Instructor's Handbook

A Guide for TAs

School of Physics and Astronomy

Fall 2007

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Introduction

*T*here is usually more than one effective method to teach a class; in other words, there is no known "best" way to teach. The methods to use will depend on the goals of the course, the strengths of the instructor(s), the needs of the students, and the constraints imposed by the situation (for example, the number of students in the introductory courses, the size of the laboratory rooms.) Among the various teaching methods which have been established, it is often nearly impossible to decide which ones are most suited for your situation. Cooperative Problem Solving (CPS) is one technique we have found that fits our goal (for students to learn physics through problem solving) and constraints for the introductory physics courses at the University of Minnesota (UMn). For this teaching method to be effective, however, it needs to be executed well. As a TA, you have important roles to play in our teaching of undergraduate students. If you do your job well, everyone around you – your students, your professor as well as the Chair of the department – will appreciate your contribution to our educational mission.

With this handbook, we hope to help you become a good teacher by providing you with (1) a background about why we organize our Freshman Physics teaching in the way we do, (2) an overview of how the lab and discussion sessions are taught, (3) a description of your main task: coaching of students on how to solve problems, (4) tips about teaching, (5) logistics such as how lab computers and their programs work and how you need to enter grades, etc.

Brief Background

As we said moments ago, **the major goal of our Freshman classes is to help students learn physics through problem solving**. But what does it mean to "learn physics" and what do we mean by "problem solving"? You should take some time to think about what these two concepts mean to you, because you will encounter this question again throughout the TA orientation and weekly TA seminar sessions. Given your understanding of these terms, does this goal make sense to you?

We (those who are involved in TA orientation) wish to make a few remarks at this point, which may help you focus your thinking:
1. Most physics classes assess students' "understanding of physics" at least partially by measuring how well they can solve problems.
2. We believe that most students we teach in our classes don't know how to solve problems and need to be taught this skill explicitly.
3. We distinguish problems and exercises. If you know the outline of your solution soon after you read the "problem", then it is an exercise. If applying the single right formula is sufficient to solve the "problem" it is an exercise. Problems force you to try to reach the goal step by step, not in one step, and to make subjective decisions about the appropriateness of your approach along the way. Long division is an exercise once one is taught how to do it. When we ask students to derive F, m or a given that the other two variables are known after they are taught $F = ma$, we are giving them an exercise.
4. When students tell you they don't know how to get started, it is a problem for them.

5. Many of perfectly good problems for our undergraduate students are actually exercises for you. Similarly, many of the problems you face in written and oral examinations or graduate classes are exercises for (some) professors. Unfortunately, some professors who teach Introductory Physics classes are oblivious to, indifferent to, or disagreeable to some of the above statements. In such a case, you may have to discuss possible compromise between his or her teaching ideas and what we ask you to do, mixing in what you personally like to do to teach well.

Even if we all accept that teaching problem solving should be a major part of our classes, we have more questions to answer. For example, how can we teach these classes as effectively as possible? Most of you are pretty good at solving problems, but that does not necessarily mean that you can teach it well. Not all good piano players can teach piano well, and not all good baseball players can teach lower-level baseball. How can we teach those who are not naturally good at solving physics-type problems so that they will be good solvers?

Should we show them examples, and explain logically how our solutions work? When you learn how to play the piano or soccer, it is certainly helpful to see (and hear) how experts play them. Then, perhaps you can emulate what you have seen. It would also be helpful to many of us if some of the experts or coaches could articulate some of the tricky points that casual observation would miss. After that, we could execute our play even better. But usually, these activities are not all learners need to do to become good players. What else should coaches and teachers do to train new players, either in piano or soccer?

Then you may ask how far this analogy between learning physics and learning music and sports can hold. It may be beneficial to have a discussion about this with your peers and the TA orientation leaders if a significant number of you are skeptical about the analogy.

We believe that CPS is a powerful tool for us to help students learn how to solve problems effectively in the lab and discussion sessions because:

(1) Students can learn to play various roles within a group, which are needed to be good problem solvers; they can focus on practicing one (or a few) things at a time instead of trying to do it all. This is, again, analogous to learning different aspects of piano playing, or soccer playing during a practice session, even though at a game or concert, you would need to execute it all. You may practice your left hand and right hand separately for piano. You may learn notes first and musical expression next. You may practice individual skills and team play strategies separately in soccer. What different skills, then, do students need to learn to become effective problem solvers?

(2) Students can get individualized feedback from the group partners about what they do to solve problems. Given that there is only one teacher to so many students, the teacher will not have many opportunities to give feedback to each student. If feedback is an important component of learning problem solving, this needs to be addressed.

At times it may seem that students are actually *more* effective than an instructor at explaining concepts to one another (refer to Eric Mazur's book on Peer Instruction.) A plausible reason is that the students who have only recently begun to understand a

concept know the difficulties involved (they can relate to their peers' confusion), and can precisely explain it in a way that other students will grasp.

(3) Although the feedback from other students may not be always correct or appropriate, this is not a serious hindrance since the process raises issues that the students encounter when they solve problems alone. For example, an essential component of being a good problem solver is to critically receive ideas and question the reasoning behind the ideas when working through each step of a problem. In groups students practice this *Skeptic* role explicitly, so they are better prepared to assess their own ideas when solving problems individually.

What would be potential negative effects of working in groups? How can we minimize these negative effects while enhancing possible positive outcomes?

With these ideas in mind, our Freshman Physics classes are organized in the following way and your major roles as a TA are also given below:

- In lectures, the professor shows examples of good problem solving techniques. He or she will explain physics concepts and apply them to simple situations to help students develop physics intuition, etc. The latter is not directly related to problem solving, but probably helpful indirectly.
- In discussion sessions, students work in groups of 3-4 students to solve a problem (or at most two) while the TA coaches them. By coaching, we mean giving feedback to students, giving a little push or some hints, if needed, to get students moving again when they are stuck. You also need to manage less-than-optimally operating groups: a group member not participating much, or a member too dominating and not utilizing the intellectual resources within the group.
- The lab sessions in our classes are very similar to the discussion sessions. They are NOT meant to have students confirm fundamental physics laws. Neither are they meant to teach students experimental techniques or details of errors analysis (though some sense of how errors propagate needs to be understood by the students). The labs provide another occasion for students to solve problems. Some problem solving happens before the lab as part of their preparation, and some is done during the class with their groups. Instead of the TA summarizing which groups' solutions are right and which are wrong, they do experiments to see themselves if their predicted solutions make sense against the results of the experiments. Your role in the lab is therefore very similar to that in the discussion session. Additionally, you need to be cognizant to where the experiments tend to go wrong, how computers tend to misbehave, when and how you need to get help on malfunctioning equipment, etc. so that students won't justify wrong problem solutions with wrong experimental results and avoid delay in their experiments due to equipment problems.

Chapter 1

Your Teaching Responsibilities

I. Description of Specific Duties

Most teaching assistants (TAs) will be assigned to a teaching team responsible for one of the introductory physics courses. Your most likely assignment is the first term of the calculus-based course for scientists and engineers (Physics 1301) since this course serves the most undergraduates. A teaching team typically consists of one faculty member and 8 - 9 TAs. This team is responsible for all aspects of the course for about 200 undergraduates.

> If you are not assigned to 1301 or 1302 (E&M part of the same sequence), you may be teaching a similar class for biology and premedicine students (1201/02), or an algebra-based course (1101/02). Many of the contents in this handbook apply to any of these classes. For the few of you who will teach upper-level courses, fewer parts of this handbook are relevant. Since you are likely to teach one of the Introductory classes at some point in your career, it is important that you learn most of the things in this handbook.

If you have a 25% appointment, you will be teaching one discussion session and one lab, with the **same** set of students (less than 20). If you have a 50% appointment, you will be teaching two discussion sessions and two labs, with two sets of students. Discussion sessions meet for 50 minutes once a week, and labs meet throughout the week for 2 hours at a time.

Failure to fulfill your TA duties in a serious way could result in a loss of teaching assistantship. Many things the mentor TA's do is to prevent this from happening by providing useful feedback to you as you accumulate teaching experiences.

Preparation for Laboratory

You will have new lab problems to teach every week. You should become very familiar with the equipment, and consult the Instructor's Guide for the Lab Manual and experienced TAs to find what might go wrong with it or what kinds of mistakes students might make. If you can, it is a good idea to observe someone else's lab session before you teach yours. With your team, select which Lab problems have priority.

- Your team should decide during each weekly team meeting (see below) which lab problems your students will solve the following weeks. **If this topic is not discussed in a timely manner (~2 weeks in advance) within the team, please don't hesitate to bring it up during the meeting. Otherwise, it will interfere with your ability to adequately prepare for the lab.**

- You need to solve the assigned lab problems by answering the Prediction and Warm-up Questions. In the team meetings (and some seminars), you will discuss difficulties that students have had with the physics principles they need to solve the lab problem.

- Most students will be required to solve computer laboratory preparation quizzes before each lab session (the professor will determine the specifics of this requirement.) You will be shown how to use a program to check whether your students have successfully passed the quiz before they get to lab. This will help you formulate how you will start your next lab session. You should go through these questions before your students do, because some of your students might ask questions about them.

- Have a goal (learning focus) for each Lab session, something you want your students to learn. This should be decided in your team meetings after discussion with the professor and other TA's. See page 89 for more about how to prepare for a lab session.

