solving problems, we have focused the laboratories toward **PROBLEM SOLVING**. Since one important reason that our students cannot solve physics problems is that they have misconceptions about the physics, our second goal is to confront some of those misconceptions in the laboratory.

Why this style of lab?

Most physicists feel that labs are an essential part of a physics course because physics is reality. Some have gone so far as to state that all physics instruction should take place in the laboratory. Nevertheless, labs are the most expensive way to teach physics. Research to determine the benefit of labs in teaching physics has consistently shown that labs that give students explicit instructions in a “cookbook” style, have little value, particularly to address a problem-solving goal. The research also shows that "hands-on" experience coupled with directed peer and instructor coaching can be an efficient way of overcoming misconceptions and helping students learn to solve problems in a logical and organized manner. In our teaching environment, the laboratory is the only opportunity for you to interact with small groups of students during an extended time period. Because the students have specific and visible goals, it is easier for the instructor (you) to determine their physics difficulties by observing them. Solving a problem in the laboratory requires the student to make a chain of decisions based on their physics knowledge. Wrong decisions based on wrong physics lead to experimental difficulties that you can observe and correct. For a comparison of our problem-solving labs with traditional and inquiry labs, see the chart on page 62.

How can I make my students like and value the labs?

Instructor attitude is the most important factor in determining what the students like. If the instructor likes the labs and thinks they are valuable, then the students will tend to like the labs.

The converse is also true. Even before starting the class, many students consider labs as "busy work" that has nothing to do with the content of the course. Labs have required attendance, so some students see their object as getting a task done as fast as possible so they can leave — the "take-the-data-and-run" approach. This view is reinforced when: (a) students are given step-by-step instructions focused on doing the task as efficiently as possible; (b) the lab instructor spends a majority of the lab time helping groups get their apparatus working so they can get done; (c) the lab instructions have all necessary information so that no use of the textbook or the lectures is needed; (d) the problems are not seen as challenging; and (e) there is no reference to the labs in the lectures or on tests.

The physical appearance of the lab is also very important in determining student attitude. Students will also dislike the labs if they are overly frustrated in their attempts to operate in the laboratory environment. An instructor who takes time to assure that the lab is neat and orderly *before* the students enter gives the message that the student's lab work is important.

Why have students work in groups?

The simplest answer is that a well-functioning group is the most efficient way to solve any problem. However, in this class we have more definite educational reasons. Students working in groups must discuss what their thoughts are -- they get practice in "talking physics." This discussion tends to bring their physics preconceptions (alternative conceptions) to the surface so they can deal with them. It is a cliché that the "best way to learn is to teach," but it is true. Working in the same groups in both laboratory and discussion section allows students to become more familiar with each other so that they feel comfortable enough to discuss their physics difficulties. Having the same groups and instructor for both the laboratory and discussion section also explicitly connects the lab to the rest of the course. In addition, group work makes teaching more manageable for the instructor. Instead of trying to serve 15 - 18 individual students, you interact with 5 - 7 groups, so you can be their "coach" to help them become better problem solvers. By pooling their knowledge and experiences, members of a group will get "stuck" less often, which leaves the instructor more freedom to concentrate on coaching to remediate serious physics or procedural difficulties.

Why are there so many problems in each lab?

Our labs have been written so that there are more problems than the typical group can complete in the time allotted. This emphasizes that the function of the lab is to learn the physics rather than just to get the problems "done." The teaching team for each course section can then choose a preferred order of problems and the minimum number of problems to be completed to match the emphasis of the lectures. In addition, the extra problems allow each lab instructor (you) the flexibility to select the material to meet the needs of each particular group. Some of your groups may understand the material and need to be challenged with more difficult problems to deepen their knowledge. This also keeps these groups from becoming bored. On the other hand, some groups will have difficulty in understanding the basic physics being presented and may need to concentrate on a specific difficulty by doing a second very similar problem.

What is the function of the pre-lab computer quiz?