Teaching Laboratory Sections

Make sure you get to your laboratory room at least 5 – 10 minutes before class starts, and do not let the students enter until you are ready. Use this time alone to check the lab equipment to make sure it is all there, neatly arranged, and in working order. If you are teaching a computer lab, you should check to make sure the computers are working properly. Any other quiet time can be used to make final preparations. Make sure the door is locked and the lab is in order before you leave.

If you are late for your lab, be sure to call Mette Marie Stewart, 624-7375.

Preparation for Discussion Sections

- Solve the group problem students will solve in discussion section. Discuss with your team the parts of the qualitative analysis of the problem that you expect will be difficult for the students. **Some professors are not attentive to the need of their TA's to have the discussion problem well in advance of the class. If this happens to you, politely remind your professor of your need to have the problem early.**

- Look at the syllabus and homework problems assigned for the week. Be prepared to tell your students which homework problems are similar to the group problem.

- In some sections, you may be asked to work with other TAs to design or write a group problem. As a first-year TA, if you don't feel comfortable about writing a problem, you may negotiate to swap this duty with another. If you accept this role, you will present the first draft of your problem to your team for critique, and may be asked to write a second draft. This will occur once or twice a semester.

- In some sections, you may be asked to choose the material for the discussion sections for some of the weeks. You may want to pool your skills and ideas with other members of your team, either during your team meeting or outside of it.

- Occasionally, a problem that is inappropriate for a group problem is selected (e.g., one-step problems). Consult with a lead TA (usually there is one TA who is more experienced than you in your team) and discuss how to deal with it. You may need to modify the problem slightly so it will work productively in a discussion session. If this happens repeatedly (because your professor's teaching philosophy is different from what we are assuming in the TA orientation) you may work with other TA's to come up with strategies to deal with it so that your discussion sessions will be productive learning experiences.

Refer to additional information about planning a discussion session on page 105.

Teaching Discussion Sections

Try to get to your assigned classroom several minutes early (before your students. You may need to tidy the classroom, clean the blackboard, rearrange the chairs (see Fig.1 and 2 on Page 38), and/or write on the blackboard (see page 101).

Well before the first class, check out the room to see if it is appropriate for a discussion section. If it is not appropriate, tell the undergrad office and they will try to get it changed.

If you are late for your discussion section, be sure to call Mette Marie Stewart, 624-7375.

Office Hours/Tutoring

Office hours are held in the tutor room, Physics 230. This is your chance to interact one-on-one with students, and it is your students' chance to get some personal tutoring. You will have one office hour a week for each of your sections (i.e., one office hour/week for 25% appointment and two office hours/week for a 50% appointment). During office hours, <u>you must wear a name tag.</u> Refer to page 135 for more information about office hours.

Meeting with Your Mentor TA

You will each have a half hour appointment with one of your mentor TAs twice in the semester. These meetings generally occur after a mentor TA has observed your class, and the purpose is to provide you with coaching to become better teachers. You might ask about problems with your students, difficulties in grading, classroom management, course organization, or other questions or problems you may have. You will also discuss other things that your mentor may have noticed in your section. Feel free to bring up anything else that relates to being a TA.

Grading Labs

You will grade written lab reports at least four times during the semester. As with all grading, prompt feedback to the students is essential. Discuss the grading policy (e.g. how many points each lab report has, the criteria to decide points) in the first team meeting because every TA in your team must have the same policy. Be sure to return graded lab reports within a week, unless otherwise specified by the professor, so that students can use the feedback to get help.

You will also collect and grade your students' answers to the Prediction and Warm-up Questions for the next lab session you will teach (see page 75). These are useful to gauge your students' understanding of the material of the lab.

Grading Homework

Different teams will make different decisions about how homework will be collected and graded. Whatever scheme you decide to use cannot take much of your time. Be sure to grade and return homework as soon as possible, so that students can use the feedback to get help. Be sure to return graded homework within a week, unless otherwise specified by the professor, so that students can use the feedback to get help.

Grading Tests

- At this time, the estimate for how much time it takes to grade a difficult problem is as follows:

$$\left(0.5\,hr\ classifying\right)+\left(\frac{200\,probs}{quiz}\times\frac{3\min}{prob}\times\frac{1hr}{60\min}\right)+\left(0.5\,hr\ recording\right)=11hr$$

On average, each TA will grade 3 such questions each semester, plus one group problem (about 70 problems). This should average to less than 3 hours/week. In your team meetings you will arrange which TAs will grade which problems.

- After you spend the time classifying a subset of tests, it is estimated that a quiz problem will take, on the average, 3 minutes to grade. Obviously some student solutions will be extremely convoluted and some will be blank (see the details of grading on page 138).

- After you have completed the grading, you will enter the grades into the computer (see Electronic Submission of Grades on page 141).

- Grading should be completed and scores should be entered into the computer as soon as possible. It is important the students receive prompt feedback on all graded assignments.

Proctoring

You will all be asked to proctor the tests for your course. While proctoring, you are responsible for answering student questions and deterring cheating. The schedule for proctoring will be discussed in one of the first team meetings. Make sure to get spare pencils and calculators from room 148 when you pick up a test. Refer to page 136 for more information.

Final Exams and Lab Grades

Each TA will probably grade one or two final exam problems that will take about 11 hours each. This grading will occur, in most cases, after your last final exam so make sure that you plan enough time at the end of the semester. Keep the record of your students' lab grades throughout the semester and make a backup of the grade periodically.

Team Organization Meetings

Each week, the TAs and professor will meet as a team to discuss their course. The most important reason for the meetings is the communication between the different members of the teaching team. Important issues are:

- The professor describing what is going on in lecture and why.

- Discussion about what to emphasize in the next discussion and lab sessions.

- Trading information and analyzing what students understand and do not understand. Since there can be a large diversity between the different discussion and lab sections, each TA should discuss and compare their section(s) with other sections. This information is an invaluable input for the professor(s), who do not have the close contact with students that you do.

The meetings also provide opportunity to discuss the mechanics of the course (e.g., who will grade what, who will proctor, etc.). It is very important that the schedule of these duties be

discussed and decided in the beginning of each semester. As a student, you need to gather information about which of your classes have tests and other major assignments due when, so that you won't have to deal with preparing for a test as a student while doing a significant grading as a TA. If needed information is not provided by your professor(s), please remind them since it is crucial to your well being later in the semester.

Attendance at these meetings is mandatory. If you inadvertently miss a meeting, be sure to call or e-mail your professor right away and find out what happened in the meeting from the professor or one of the other TA's.

TA Seminar

All new TAs are required to take the course "Teaching Introductory College Physics (Phys 5072)" in both Fall and Spring semesters. In the seminar, you will prepare for the next labs by becoming familiar with the equipment and procedures for them you will teach (part of your lab preparation time). Instructors will also help you deal with various issues which arise in your classes. The fall semester seminar has one credit; the spring semester seminar has two credits to include the work from TA orientation.

Average Time/Week During the Semester

Your average weekly work load during the entire semester (for a 50% appointment) should be approximately that listed below. It includes a week leading to the start of the actual teaching and completion of the final exam grading and entering of the results

Contact with Students:

2 Discussion Sections	2.0 hrs	
2 Laboratory Sections	4.0 hrs	
Office Hours	2.0 hrs	
	8.0 hrs	

Preparation:

Laboratory	1.0 hrs	
Discussion	1.0 hrs	Teams will decide how to
Team Meeting	1.0 hrs	structure this between team
TA Seminar	1.0 hrs	meetings and individual prep.
	4.0 hrs	

Proctoring, Grading and Entering Grades:

Labs	2.5 hrs	(average)
Tests and Homework	4.0 hrs	(average)
	6.5 hrs	

Feedback and Support:

Meet with Mentor TA	0.5 hrs
	0.5 hrs

Miscellaneous:	1.0 hrs
(dealing with the front office, helping	
students outside of office hours, etc.)	

TOTAL	20.0 hrs/week

If you are spending more time than the above estimate, you need to do something since it will affect your performance as a student. For example, if the grading is taking more time than the estimate, please consult with the mentor TA to see how you can do this more efficiently. Perhaps, the first time will take more time, but by the 2nd grading you should be able to grade within the allotted time.

On the other hand, if your professor is asking you to do more things beyond those included in the above table without compensating it by reducing the standard duties, you should gently remind him that you don't have infinite amount of time, and need to be relieved of some of the

duties. If this gentle reminder does not solve the problem, you should talk to the other TAs in the same team to increase the pressure on the professor or talk to mentor TA, DGS, Department Chair, or grievance committee members as you see appropriate. Do not do simply disregard the issue if you suffer from overworking as a TA.

The University does not recognize the time between terms as holidays. i.e. you are paid to work as a TA during the holidays. Although the Physics Department typically does not assign TA duties after final exam grades are recorded, you are obliged to carry out any duties associated with teaching assistantship even if they fall during the break time. Check with your professor before you make a holiday plan which involves leaving town that you are not expected to do something which requires you to be in town during that time. In particular, do not plan to be away right up until the day before the new semester starts as some of the planning meeting for the new class may take place up to a week before the actual start of the new semester. If you want to leave before the grading of the final examination is complete, you should plan to do a larger share of grading during the semester so that you are not obliged to grade the final exam.

II. Using Your Mentor TAs

Your mentor TAs are there to help you grow as a TA. They will help you cope with problems you may encounter in your teaching and in graduate school. They will also help you improve the skills you need to become a better TA. If you ever need help, talk to them.

Specifically, the duties of the mentor TAs include:

- Be active instructors in the TA orientation in August.
- Co-teach the TA Seminar in the Fall and Spring, to discuss topics such as:
  - lab preparation;
  - grading exams and homework;
  - alternative conceptions your students may have;
  - effective coaching of problem solving;
  - difficult students; and
  - issues you have encountered and your ideas about teaching.
- Visit several of your labs and discussion sessions to:
  - observe your teaching techniques;
  - give you feedback and answer questions about your teaching.
- Make recommendations for the TA award given at the end of the year.

If you ask them to, the mentor TAs will also:

- be resources for you in the physics department.
- serve as an anonymous conduit of your concerns to an individual professor or the department.
- help you find information in the education literature.

- help you write your lesson plans.
- help you find and practice with the laboratory equipment.
- advise you on grading, writing cooperative group problems, interacting with professors, and forming new groups.
- write letters of recommendation about your teaching.
- be willing to discuss the graduate school experience (both good and bad.)
- respond to any reasonable questions, requests, … The only limit is your imagination☺

Chapter 2

Cooperative Problem Solving

I. How Do I Coach Students in Problem Solving?

*Y*our role during discussion and lab sessions is to coach students in physics problem solving, particularly the qualitative analysis of the problem. That is, you want to coach students so they will slowly abandon their novice problem-solving strategies (e.g., plug-and-chug or pattern matching) and adopt a more expert-like problem solving procedure that includes the qualitative analysis of the problem. "In order for most students to learn how to learn and think about physics, they have to be provided with *explicit* instruction that allows them to explore and develop more sophisticated schemas for learning." (Recall Redish's second teaching Commandment)

Learning physics through problem solving is a difficult, time consuming, and frustrating process -- like climbing a steep mountain. Many students try to run around this mountain by using their novice problem-solving strategies. Some of them give up (drop the course). A course structure must include scaffolding (ladders) that help students learn how to solve problem solving and barriers (fences) to keep students from succeeding using their novice strategies
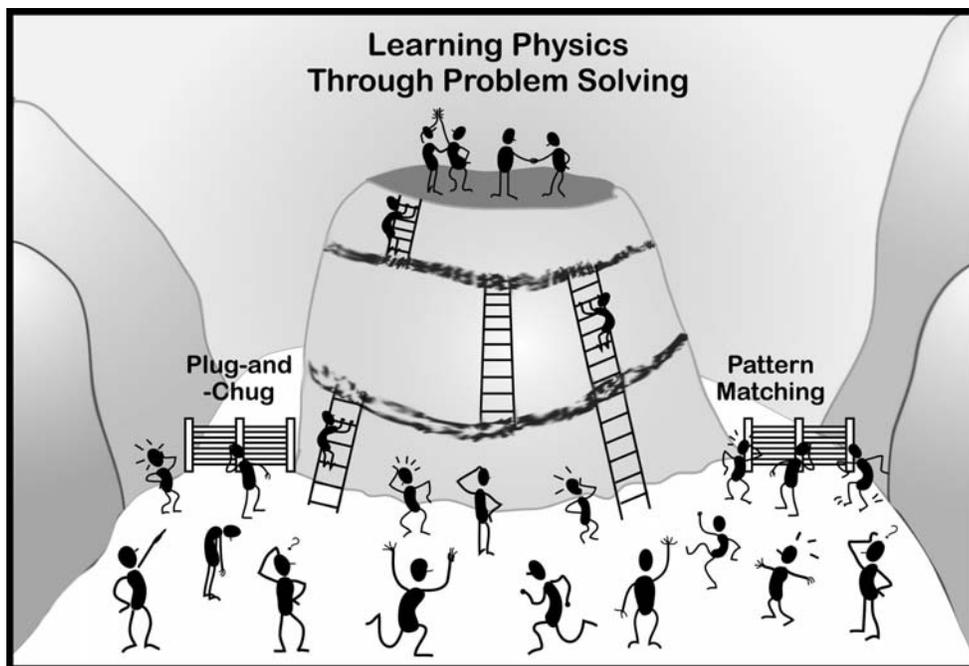
For efficient coaching in problem solving, you will use several instructional "tools." One tool is a problem solving framework and answer sheet you design during TA Orientation. The second tool is the *Warm-Up Questions* in the labs (see Chapter 3). A third tool is the assignment and rotation of group roles.

Group Roles

Many different roles can be assigned for different types of tasks. For physics problem solving, you will assign planning and monitoring roles that each student will have to assume when they solve challenging physics problems *individually* -- Manager, Summarizer, Recorder, and Skeptic. When a student solves a homework or test problem, she has to be an executive *manager*, organizing a plan of action to solve the problem, and making sure that she doesn't lose track of where she is relative to the final goal of solving the problem and decide what may be the best thing to do next. This requires that she continually *summarizes* what decisions she has made. At the same time, she is also a *recorder* of the solution. During this process, she must check her solution and make sure it *explains* what she did (to a knowledgeable reader) in a logical and organized fashion. Finally, she has to continually be *skeptical*, asking herself questions about each step -- "Am I sure that I am going in the right direction and getting closer to the final solution?" "This doesn't seem right. What have I forgotten to take into account?"

One reason for assigning roles (and rotating the roles among group members) is that it allows students to *practice* the different metacognitive actions individually. Students also have an opportunity to *observe* other people executing metacognitive actions as the group co-constructs a problem solution.

The second reason for assigning the roles is that they provide you with a useful tool for coaching students in the metacognitive skills that they need to learn in order to become better problem solvers.

If you read Redish, 2003, pages 62 – 65[1], you will recognize the roles of Manager, Summarizer, Recorder, and Skeptic as "metacognitive" roles. A copy of the group roles you will give your students is shown on the next page (copies of the group role sheets are available on the bookshelf in room 146, or you can make copies of the following handbook pages.) The metacognitive actions are in ALL CAPS. The remaining actions (Small Caps) are group functioning actions. These are discussed in the next section.

Group Roles for Discussion Sessions

In your discussion sessions for this course, you will be working in **cooperative** groups to solve written problems. To help you learn the material and work together effectively, each group member will be assigned a specific role. Your responsibilities for each role are defined on the chart below.

ACTIONS	WHAT IT SOUNDS LIKE
MANAGER DIRECT THE SEQUENCE OF PROBLEM-SOLVING STEPS. KEEP YOUR GROUP "ON-TRACK." WATCH THE TIME SPENT ON EACH STEP. MAKE SURE EVERYONE IN YOUR GROUP PARTICIPATES.	*"First, we need to draw a picture of the situation."* *"Now we need to draw a motion diagram and define our symbols."* *"Let's come back to this later if we have time."* *"We only have 5 minutes left. Let's finish the algebra solution."* *"Chris, what do you think about this idea?"*
RECORDER/CHECKER RECORD YOUR GROUP'S PROBLEM SOLUTION. CHECK FOR UNDERSTANDING OF ALL MEMBERS. MAKE SURE ALL MEMBERS OF YOUR GROUP AGREE WITH EACH THING YOU WRITE. MAKE SURE NAMES ARE ON THE GROUP SOLUTION.	*"Is this where you wanted the acceleration on the motion diagram?"* *"Does everyone agree this algebra is correct?"* *"Explain why you think that …?"* *"Do we in agree that this term is zero?"*
SKEPTIC/SUMMARIZER HELP YOUR GROUP AVOID COMING TO AGREEMENT TOO QUICKLY BY • MAKING SURE ALL POSSIBILITIES ARE EXPLORED. • SUGGESTING ALTERNATIVE IDEAS. KEEP TRACK OF DIFFERENT POSITIONS OF GROUP MEMBERS AND SUMMARIZE BEFORE DECIDING. SUMMARIZE (RESTATE) YOUR GROUP'S DISCUSSION AND CONCLUSIONS.	*"Why do you think this moves with a constant acceleration?"* *"I'm not sure we're on the right track here. Let's try to look at this another way. . ."* *"Why?"* *"What about using conservation of energy ... instead of forces?* *"Chris thinks we should …, while Pat thinks we should …." Are these really different?* *"So here's what we've decided so far..."*

Group Roles for Laboratory Sessions

In your laboratory for this course, you will be working in **cooperative** groups to solve laboratory problems. To help you learn the material and work together effectively, each group member will be assigned a specific role. Your responsibilities for each role are defined on the chart below.