This set of questions is available on the website (http://labquiz.physics.umn.edu). They are designed to make sure that students have read the relevant sections of the text ***before*** they come to your laboratory. There is nothing more wasteful of both your time and that of your students than their having to read the text during the laboratory period for the first time. The questions require minimal understanding of the concepts in the text and are a good preparation for the lectures as well as the laboratory. Students are required to score at least 70% to pass. If a student misses a question, the test is expanded to give them another chance to answer a similar question correctly. The more questions that the student misses, the longer the test. Student can take the quiz as many times as they wish. They can use their textbook, their notes, and consult with other students when they take the quiz. The important thing is that they come to lab prepared. When a student keeps getting the same question wrong even though they are sure they put in the right answer, it is almost never a computer glitch -- usually the student has an alternative conception. This is an excellent opportunity for instruction. Each student's score is recorded in a file for your use (http://labquiz.physics.umn.edu/report). A student who has read the material with some understanding should pass the quiz in less than 15 minutes. Of course, this rarely happens. Typically students read their text *for the first time* while they are taking the quiz, so they can take from 30 - 45 minutes to learn the information. If a student is taking more than 60 minutes to pass the check out, this is probably too much time and you should discuss the difficulty with the student.

Why don't the lab instructions give the necessary theory?

This is to emphasize that the laboratory is an integral part of the entire course. The theory is available in the textbook, and the preparation section for each laboratory states which sections should be read. Reading the text and doing the predictions and questions preceding each problem gives an adequate preparation for the lab. A computer quiz assures both you and your students that they have a basic understanding of the necessary text material before coming to class. Doing the lab problems should help students, with your guidance, clarify and solidify the ideas in the text and in the lecture.

Why have students answer the Methods Questions?

Most students solve problems by either the plug-and-chug method or the pattern matching method (see *Research Review: How Beginning students Solve Physics Problems* in Selected Readings). That is, many students can come up with a correct prediction equation or reasonable looking graphs for strange reasons that do not follow the accepted laws of physics. The Methods Questions provide explicit coaching for students in a logical, organized approach to solving a problem. They require students to think about the physics concepts and principles needed to solve the problem.

Remember the Zeroth Law of Education: If you don't grade for it, students won't do it. One of the purposes of having students solve the Methods Questions *before* the lab is for students to learn how to figure out for themselves at what point in the problem they get stuck and why. This problem-solving skill is very difficult for most students.

What is the reason for minimal laboratory instructions?

One of the primary goals of the laboratory is to help students learn to solve physics problems *better*. Good problem solving requires informed decision making. Most of our students need a great deal of practice in making analytical decisions. The labs are designed to leave most of the decisions up to the students. As with any problem, there are usually several correct paths. Discussing the possible choices within the group gives each student the opportunity to solidify correct concepts and dispel alternative conceptions. This freedom also allows groups to make incorrect choices. It is another true cliché that "we learn from our mistakes." Observing students' incorrect decisions allows the instructor (you) to teach to the needs of the particular students or groups.

Why should the students write up lab problems?

No matter how conscientious the lab instructor, many students will leave the lab with some of the same misconceptions as when they entered. The presentation of the course material may also generate new misconceptions. Reading a student's words gives you valuable knowledge about that student's knowledge of the physics. This can help you direct your teaching more effectively. In addition, our students should begin the process of clear, concise, meaningful written technical communication that they will need in their future careers.

Why have team meetings?

To teach large classes as efficiently as possible, we divide the teaching responsibilities among members of a team. A lecturer in front of a large class best does some functions, and some are best done with a small group. Because different people perform these functions, extensive communication is necessary. The presentation of a coherent picture of introductory physics to our students requires that the lectures, labs, and discussion sections be highly coordinated. There are usually several ways to present a topic in physics each with different notation, terminology, and emphasis. These different approaches, while interesting to the expert, are confusing for an introductory student. The team meetings serve to make sure that everyone knows and abides by the approach chosen for the class. At your team meetings, discuss a rationale for the class "party line" until everyone feels that they know the reason for it and can enthusiastically support it to their students. Nothing is more demoralizing for the students than decisions that are not supported by *all* of their instructors. Ideally, coherence would be maintained by having every instructor visit every other instructor's class. Since this is not always possible, the team meetings serve this purpose.

Team meetings also allow the lecturer to discuss with the lab/discussion section instructors the pace and organization of the lectures and what the lecturer assumes the students understand and can do. The lab/discussion section instructors discuss with the lecturer and among themselves the extent to which the students understand the material and which approach to teaching may help. Fast feedback is essential if this information is to influence the pacing and approach of the course. Of particular importance is detailed feedback from the grading of tests and lab reports. All instructors are encouraged to visit the lectures, discussion sections, and labs of other instructors as much as possible. The lecturer will visit your sections as much as possible and you should attend lecture whenever you can.