ACTIONS	WHAT IT SOUNDS LIKE
MANAGER MAKE SURE THE GROUP FOLLOWS THE INSTRUCTIONS FOR EACH LAB PROBLEM. MAKE SURE GROUP MEMBERS ROTATE ENTERING PREDICTIONS AND ANALYZING DATA ON THE COMPUTER. KEEP YOUR GROUP "ON-TRACK." MAKE SURE EVERYONE PARTICIPATES IN DECISIONS AND MEASUREMENTS. WATCH THE TIME!	*I think we forgot to try enough different masses for the object (Exploration).* *Last time Pat was at the keyboard, so this time Chris should do it.* *I think we forgot to measure the length of the string.* *"Pat, what do you think about doing it this way?"* *"We only have 10 minutes left. Let's finish the analysis."*
RECORDER/CHECKER MAKE SURE ALL MEMBERS OF YOUR GROUP ARE WRITING IN THEIR LAB JOURNALS. MAKE SURE ALL MEMBERS OF YOUR GROUP AGREE WITH EACH PREDICTION TYPED IN THE COMPUTER. CHECK FOR UNDERSTANDING OF ALL GROUP MEMBERS. MAKE SURE ALL OF THE COMPUTER DATA IS SAVED OR PRINTED CORRECTLY.	*"Hey Pat! You forgot to write our measurement plan in your journal."* *"Do we all agree on this prediction before we accept it on the computer?"* *Can everyone explain the shape of this graph?"* *Before we go on to the next problem, can everyone explain the solution of this problem?*
SKEPTIC/SUMMARIZER HELP YOUR GROUP AVOID COMING TO AGREEMENT TOO QUICKLY BY: • MAKING SURE ALL POSSIBILITIES ARE EXPLORED; • SUGGESTING ALTERNATIVE IDEAS. SUMMARIZE (RESTATE) YOUR GROUP'S DISCUSSION AND DECISIONS. KEEP TRACK OF DIFFERENT POSITIONS OF GROUP MEMBERS AND SUMMARIZE BEFORE DECIDING.	*"How do you know this is the right function for the prediction?"* *"I'm not sure we're on the right track here. Another way to do this is …"* *"Why?"* *"Isn't it more accurate to measure from the top instead of from the bottom?* *"So here's what we've decided is our measurement plan. ..."* *"Pat thinks we should …, while Chris thinks we should …." Which should we do, or can we do both?*

Coaching Groups

You can use the following two actions to coach your students efficiently and in a timely manner while they are working to solve a problem:

♦ monitoring *all* groups and diagnosing their difficulties; and

♦ intervening and coaching ***the groups that need the most help***.

Monitor and Diagnose

Coaching groups that are solving problems is similar to triage in a medical emergency room. When there are more patients than available doctors, doctors first *diagnose* what is wrong with each patient to decide which patients need immediate care and which can wait a short time. The doctors then treat the patient with the most need first, then the second patient, and so on. Similarly, with CPS the instructor needs to first diagnose the "state of health" of each group by observing and listening to each group (without interacting with the groups). As with medical triage, your next step is to intervene with the group that is in the *worst* state of health -- the group that is having the most difficulty solving the problem or with group functioning.

With CPS, you diagnose:

♦ what physics concepts and problem-solving procedures each group does and does not understand; and

♦ what difficulties group members are having working together cooperatively (see Section IV).

The following steps are helpful to monitor and diagnose the progress of *all* groups:

Step 1. Establish a circulation pattern around the room. Stop and observe each group to see how they are solving the problem and how well they are working together. Don't spend a long time observing any one group. Keep well back from students' line of sight so they don't focus on you.

Step 2. Make mental notes about each group's difficulty, if any, with group functioning or with recognizing and applying appropriate physics principles to the solution, so you know which group to return to first.

Step 3. If several groups are having the **same** difficulty, you probably want to stop the whole class and clarify the task or make additional comments that will help the students get back on track. For example, there is a tendency for students to immediately try to plug numbers into equations each time new physics concepts and principles are introduced. If about half of your groups are doing this, stop the whole class. Remind your students that the first steps in problem solving are to understand and analyze the problem qualitatively *before* the generation of mathematical equations.

If you begin intervening immediately (without first diagnosing all groups), it is not fair to the last groups. By the time you recognize that all groups have the same difficulty, the last groups will have wasted considerable time while you went from one group to the next. The monitor and diagnose actions will help you maintain efficient and timely coaching of all groups.

Intervene and Coach

From your observations (circulation pattern), decide which group is obviously struggling and needs attention most urgently. Return to that group and watch for a few minutes to diagnose the exact nature of the problem, and then *join the group at eye level.* You could kneel down or sit on a chair. Do not loom over the students.

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 with the group that needs the most help.

The general approach to coaching is to ask questions to give a group just enough help to get them back on track, then leave. That is, spend as little time as possible with a group, then go to the next group that needs help, and so on. Below are some general guidelines for coaching groups that are having difficulty applying physics concepts and principles to solve a problem.

Step 1. Before you intervene, listen to the discussion in a group for a few minutes while you examine the picture, physics diagram, and/or the first one or two equations the Recorder/Checker has written. <u>Diagnose the group's problem solving difficulty</u>.

- Have they drawn a picture of the problem, and/or a physics diagram?

- Does the picture include all of the important information needed to solve the problem?

- Is the physics diagram(s) (motion, free-body force, energy, or momentum diagram) complete and correct? If not, what is missing or incorrect?

- Are the first equations complete and correctly applied to the problem with specific variables appropriate to the problem rather than generic ones which are used to express the formula in a general way? If not, what is missing or incorrect?

A more detailed checklist of common student difficulties is shown in Table 1 on the next page.

Step 2. Based on the nature of the group's difficulty, <u>decide *how* to begin your coaching</u> of the group. There are two general coaching approaches, depending on whether you can point to the difficulty on the group's answer sheet.

Table 1. Common Difficulties in Solving a Problem

Understand and Analyze the Problem
1. Picture of situation is missing, misleading, or inaccurate

a.   picture is missing
    b.   picture is missing important objects or time sequence of events
    c.   picture includes spurious (irrelevant) objects or events.
    d.   given quantities are not labeled on or near the picture.

2. Physics Concepts and principles, assumptions, and special conditions

a.   application of principles is inappropriate (e.g., trying to solve a problem with a principle that will not lead to a solution)
    b.   misunderstanding of a specific concept (e.g., frictional force, tension force)
    c.   simplifying approximations not stated or inappropriate

3. Physics Diagram(s) missing, misleading, or inaccurate

a.   physics diagram (motion, force, energy, momentum) is missing
    b.   diagram is missing important objects, events, or interactions
    c.   diagram includes spurious (irrelevant) objects or interactions
    d.   other incorrect diagrammatic translations of problem information

4. Relevant variables not assigned and clearly labeled

a.   many important unknown variables are not defined on the physics diagram(s)
    b.   defined variables are not clearly distinguished from each other (e.g., same symbol for two variables)
    c.   does not explicitly state target variable
    d.   target variable does not match problem statement (will not solve problem)

5. Incorrect assertion of relationships between variables

a.   application of principles to inappropriate parts of the problem
    b.   incorrectly assumed relationship between unknown variables, such as $T_1=T_2$.
    c.   overlooked important relationship between unknown variables (e.g., $a_1=a_2$. or spatial relationship between variables)
    d.   misunderstanding of a physics concept

6. Major misconception (alternative conception) about a fundamental principle (e.g., confusion between v and a, incorrect concept of the nature of forces or Newton's Laws of Motion).
CONSTRUCT A SOLUTION
7. Poor use of the physics description to generate a set of equations

a.   physics description was not used to generate a set of equations
    b.   inappropriate equation(s) introduced
    c.   undefined variables used in equations

8. Improper construction of specific equations
a.   inappropriate substitution of variables into equations   b.   numerical values were substituted too soon
9. Solution order is missing or unclear
a.   there is no clear logical progression through the problem   b.   solution order can't be understood from what is written
10. Equations can't lead to a solution
a.   there are not enough equations (usually an equation needed from analysis of problem)   b.   a relationship was used more than once

♦ Use Group Roles. Point to something on the answer sheet and state the general nature of the difficulty or error. Then ask, "Who is the Manager (or Skeptic/Summarizer, or Recorder/Checker)? What could you be doing to help resolve this difficulty?" Using roles can also make calling on a person less personal and reduce its potentially negative effect on the student. If the student/group does not have any suggestions, then model several possibilities.

♦ General Metacognitive Questions. If you can not point to something specific written on the group's answer sheet, begin by asking Alan Schoenfeld's questions for helping students learn to focus on metacognitive issues:[2]

   o What (exactly) are you doing? (Can you describe precisely what you are doing? What would be the final outcome of this step?)

   o Why are you doing it? (How does what you are trying to do fit into the final solution?)

   o How does it help you? (What will you do with the outcome when you get it?)

♦ If the students do not seem to figure out what the next step might be,
   o What information do you wish you knew?

Step 3. Based on the answers you get to your initial question(s), ask additional questions until you get the group thinking about *how* to correct their difficulty. That is, try to give a group just enough help to get them back on track, then leave. Check back with the group later to see if your coaching was sufficient for the group to discuss the difficulty and get back on track.

A general rule-of-thumb for coaching is that you do NOT draw or write anything on your groups' answer sheets. If you need to show a group how to do something, first select an example that is *similar* to the problem they are working on (but not the same). For example, you might want to show a group how to find the components of a vector. On a blank sheet of paper, draw a vector and show the coordinate axes. Then draw and explain how to find the components of this vector. Tell the group to use this same procedure on their problem, then leave the group. Check back later to see if the group was able to draw the correct components.

Examples of Coaching a Discussion Session Using Roles

Suppose your students are solving the following modified Atwood machine problem

You have taken a summer job at a warehouse and have designed a method to help get heavy packages up a 15° ramp. A package is attached to a thin cable that runs parallel to the ramp and over a pulley at the top of the ramp. After passing over the pulley, the other end of the cable is attached to a counterweight that hangs straight down. In your design, the mass of the counterweight is always adjusted to be twice the mass of the package (so all packages will accelerate up the ramp). Your boss is worried about this pulley system. In particular, she is concerned that the package will be too difficult to handle at the top of the ramp and tells you to calculate its acceleration. You run some tests and determine that the coefficient of kinetic friction for a package on the ramp is 0.51, and the coefficient of static friction is 0.85.

Some examples of coaching with group roles are on the following pages.

Example 1. Misunderstanding of a Physics Concept (difficulty 2b)

You observe that a group has drawn the frictional force in the wrong direction on their free-body diagram of the package. Point to the diagram: "There is something wrong with one of the forces in this diagram. *Skeptic*, what questions could you ask about each of these forces that would help correct the mistake?"
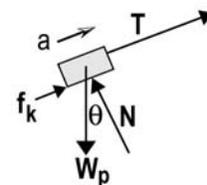
If the Skeptic knows what questions to ask (Is each type of force a push or a pull on the package? In what direction?), then leave the group.

If the Skeptic (and the rest of the group) can not think of appropriate questions to ask, then:
*   Early in semester. Point to the section of the Skeptic/Summarizer's *Problem Framework Roles* sheet and have her/him read the questions our loud.
*   Later in semester. Tell group: "Two questions a Skeptic can always ask about each force in a diagram: Is the force a push or a pull? In what direction?

Example 2. Improper Construction of Specific Equation
(difficulty 8a)

You observe that a group has drawn a correct force diagram for the package, but there is a wrong sign for the weight component in Newton's 2nd Law component equation, as shown at right.

$$\sum F_x = ma_x$$
$$T + W_p \sin\theta - f_k = m_p a$$
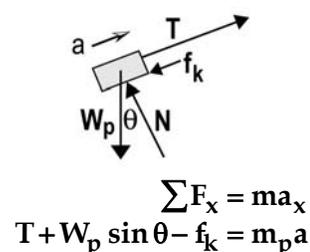
Point to the force diagram *and* the equation: "You have made a mistake in translating from your free-body diagram to this equation. Who is the skeptic? *Skeptic*, what questions could you ask about each translation?" When the group has responded (i.e., Is the sign right?), then leave the group.

Example 3: Incorrect Physics Diagram
(difficulty 3d)

In your second circulation around the room, you observe a group who drew an incorrect free-body diagram of the counterweight. They also wrote the equations shown at right.

Point to the diagram of the counterweight: "There is something wrong with one of the forces in this diagram. There is also some information about the motion of the counterweight that would help. Who is the Manager? *Manager*, describe how the counterweight is moving."
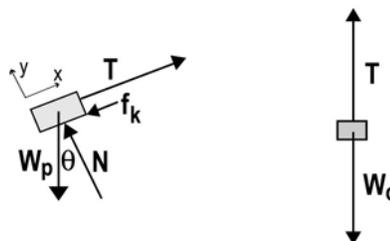
$$\sum F_x = m_p a$$
$$T - f_k - W_p \sin\theta = m_p a$$
$$T = m_c g$$
$$f_k = \mu_k m_p g \cos\theta$$
$$m_c g - \mu_k m_p g \cos\theta - m_p g \cos\theta = m_p a$$

After the *Manager* has concluded that the counterweight is accelerating downwards:

"*Recorder/Checker*, draw an acceleration vector to the right of your force diagram."

After the *Recorder/Checker* has drawn the acceleration vector, point to the counterweight diagram.

"*Skeptic*, what question could you ask about the size (magnitude) of the tension force (**T**) compared to the size (magnitude) of the gravitational force (**W$_c$**)?" (e.g., According to Newton's 2nd Law, should these forces be the same magnitude or different magnitudes? Why?) If the *Skeptic* has no ideas, then model (in this case tell) the group the questions they should ask.

After the group has concluded that **W$_c$** must be larger than **T** for the counterweight to be accelerating downwards, the group members may conclude right away that their equation, **T = m$_c$g,** is incorrect, and you can leave the group.

If this does not happen

"*Recorder/Checker*, correct the free-body force diagram."

After the *Recorder/Checker* has corrected the force diagram, point to the equation **T = m$_c$g**

"*Skeptic*, one question you can **always** ask is whether a specific equation like this is the correct application of Newton's 2nd Law of motion. What do you (group) think here? Does this specific equation match the force diagram for the counterweight? Why or why not?"

Example 4: Major Misconception – Nature of Forces and Newton's 2nd Law (difficulty 6)

You observe a group that has not drawn separate free-body force diagrams for the package and the counterweight. Instead, they sketched some forces on their picture. In addition, they did not start their equations with Newton's 2nd Law in its general form, $\Sigma F_x = ma_x$. Instead, they wrote the equations shown at right.

$$F_{net} = f = ma$$
$$f = \mu mg \cos\theta$$
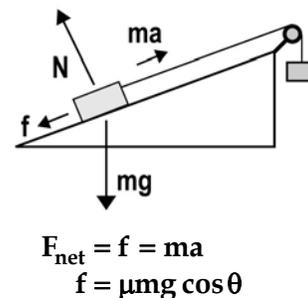
There are several possible conceptual difficulties the students may have:

- They may not understand the nature of forces. [for example: passive forces described in McDermott (1984) or pseudo-forces like inertia described in McDermott (1984), Hughes (2002), and Arons (1997)]

- They may not understand or know how to apply Newton's 2nd Law. Research at the University of Minnesota indicates that about 20% of students in the calculus-based course for scientists and engineers solve Newton's 2nd Law problems by setting an unknown force (e.g., friction, tension) equal to "ma" or by setting the sum of the forces equal to zero, even when there is acceleration. In addition, about 20% of students solve Newton's 2nd Law problems by setting an unknown force (e.g., tension) equal to the sum of all the known forces, as shown at right.

Example of Setting Unknown Force Equal to the Sum of the Known Forces
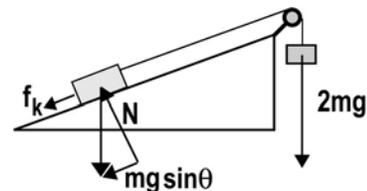
$$T = 2mg - f_f - mg\sin\theta$$
$$= 2mg - \mu_k mg\cos\theta - mg\sin\theta$$

This group could take *a very long time to coach*. You decide to circulate around the class one more time to make sure that your other groups are on track. You quickly coach another group with a minor difficulty (Example 2), then return to this group. You need to ask questions to diagnose the group's misconceptions.

You could start by asking the Recorder/Checker or the Skeptic/Summarizer to explain each force on their diagram. If students have a misconception about the nature of forces, you could:

1. Model drawing a free-body diagram of a book at rest; or
2. Hand out the part of the *Competent Problem Solver* that explains how to draw free body diagrams (pp 4-1 to 4-6); or
3. Hand out the *Table of Interactions and Forces* (see Chapter 4, pp 110); or
4. Do some combination of 1 – 3.

What are the
Misconceptions?

$$F_{net} = f = ma$$
$$f = \mu mg \cos\theta$$
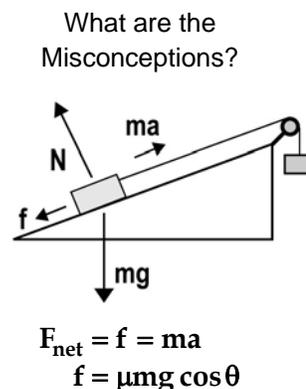
You would **not** have time to coach these students completely through all of their difficulties. Even with coaching about the nature of forces, the students probably have additional misconceptions about Newton's 2nd Law.

Remember

Guidelines for Coaching Groups During a Lab Session

At the beginning of the lab session, while students are coming to consensus about the answers to warm-up questions you asked them to put on the board, your coaching is similar to what you do in a discussion session.

Below are some guidelines and a few examples for coaching students in solving problems (making decisions) while they are checking their solutions.

Exploration. Give students a lot of encouragement to explore with the equipment. We know that exploration is the essence of physics, but many students view it as a "waste of time."

Example. Your students have just started to check their solution to the Lab problem: Mass and the Acceleration of a Falling Ball. You circulate around the class and help a few groups. When you get back to the first group, you notice that they appear to be taking data from a video. You do not think that this group had enough time to complete the exploration and come up with a measurement plan. They were not very efficient in the last lab session.

Join the group and ask: Who is the Skeptic/Summarizer? Skeptic/Summarizer, summarize your groups' decisions about how far the camera should be positioned from the falling ball to get enough data points, what reference object to use, and where the reference object should be placed to determine the distance scale." Some follow up questions could include: " How do you know the

camera is positioned in the right place? How do you know where the reference object should be placed?"

If the group gives satisfactory answers to these questions, then congratulate the group on their efficiency and move on. If the group does not give satisfactory answers, then ask: "Who is the Manager? Manager, remember that part of your job is to make sure the group follows the instructions for each part of the lab. Help your group follow the directions in the Exploration section, so each group member could write a good lab report (if this problem were assigned)."

Measurement. Students need encouragement to pay attention to their measurements **as they take them**. While they are taking data, 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 about the measurement process. In either case, you should work with them to set them straight.

Example. You are watching a student take data using videoTOOL. She is not being very careful about selecting the same spot on the on the ball. She has not adjusted the position versus time graph scale to show the data points as they are taken. You also notice that the other students are not paying much attention to what is going on.

Join the group and ask the keyboarder what her group role is. If she is not the Manger, then ask: "Who is the Manager? Manager, one of you jobs is to make sure that the group follows the lab instructions. What instruction is not being followed right now?" [Make sure you set the scale of the axes on your graph so you can see the data points as you take them.]