III. Grading the Labs

At the end of each lab topic (2-3 weeks), students will receive a grade for that lab. There are three ways students are graded.

1. About 1 - 2 days before each lab session, your students will give you their journals with their Methods Questions and Prediction for the assigned lab problem(s). The Methods Questions set for each assigned problem are graded quickly as either 0 points or the maximum points.
2. Each student is also graded once on their lab procedure during the 2-3 lab sessions.
3. At the end of a lab topic, you randomly assign *a different lab problem for each student in a group* to write a Problem Report. Students should never know ahead of time which lab problem they will write up as a report.

When the students turn in their Problem Report, they should attach the Laboratory Report Form that is included in their lab manuals. The Checklist from this form is shown below. You fill out this form and return it to students with their graded Problem Report

GRADING CHECKLIST	Points
LABORATORY JOURNAL:	
METHODS QUESTIONS AND REDICTIONS (individually completed before each lab session)	
LAB PROCEDURE (measurement plan recorded in journal, tables and graphs made in journal as data is collected, observations written in journal)	
PROBLEM REPORT:*	
ORGANIZATION (clear and readable; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (clear and readable; units and assigned uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	
TOTAL (incorrect or missing statement of physics will result in a maximum of 60% of the total points achieved; incorrect grammar or spelling will result in a maximum of 70% of the total points achieved)	
BONUS POINTS FOR TEAMWORK (as specified by course policy)	

* An "R" in the points column means to <u>rewrite that section only</u> and return it to your lab instructor within two days of the return of the report to you.

Each of the three grading procedures is described below.

Grading Predictions.

About 1 - 2 days before each lab session, your students will give you their journals with their answers to the Methods Questions and Prediction for the assigned lab problem(s).

- **The Prediction is *not* graded.**
- **The Methods Questions are graded for REASONABLE EFFORT, and *not* for the correct answers**.
- **Never indicate in the students' journal whether their answers are right or wrong.** This would spoil the whole purpose of the labs.

One of the purposes of solving the Methods Questions *before* the lab is for students to learn how to figure out for themselves at what point in the problem they get stuck and why. This problem-solving skill is very difficult for most students.

So what does reasonable effort mean? Students receive the maximum number of points if they:
- answer all the questions correctly;
- answer all the questions, *even if some of answers are incorrect*;
- answer some of the methods questions, and clearly indicate where they got stuck and why.

Students receive no points (0) if they
- made no attempt to answer the methods questions (even if they answered the prediction)
- answer some of the methods questions, but do not indicate why they did not finish (why they got stuck)

When you have finished the grading, you will know which method question(s) to have groups discuss and put on the board at the beginning of the lab session – the one or two questions that students did had the most difficulty answering correctly.

Grading Lab Procedures

Grade each students' lab procedure and journal at least once during the 2 – 3 sessions of a lab. Observe whether
- a measurement plan recorded in journal **before** students begin making measurements;
- tables and graphs made in journal **as data is collected**;
- observations are written in the journal;
- analysis is completed before students discuss conclusions.

Written Laboratory Report.

The written laboratory report is one of your most important tools in coaching the student in physics. From a student's writing, you can usually tell if they have a firm grasp of the concepts being taught in the class, are confused about the concepts, or still have important misconceptions. After all, a student writing a laboratory report has time to think and can use the textbook, notes, or advice from other students. This truly represents the student's best expression of their knowledge on the subject matter. Based on your reading of the lab report, you may want to talk to that student during the next laboratory period or schedule an appointment with them. At the very least you should communicate forcefully to the student if there is a difficulty in physics understanding. Errors in understanding concepts of physics, problem solving, or measurement will seriously affect a student's ability to succeed in the course as time goes on. It is unfair to lull the student with a good grade on a lab report only to have them get a bad grade on the exams.