Wait until the keyboarder has adjusted the scale of the graph so the data points are showing. Ask the group: "Do these data points make sense?" You may need to follow up with: "Skeptic, What are some possibilities for why the data looks like this? Keep asking questions until the group agrees that the keyboarder needs to be more careful about measuring the position on the same part of the object each time.

Analysis. 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 analyzing the data with computer programs such as VideoTOOL, 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.

Example. You are watching a student at the keyboard making repeated guesses for the values of the constants in the function for the position-versus-time graph *of a freely falling ball*. The other group members are watching passively.

Join the group and ask: "Who is the Manager? Manager, you are letting the group waste a lot of time trying to guess the constants of this function. Have the manager write the function with the dummy variables and the function with the kinematics quantities:

$$x(t) = a + bt + ct^2$$
$$x(t) = x_o + v_o t + \frac{1}{2} at^2$$

The sequence of questions you ask next depends on the knowledge of the group. Here is a brief outline of a series of possible questions:

"What kinematics quantity does the constant "a" represent? [a is x_o] What is the meaning of x_o? [the position of the ball at time t = 0] Look at your graph. How can you estimate the constant x_o from the graph? Have the group show you and write down their estimate in their journal. What are the units of x_o? [m or cm]

"What kinematics quantity does the constant "b" represent? [b is v_o] What is the meaning of v_o? [the instantaneous velocity of the ball at time t=0] Look at your graph. How can you estimate the constant v_o from the graph? Have the group show you and write down their estimate in their journal. What are the units of v_o? [m/s or cm/s]

"What kinematics quantity does the constant "c" represent? [c is 1/2 a] What is the approximate value of the acceleration for freely falling bodies? [9.8 m/s^2 or 980 cm/s^2] What value of "c" would be a good place to start? [4.9 m/s^2 or 490 cm/s^2]. Have the students write down the estimate in their journal

Have the keyboarder put in the estimates of the constants in the function. Tell the group to read the lab instructions for how to estimate the constants in the velocity versus time graph. Before you leave the group, tell the Recorder/Checker that one of his/her jobs is to make sure everyone writes the groups' estimates of the constants of a function (with units) in their journal. Everyone should also write the fitted constants (results of analysis) in their journals.

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. Use the roles of Manager and Recorder/Checker to remind groups to record all the information they need to solve the problem in their journals.

Conclusion. This section gives many students a great deal of difficulty, especially at the beginning of the course.
- Make sure they write an outline of their conclusions for the problem before going on to the next problem.
- **The conclusion should include a corrected, logical, and organized solution to the problem.**
- 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.

Expectations

Learning how to be a good coach of problem solving is very, very difficult. During the first few weeks of the semester, you may not be able to think of appropriate metacognitive questions to ask. If you intervene to coach a group and end up telling the group what to do instead of asking metacognitive questions, don't be too hard on yourself. **The important thing is that the next time you intervene with a group, you** *try* **asking using the roles to ask some questions.** Like learning to drive a car or learning a new sport, with *practice*, coaching gets easier and easier.

You also have available other tools to make your coaching easier. One tool is the problem-solving framework and answer sheets you designed during the TA Orientation. It is much easier for you to diagnose students' difficulties when they draw pictures and physics diagrams, define variables, and try to construct a logical solution. Without these written cues, you could not coach 5 - 6 groups during discussion and labs. Instead, you would probably either give up or spend all you time coaching only one or two groups, while the majority of your students fail to learn.

II. How Do I Form Cooperative Groups?

*T*he learning advantage of CPS lies in the students' *co-construction* of a problem solution. There are several aspects of group structuring that affect learning, such as group size, group composition, how long groups stay together, and the roles of individual students in the groups. The structures you will use and their rationale are described in this section. The sidebars in the next few pages contain a brief description of the research that supports each structure (taken from published papers[3],[4] of research conducted at the University of Minnesota).

Group Size and Assignment

The optimal group size for solving physics problems is three. Of course, if your class is not divisible by three, then you will have a few pairs or a four-member group. We found that four-member groups generally work better than pairs in discussion sections. For the laboratory, break the group of four into two pairs.

You will assign students to groups, rather than letting students form their own groups. Below are the advantages of group assignment.

Optimal Learning.   The **most important** reason to assign students to groups is because over 25 years of past research in cooperative group learning indicates that students learn more (become better problem solvers) when they work in *mixed-achievement groups* (i.e., based on past test performance) than when they work in homogeneous-performance groups. You do not, however, want students to wonder whom the high, medium and lower-performance students are in their groups, so do not tell them directly that this is how we assign group membership.

Psychological Advantage.   There is a psychological reason for assigning groups. This reason is so important it is called the 2nd Law of Instruction:

> Don't change course in midstream. Instead, structure early then fade.

It is much easier to set and enforce rules in the beginning of a class and loosen the enforcement later than it is to not have any rules at the beginning, and discover later that you have to establish a new rule. By assigning groups at the beginning, you will have fewer disgruntled students.

> **Why are three-member groups better than pairs or four-member groups?**
>
> For the co-construction of a physics problem solution by students in introductory courses, we found the "optimal" group size to be **three** members. A three-member group is large enough for the generation of diverse ideas and approaches, but small enough to be manageable so that all students can contribute to the problem solution.
>
> An examination of written group problem solutions indicated that three- and four-member groups generate a more logical and organized solution with fewer conceptual mistakes than pairs. About 60 - 80% of pairs make conceptual errors in their solution (e.g., an incorrect force or energy), whereas only about 10 - 30% of three-or four member groups make these same errors. Observations of group interactions suggested several possible causes for the lower performance of pairs. Groups of two did not seem to have the "critical mass" of conceptual and procedural knowledge for successful completion of context-rich problems. They tended to go off track or get stuck with a single approach to a problem, which was often incorrect.
>
> With larger groups, the contributions of the additional student(s) allowed the group to jump to another track when it seemed to be following an unfruitful path. In some groups of two, one student dominated the problem solving process, so the pair did not function as a cooperative group. A pair usually had no mechanism for deciding between two strongly held viewpoints except the constant domination of one member, who was not always the most knowledgeable student. This behavior was especially prevalent in male-female pairs. In larger groups, one student often functioned as a mediator between students with opposing viewpoints. The issue was resolved based on physics rather than the personality trait of a particular student.
>
> In groups of four students, however, one person was invariably left out of the problem solving process. Sometimes this was the more timid student who was reticent to ask for clarification. At other times, the person left out was the most knowledgeable student who appeared to tire of continually trying to convince the three other group members to try an approach, and resorted to solving the problem alone. To verify these observations, we counted the number of contributions each group member made to a constant-acceleration kinematics problem from the videotapes of a three-member and four-member group. Each member of the group of three made 38%, 36%, and 26% of the contributions to the solution. For the group of four, each member made 37%, 32%, 23%, and 8% of the contributions to the solution. The only contribution of the least involved student (8%) was to check the numerical calculations. Our results are consistent with the research on pre-college students.[5]

Practical Advantage. There are practical reasons for assigning students to groups. For example, most of our students do not know each other at the beginning of class. They would feel very uncomfortable being told simply to "form your own groups." Even if students know each other well, they typically have established behavior patterns that are not based on learning physics and are not conducive to it. Assigning groups allows the natural breakup of existing social interaction patterns.

Changing Groups

There are both optimal-learning and practical reasons for changing groups.

Avoid Homogeneous Groups. One reason to change groups is that you are likely to have many homogeneous-achievement groups, which is not optimal for student learning. Normally you do not know the problem-solving performance of your students at the beginning of class. With a small number of students, there can be large random fluctuations in the achievement-mix of your groups.

Avoid Role Patterns. In groups, the necessity to verbalize the procedures, doubts, justifications and explanations helps clarify the thinking of all group members. In addition, students can rehearse and observe others perform these roles, so they become better individual problem solvers. If students stay in the same group too long, they tend to fall into role patterns. The result is that they do not rehearse the different roles they need to perform on individual problems, and consequently do not achieve optimal gains in improving their problem solving performance.

Difficult Students. A third, practical reason for changing groups is that your first groups may have some very dysfunctional groups (because of personality conflicts). Students find it miserable to contemplate working a whole semester with someone who isn't compatible, and may disengage. However, most will accept the challenge of working together if they know that it is for a limited time. After you get to know the students better, you can place the "difficult" students in better groups. Strategies for dealing with difficult group members are discussed in Section IV.

Individual Responsibility. Finally, one of the most important reasons to change groups is to reinforce the importance of the individual in cooperative problem solving. The most difficult point in the course for group management is the first time you change groups. By that time, most groups have been reasonably successful, and students are convinced they are in a "magic" group. Changing groups elicits many complaints, but is necessary for students to learn that success depends on individual effort and not on a particular group.

How often should groups be changed? Students need to work in the same group long enough to experience some success. The frequency of changing groups can fade over the course as students become more confident and comfortable with CPS. For example, change groups about 3 - 4 times in the first semester, but fewer times in the second semester. Since students are very sensitive to grades, change groups only after a class test.

Why is it better to assign students to groups?

In our research, we examined the written problem solutions of both homogeneous and mixed-achievement groups (based on past problem-solving test performances). The mixed-performance groups (i.e., a high, medium and lower performing student) consistently performed as well as high performance groups, and better than medium and low performance groups. For example, our algebra-based class was given a group problem that asked for the light energy emitted when an electron moves from a larger to a smaller Bohr orbit. 75 percent of the mixed-performance groups solved the problem correctly, while only 45% of the homogeneous groups solved this problem.

Observations of group interactions indicated several possible explanations for the better performance of heterogeneous groups. For example, on the Bohr-orbit problem the homogeneous groups of low- and medium-performance students had difficulty identifying energy terms consistent with the defined system. They did not appear to have a sufficient reservoir of correct procedural knowledge to get very far on context-rich problems. Most of the homogeneous high performance groups included the gravitational potential energy as well as the electric potential energy in the conservation of energy equation, even though an order-of-magnitude calculation of the ratio of the electric to gravitational potential energy had been done in the lectures. These groups tended to make the problem more complicated than necessary or overlooked the obvious. They were usually able to correct their mistake, but only after carrying the inefficient or incorrect solution further than necessary. For example, in the heterogeneous (mixed-performance) groups, it was usually the medium or lower performance student who pointed out that the gravitational potential energy term was not needed. ["But remember from lecture, the electric potential energy was lots and lots bigger than the gravitational potential energy. Can't we leave it out?"] Although the higher performance student typically supplied the leadership in generating new ideas or approaches to the problem, the low or medium performance student often kept the group on track by pointing out obvious and simple ideas.

In heterogeneous groups, the low- or medium-performance student also frequently asked for clarification of the physics concept or procedure under discussion. While explaining or elaborating, the higher-performance student often recognized a mistake, such as overlooking a contributing variable or making the problem more complicated than necessary. For example, a group was observed while solving a problem in which a car traveling up a hill slides to a stop after the brakes are applied. The problem statement included the coefficient of both static and kinetic friction. The higher performance student first thought that both static and kinetic frictional forces were needed to solve the problem. When the lower-performance student in the group asked for an explanation, the higher-performance student started to push her pencil up an inclined notebook to explain what she meant. In the process of justifying her position, she realized that only the kinetic frictional force was needed. Our results are consistent with the research on pre-college students.[3]

III. What Criteria Do I Use to Assign Students to Groups?

*T*here are three criteria for assigning students to groups.

1. Problem-solving Performance. The most important criterion for assigning students to groups is their problem solving performance based on past problem-solving tests. That is, a three-member group would ideally consist of a higher-performance, a medium-performance, and a lower-performance student. Four-member groups would ideally consist of a high performance, medium-high performance, medium-low performance, and a low-performance student. There are two other "rules of thumb" for assigning students to groups.

2. Gender. Our observations indicated that frequently groups with only one woman do not function well, especially at the beginning of class. To be on the safe side, avoid groups with only one woman. We found the difficulty is with the men, not the women (see example at right). Regardless of the strengths of the lone woman, the men in the group tend to ignore her. On the other hand, we found it is dangerous to assign all the students in a class to same-gender groups. The women notice and tend to suspect gender discrimination. Curiously, no one seems to notice when all mixed-gender groups have two women.

3. English as a Second Language (ESL). Students from other cultures often have a difficult time adjusting to group work, especially in mixed-gender groups. Their difficulties are exacerbated if English is their second language (ESL). So to be on the safe side, whenever possible we assign each ESL student to a different, *same-gender* group.

> We observed a group, consisting of a lower-performance man, a medium performance man and a high performance woman, having a vigorous discussion about the path of a projectile. The men insisted on a path following the hypotenuse of a triangle; while the woman argued for the correct parabolic trajectory.
>
> At one point, she threw a pen horizontally, commenting as it fell to the floor, "There see how it goes. It does **not** go in a straight line!" Even so, she could not convince the two men, who politely ignored her.

An Example of How to Assign Students to Groups

The following example, for a class of 17 students, describes the steps you can follow to assign students to groups with roles.

Step ① Calculate the total test score (sum of test scores) for each student. Identify each student's gender (M for male and F for female) and whether English is a second language (ESL). A spreadsheet is the most convenient way to do this.

Name	Gen.	ESL	Test 1	Test 2	Total
Anderson, Max	M		62	71	133
Black, Jennifer	F		93	85	178
Brown, John	M		78	79	157
Edwards, Mark	M		54	58	112
Fairweather, Joan	F		73	65	138
Freedman, Joshua	M		86	92	178
Good, Mary	F		100	95	195
Green, Bill	M		79	83	162
Johnson, Fred	M		69	70	139
Jones, Rachel	F		59	63	122
Nygen, Tan	M	Yes	84	85	169
Peterson, Scott	M		69	61	130
Smith, Patricia	F		70	77	147
South, David	M		48	50	98
West, Tom	M		52	55	107
White, Sandra	F		55	49	104
Yurrli, Tamara	F	Yes	57	60	117

Step ② Sort the class by total test score (highest to lowest). Divide the class into approximate thirds (high performance, medium performance and low performance students). Identify the performance level (Perf.) of each student, as shown below.

Name	Sex	ESL	Test 1	Test 2	Total	Perf.
Good, Mary	F		100	95	195	Hi
Black, Jennifer	F		93	85	178	Hi
Freedman, Joshua	M		86	92	178	Hi
Nygen, Tan	M	Yes	84	85	169	Hi
Green, Bill	M		79	83	162	Hi
Brown, John	M		78	79	157	Hi/M
Smith, Patricia	F		70	77	147	Med
Johnson, Fred	M		69	70	139	Med
Fairweather, Joan	F		73	65	138	Med
Anderson, Max	M		62	71	133	Med
Peterson, Scott	M		69	61	130	Med
Jones, Rachel	F		59	63	122	M/Lo
Yurrli, Tamara	F	Yes	57	60	117	Lo
Edwards, Mark	M		54	58	112	Lo
West, Tom	M		52	55	107	Lo
White, Sandra	F		55	49	104	Lo
South, David	M		48	50	98	Lo

Step ③ Within each performance group, sort by gender and ESL. Assign each student to a numbered group (Gr.). First, assign the ESL students to same-gender, mixed performance groups of three (high, medium, and low performance), as illustrated on the next page (bolded group numbers). Assign the remaining students to three- or four-member groups using the mixed-performance and gender criteria.

Name	Gen.	ESL	Test 1	Test 2	Total	Perf.	Gr.
Nygen, Tan	M	Yes	84	85	169	Hi	**1**
Freedman, Joshua	M		86	92	178	Hi	3
Green, Bill	M		79	83	162	Hi	4
Brown, John	M		78	79	157	Hi/M	5
Good, Mary	F		100	95	195	Hi	**2**
Black, Jennifer	F		93	85	178	Hi	4
Johnson, Fred	M		69	70	139	Med	5
Anderson, Max	M		62	71	133	Med	5
Peterson, Scott	M		69	61	130	Med	**1**
Smith, Patricia	F		70	77	147	Med	3
Fairweather, Joan	F		73	65	138	Med	**2**
Jones, Rachel	F		59	63	122	M/Lo	4
Edwards, Mark	M		54	58	112	Lo	**1**
West, Tom	M		52	55	107	Lo	4
South, David	M		48	50	98	Lo	5
Yurrli, Tamara	F	Yes	57	60	117	Lo	**2**
White, Sandra	F		55	49	104	Lo	3

Then sort the groups by group number.

Name	Sex	ESL	Perf.	Gr.
Nygen, Tan	M	Yes	Hi	1
Peterson, Scott	M		Med	1
Edwards, Mark	M		Lo	1
Good, Mary	F		Hi	2
Fairweather, Joan	F		Med	2
Yurrli, Tamara	F	Yes	Lo	2
Freedman, Joshua	M		Hi	3
Smith, Patricia	F		Med	3
White, Sandra	F		Lo	3
Black, Jennifer	F		Hi	4
Green, Bill	M		Hi	4
Jones, Rachel	F		M/Lo	4
West, Tom	M		Lo	4
Brown, John	M		Hi/M	5
Johnson, Fred	M		Med	5
Anderson, Max	M		Med	5
South, David	M		Lo	5

Step ④ Check the groups. If necessary, modify the groups using your knowledge of your students' strengths and weaknesses working cooperatively. For example, suppose Joshua Freedman (Group 3) tries to dominate groups by "railroading" his ideas through a group without listening to other ideas. Patricia Smith and Sandra White are shy and quiet, but work well in congenial groups. You could replace Joshua with another higher-performance male who is listens well and is good at clarifying and explaining ideas, for example Bill Green (Group 4). However, you also have to make sure Joshua is placed in a group that will not let him dominate. Max Anderson has excellent group management skills, so you could put Joshua in Group 5, and move John Brown to Group 4.

If you teach a calculus-based course, you may not have many women in your discussion class, and you cannot put them in the same group all the time. Use your knowledge of their strengths and weaknesses in working cooperatively to assign them to groups.

Step ⑤ Sort the students by group number, as shown below. Then assign roles to each group member: Manager (M), Skeptic/Summarizer (Sk/Su), and Recorder/Checker (R/C) for three-member groups and Manager (M), Skeptic (Sk), Recorder/Checker (R/C) and Summarizer (Su) for four-member groups. [See Section I for the reasons for assigning roles.]

Use two rules of thumb for the assignment of roles to *new groups*:

a. Assign the role of Recorder/Checker to the ESL students (see bolded R/C roles in groups 1 and 2 below); and

b. Do not assign the role of Recorder/Checker to the man in a mixed-gender group of three (see italicized R/C role in group 3 below).