Because this course satisfies the University's Writing Intensive requirement, the grading of student laboratory reports takes on added significance. To be acceptable, a laboratory report must always be a coherent technical communication. It must be mechanically correct in spelling, grammar, and punctuation. It must be well organized with a logical presentation and purpose that is communicated clearly. It must have a content supported appropriately with neat and clearly labeled pictures, diagrams, equations, graphs, and tables. It must be expressed in a manner appropriate to a technical report written to an audience of the student's peers. Most importantly, the content must be correct. You can help your students achieve better writing by insisting on it. Students with serious communications problems can be referred to a central web based writing center. An added benefit is that a well-communicated laboratory report is easier for you to grade and enables you to give a student focused coaching on specific physics weaknesses.

Each student is required to write an individual lab report for one problem per laboratory topic (usually two weeks). You will assign each member of a group a different problem at the end of the two-to-three week lab period. ***Assigning the problem at the end of the laboratory period assures that all members of the group attend to every problem.*** Make your problem assignments based on your knowledge of the individual students. This is one of your opportunities to tailor the course to the needs of each individual student. Some students may need the challenge of the most difficult problem and some may need the consolidation offered by an easier problem. You might assign a student needing encouragement a problem you are confident they understand. On the other hand, you might assign a problem to a student because you suspect that they were not adequately involved in the data acquisition or did not understand its point.

The grading criteria are briefly given on the laboratory cover sheet in the laboratory manual. This sheet is to accompany every laboratory report. Students are graded on a total point scale, but you need not accept a report that is not adequately communicated. Each week students receive points for having a logically written *Prediction* and the answers to the *Methods Questions*. Also, each week students receive points for keeping a competent lab journal. The report should be a concise and self-contained technical report that is essentially an elaboration of the student's lab journal. It should only be about four pages in length, including graphs, tables, and figures. If you make sure that the students leave the laboratory with a well organized and complete laboratory journal, the laboratory report should not take them long to write.

To encourage students to use the powerful tool of peer learning, award bonus points if everyone in a group does well on the report. Typically, this has been defined as better than eighty percent. You may want to generate a little peer pressure for preparation by giving a bonus point if everyone in a group comes to lab with a complete set of answers for the prediction and methods questions (see the chapter by Karl Smith in your Reading Packet).

IV. Outline for Teaching a CPS Lab Session

This outline, which is described in more detail in the following pages, could serve as your "lesson plan" for each lab session you teach.

- ❑ assign new roles (and groups when appropriate)
- ❑ solve *Methods Questions* to arrive at *Prediction*
- ❑ review comments and suggestions in *Lab Instructor's Guide*
- ❑ decide what to have students put on board
- ❑ □□□□□ pre-lab scores (when appropriate)

	Instructor Actions	What the Students Do
Opening Moves ~15 min.	⓪ Be at the classroom early ① Prepare students for group work by showing group/role assignments. ② Prepare students for lab by: a) diagnosing difficulties while groups discuss and come to consensus on *Methods Questions*. b) selecting one person from each group to write/draw on board answers to your selected *Methods Questions*. c) leading a class discussion about the group answers (without giving correct answer). d) leading a class discussion about measurements for prediction equation and measurements for checking the prediction. e) telling students how much time they have to check their predictions	• Students move into their groups. • Work cooperatievely. • Write on board. • Participate in class discussion. • Participate in class discussion.
Middle Game (depends on problem)	③ Coach groups in problem solving (making decisions) by: a) monitoring (diagnosing) progress of all groups b) coaching groups with the most need. ④ Grade Lab Procedure (journal). ⑤ Prepare students for class discussion by: a) giving students a "10-minute warning." b) selecting one person from each group to put the group's corrected Methods Questions and results on board.	• Check their group prediction: - explore apparatus - decide on measurement plan - execute measurement plan - analyze data as they go along - discuss conclusions . . . • Finish work on lab problem; discussing their group effectiveness • Write on board
End Game ~10 min.	⑥ Lead a class discussion focusing on what you wanted students to learn from solving the lab problem. ⑦ Lead a class discussion of group functioning (optional). ⑧ Start next lab problem (repeat Steps 1 – 7) ⑧ At end of session, assign next lab problems; assign Problem Reports (if last week of lab)	• Participate in class discussion • Participate in class discussion

NOTES:

V. Detailed Advice About Laboratory Lesson Plan

You should notice a lot of repetition of the same advise given for teaching a discussion session (pages // to //) because the purpose of the labs and discussion sessions are the same – practice and coaching in a logical, organized problem solving process.

Opening Moves

Step ⓪. Be at the Classroom Early

When you get to the classroom, go in and lock the door, leaving your early students outside. The best time for informal talks with students is after the lab!

- Prepare the classroom by checking to see that there is no garbage around the room and that the proper equipment is on student tables and on the front table. On the blackboards, provide space for each group to present its predictions. If you have changed groups, list the new groups and roles on the board at this time also. (Remember to follow the guidelines for forming groups (pages // - //) and rotating roles (page //).
- Let your students into the classroom when you are prepared to teach the lab. To keep the students from collecting data before they discuss their *Methods Questions* and *Predictions*, set aside a small but necessary piece of equipment. Pass this out only after the discussion are finished.

Step ①. Prepare Students for Group Work (~ 1 minute)

If students are working in the same groups, remind them to rotate roles. For computer labs, it is particularly important that the Recorder/Checker is different each week so ***every*** student spends the same time using the keyboard.

Pass out the students' solutions to the lab problem.

Step ②. Prepare Students for Lab (~ 15- 20 minute)

a) Focus on what students should learn (~ 1 minute). Tell your students which Methods Question(s) they should discuss and put on the board.

b) Diagnose student difficulties (~ 5 minutes). While the students are discussing the assigned Methods Questions, circulate around the class and ***observe/listen to*** all groups. [Do not intervene with any group unless they have a simple clarification question.] Try to diagnose the difficulties groups are having answering the Methods Questions. This is easier to do for some lab problems than others.

   No matter how severe students' conceptual difficulties seem to be, or how unprepared students seem to be, **DO NOT LECTURE** to students at the start of lab. They have an opportunity to see the theory of physics in their lectures and textbooks, but lab gives them an opportunity to find out for themselves whether they are right about the way the world works.

Even if the lecturer has not yet covered the material (which happens occasionally), **do not lecture** the students about the concepts or lab procedures. Many lab problems serve as good introductions to a topic, and need only minimal reading from the text for students to be able to complete the Predictions and Methods Questions before the lab.

c) `Posting group answers (~ 2 minutes).` Select one person from each group to write their group answer to the methods question(s) on the board.

d) `Lead a class discussion (~ 5 - 10 minutes).` Many students can come up with a correct prediction equation or reasonable looking graphs for strange reasons that do not follow the accepted laws of physics. If you do not discuss these reasons, your students will never realize later that their reasoning is incorrect. The Methods Questions on the board give you an easy way to have students discuss the physics involved in making their predictions.

Give students a few minutes to read all the answers on the board. Ask the representatives of each group to give their reasons for each of their answers.

DO NOT TELL THE STUDENTS IF THEIR ANSWERS ARE CORRECT! This would spoil the whole purpose of the labs. Tell the students that they will discuss the answers to the methods questions at the end of the lab problem.

e) `How Much Time (~ 1 minute).` Tell students how much time they have to check their prediction. If you see from the class discussion that there are prevalent or varied alternative conceptions shown in students' group answers to the Methods Question(s), you will want to stop students earlier so that you can have a longer discussion of their ideas at the end of the lab problem. If, on the other hand, students seem to understand the relevant physics reasonably well before they begin their laboratory problem, you will not need as much time for discussion. The students should then be able to check their prediction very quickly.

Middle Game

There are three instructor actions during the middle game: coaching students in problem solving, grading journals, and preparing students for a whole class discussion. You will spend most of this time coaching groups.

Step ③. Coach Groups in Problem Solving

Below is a brief outline of coaching groups. For detailed suggestions for coaching and intervening techniques, see pages 25/ - 33.

a) Diagnose initial difficulties with the problem or group functioning. Once the groups have settled into their task, spend about five minutes circulating and ***observing*** all groups. Try not to explain anything (except trivial clarification) until you have observed all groups at least once. This will allow you to determine if a whole-class intervention is necessary to clarify the task (e.g., “I noticed that very few groups are not exploring the range of values for . . . What do you think . . .”).

b) Monitor groups and intervene to coach when necessary. Establish a circulation pattern around the room. Stop and observe each group to see how well they are working together and how they are making decisions. Don't spend a long time with any one group. Keep well back from students' line of sight so they don't focus on you. Make a mental note about which group needs the most help. Intervene and coach the group that needs the most help. If you spend a long time with this group, then circulate around the room again, noting which group needs the most help. Keep repeating the cycle of (a) circulate and diagnose, (b) intervene and coach the group that needs the most help.

   If a group finishes early, have then start to work on the next assigned lab problem.

Step ④. Grade Lab Procedure

This should be easy and quick to do. Check to see that students are keeping track of their data in their journals and that they are doing analysis in their lab journals ***as they go along.*** If they are not, tell the students they have lost their journal point(s). Losing a point once will prompt almost any student to improve his or her journal keeping.

In computer labs, not all analysis is completed on the computer. Students should be taking data and writing down coefficients and equations *as they analyze their data*.

Step ⑤. Prepare Students for Class Discussion (~ 10 minutes)

a) Ten-minute Warning. Ten minutes before you want them to stop, tell students to find a good stopping place and clean up their area. Make sure you are done grading journals. Also, pass out group-functioning forms at this time (if necessary, about every 2 - 3 weeks).

When you were an undergraduate, your laboratory instructor probably did not stop you to have a class discussion at the end of the laboratory period. Doing this is one of the hardest things you will have to do as a TA. You may be tempted to let students keep working so that they can get as much done as possible, or to let them go home early so that they like you better. However, research has shown that students do not learn from their laboratory experiences unless they have the chance to process their information. One good way to do this is by comparing their answers to the methods questions.

Some may try to keep working. If it is necessary, you can make your students stop working by removing a small but essential piece of equipment (i.e., a battery or a connecting cable) so that they are forced to stop taking data. You are in charge of the class, and if you make it clear that you want the students to stop, they will.

b) `Posting Corrected Methods Questions and/or Results.` Tell one person in each group, who is *not* the Recorder/Checker, to write their corrected answers (if necessary) to the methods questions on the board (and/or their results).

End Game (~ 10 - 15 minutes)

The end-game discussion focuses on what you told students they would learn from checking their lab problem solution. The purpose is to help students consolidate their ideas and produce discrepancies that stimulate further thinking and learning.

Step ⑥. Lead a Class Discussion (~ 10 minutes)

There are many similarities to leading a class discussion at the end of a lab problem and at the end of a discussion section. Read the general advise given for the a discussion section (pages 41 – 42). We will discuss leading a class discussion in Orientation and in the seminars throughout the year.

Students should be able to explain to their classmates how they collected and analyzed their data in order to come up with the answer to the experimental problem. If their predictions were very different, ask students to think about and discuss why they might have thought differently before and after the lab.

In <u>computer labs</u>, there is a tendency for students to rely too much on the printout of their analysis. The printout, however, does not give the solution to the problem – it is only a step toward the solution. The remainder of the information they need to solve the problem should be in their journals. Make sure you focus the discussion on the analysis and conclusion, not just the printed report.

Step ⑦. Discuss group functioning (optional, ~ 5 minutes)

An occasional whole-class discussion of group functioning is essential. Students need to *hear* the difficulties other groups are having, *discuss* different ways to solve these difficulties, and receive *feedback* from you (see Chapter 7, page /31/). Randomly call on one member of from each group to report their group answer to the following question on the Evaluation form:

- ♦ one difficulty they encountered working together, or
- ♦ one way they could interact better next time.

After each answer, ask the class for additional suggestions about ways to handle the difficulties. Then add your own feedback from observing your groups (e.g., "I noticed that many groups are coming to an agreement too quickly, without considering all the possibilities. What might you do in your groups to avoid this?")

Step ⑧. Start Next Lab Problem

If there is time, have students start the next assigned lab problem. Repeat Steps 1 through 7.

Step ⑨. End of Lab Session

a) Tell students what lab problem to do Methods Questions for next week. You will decide what lab problems all students should do in your team meetings. If there is extra time, you can decide what problem all students will do based on your knowledge of the conceptual difficulties your students have experienced up to this point.

b) Assign students problems to write up (if last session of lab). Each student will write up one problem from each lab individually. If there was one person in a group that was not participating as well as you would like in a particular problem, you might want to assign that problem to the student. This way either the group will help the student catch up with the important information, or the student will be taught (by the bad grade you will give) to participate in the future.

c) Leaving the Lab. Leave a neat lab room for the next class. Do NOT let the next group of students into the classroom. Write down the comments on the lab-room sheet if any (e.g. which equipment did not work). The sheet is on the wall near the door.