Name	Sex	ESL	Perf.	Gr.	Role
Nygen, Tan	M	Yes	Hi	1	**R/C**
Peterson, Scott	M		Med	1	M
Edwards, Mark	M		Lo	1	Sk/Su
Good, Mary	F		Hi	2	M
Fairweather, Joan	F		Med	2	Sk/Su
Yurrli, Tamara	F	Yes	Lo	2	**R/C**
Green, Bill	M		Hi	3	Sk/Su
Smith, Patricia	F		Med	3	*R/C*
White, Sandra	F		Lo	3	M
Black, Jennifer	F		Hi	4	M
Brown, John	M		Hi/M	4	Sk
Jones, Rachel	F		M/Lo	4	R/C
West, Tom	M		Lo	4	Su
Freedman, Joshua	M		Hi	5	Sk
Johnson, Fred	M		Med	5	Su
Anderson, Max	M		Med	5	M
South, David	M		Lo	5	R/C

Step ⑥ Make a copy of your group assignments and roles. You can write the assignments on the board before a discussion class, or project the group and role assignment in a laboratory session. An example is shown below.

#1	M. Edwards	Sk/Su		#4	J. Black	M
	T. Nygen	R/C			J. Brown	Su
	S. Peterson	M			R. Jones	R/C
					T. West	Sk
#2	J. Fairweather	Sk/Su				
	M. Good	M		#5	M. Anderson	M
	T. Yurrli	R/C			J. Freedman	Sk
					F. Johnson	Su
#3	B. Green	Sk/Su			D. South	R/C
	P. Smith	M				
	S. White	R/C				

Step ⑦ Each subsequent time the same group works together, their roles **MUST ROTATE.** One way to accomplish this is to list the group members with roles on the board each session, as shown above. You can use a spreadsheet to keep track of the roles you have assigned to each group member. An example is shown below.

Name	Gr.	DS 10/15	Lab 10/20	DS 10/22	Lab 10/27	DS 10/29	Lab 11/3
Nygen, Tan	1	R/C	M	Sk/Su	R/C	M	Sk/Su
Peterson, Scott	1	M	Sk/Su	R/C	M	Sk/Su	R/C
Edwards, Mark	1	Sk/Su	R/C	M	Sk/Su	R/C	M
Good, Mary	2	M	Sk/Su	R/C	M	Sk/Su	R/C
Fairweather, Joan	2	Sk/Su	R/C	M	Sk/Su	R/C	M
Yurrli, Tamara	2	R/C	M	Sk/Su	R/C	M	Sk/Su
Green, Bill	3	Sk/Su	R/C	M	Sk/Su	R/C	M
Smith, Patricia	3	R/C	M	Sk/Su	R/C	M	Sk/Su
White, Sandra	3	M	Sk/Su	R/C	M	Sk/Su	R/C
Black, Jennifer	4	M	Sk	R/C	Su	M	Sk
Brown, John	4	Sk	R/C	Su	M	Sk	R/C
Jones, Rachel	4	R/C	Su	M	Sk	R/C	Su
West, Tom	4	Su	M	Sk	R/C	Su	M
Freedman, Joshua	5	Sk	Su	M	R/C	Sk	Su
Johnson, Fred	5	Su	M	R/C	Sk	Su	M
Anderson, Max	5	M	R/C	Sk	Su	M	R/C
South, David	5	R/C	Sk	Su	M	R/C	Sk

IV. How Can I Structure CPS to Maintain Well-functioning Groups?

*I*deally, you want your CPS discussion and lab sessions to be enjoyable for both you and your students, with a lot of learning going on within each group. In well-functioning groups, members share the metcognitive roles of manager, checker, explainer, skeptic and conciliator (who solves conflicts and strives to minimize interpersonal conflict), and role assumption usually fluctuates over the time students are solving a problem. Students in these groups do not need to be reminded to "stick to their roles." You will use the roles only as a convenient, efficient way to coach the metacognitive skills students need when they are having difficulty with a specific physics concept or problem-solving procedure.

The opposite of well-functioning groups is "dysfunctional" groups. Dysfunctional groups exhibit one or more of the following behaviors.

- Less able members sometimes "leave it to John" to solve the group problem, creating a **free-rider** effect.

- At the same time, more able group members expend decreasing amounts of effort to avoid the **sucker** effect.

- High ability group members may be deferred to and take over leadership roles in ways that benefit them at the expense of the other group members (the **rich-get-richer** effect).

- Groups with no natural leaders may avoid conflict by "voting" rather than discussing an issue (**conflict avoidance** effect).

- Group members argue vehemently for their point of view and are unable to listen to each other or come to a group consensus (**destructive conflict** effect).

Students in dysfunctional groups *cannot* learn, and the result is very disgruntled students. This, in turn, leads to very disgruntled instructors. So how can you make your job easier and more enjoyable? This section includes suggestions for how to get started and structure your classes for well-functioning groups.

Seating Arrangement

In discussion section, make sure the seats are arranged so students are facing each other, "knee-to-knee". [See Figures 1 and 2 on the next page.] This seating arrangement makes it much harder for a student to remain uninvolved with a group. If you observe students sitting in a row with one person not involved, or one student sitting "outside" a pair, go over to the group and make them stand up and rearrange their chairs.

In labs, make sure students are standing or sitting so they are all facing each other. In computer labs, make sure all students can see the screen. If you observe a group with one member doing all the work or one member left out, go over to the group and make them rearrange their seating/standing.

Figure 1. Bad Example of Seating Arrangement

Figure 2. Good Example of Seating Arrangement

Start the Semester with Group Roles for Each Step in the Problem-solving Framework

At the beginning of an introductory class, some students have never participated in Cooperative Problem Solving (CPS) and do not know how to co-construct a problem solution in a group. Look at the Group Roles on page 15. The roles remind students of appropriate individual actions in a group. Each role includes some action that may not be natural for students, or even socially acceptable. For example, "I don't want to be bossy, but I am the manager. Let's move on to . . ." The role of "Skeptic" allows students a socially acceptable way to disagree. Most of the actions described for each role are metacognitive. However, each role also includes some group-maintenance actions.

MANAGER: MAKE SURE EVERYONE IN YOUR GROUP PARTICIPATES.

RECORDER/CHECKER: MAKE SURE ALL MEMBERS OF YOUR GROUP AGREE WITH EACH THING YOU WRITE.

SKEPTIC/SUMMARIZER: KEEP TRACK OF DIFFERENT POSITIONS OF GROUP MEMBERS AND SUMMARIZE **BEFORE** YOUR GROUP MAKES A DECISION.

All of the actions on the Group Role sheets (both metacognitive and group- maintenance) are stated in general terms. Many students do not know what it means to apply these actions at different places in the problem-solving framework. Look at the *Problem Framework Roles* sheets at the end of this section (pp 46 to 55). These sheets provide specific coaching for each role through all the problem-solving decisions.

In the first (or second) week of the discussion session, you will introduce the Group Roles and the problem-solving framework and answer sheet and explain them briefly. In the next discussion session, tell your students that you have something that will help them learn how to solve problems in a logical, organized fashion. Pass out the *Problem Framework Roles* sheets and tell the students to glance through the sheets.

Notice that this procedure is a direct application of two of the "2nd Law of Education."

Don't change course in midstream.

It is easier on both instructors and students to start with what may seem a rigid structure, then fade slowly as the structure is no longer needed. It is almost impossible to impose a different or more structured procedure in the middle of the course, after you discover that students need the structure.

You will decide when students no longer need the *Problem Framework Roles* sheets and the answer sheets in the discussion section.

Examples of Coaching to Maintain Well-functioning Groups in Discussion Session

With the *Problem Framework Roles* sheets, you should have very few problems with dysfunctional groups. The examples suggest how to deal with the occasional group that is not working well together.

Example 1: Individual Problem Solving. You observe a group in which the members are not talking to each other, but solving the group problem individually (not on the answer sheet).

Say something like: "I notice that you are solving the problem individually, not as a group. Who is the Recorder/Checker? You should be the only person writing the solution on the answer sheet as you solve the problem together. Manager and Skeptic/Summarizer put your pencils away and work with the Recorder/Checker to solve the problem." Make the students rearrange their chairs so they can all see what the Recorder/Checker is writing.

<u>Drastic Measure</u>. If the students persist in solving the problem individually and only then return to the group to compare answers, explain again that they should be solving the problem together. Take away the papers students have written on, the pencils from the Manager and Skeptic (return them at the end of class), and give the recorder a new answer sheet (if necessary). Have the group start again, using their *Problem Framework Roles* sheets. Do not leave until they have started solving the problem together.

Example 2: A Lone Problem Solver. You observe a group in which two members, including the Recorder/Checker, are working together, but one member is working alone to solve the problem (hereafter called "the loner.") First, try to determine why the loner is solving the problem alone. Say something like: "I notice that while two of you are working together, you (loner) appear to be solving the problem by yourself. What are each of your group roles? Why are you (loner), as the group Manager (or Skeptic/Summarizer) solving the problem by yourself?"

Frequently, the loner will sheepishly mumble something about not being used to working in a group. This individual may need only a gentle reminder to give group work a try. Ask the Recorder/Checker to explain to the loner what they have done so far to solve the problem. If necessary, make the students rearrange their chairs so they can all see what the Recorder/Checker is writing.

Infrequently, a loner is more adamant about needing to solve the problem alone before talking with the group. Maintain a sympathetic attitude, but explain to the loner that research shows that *all* students learn much more about physics and problem solving when they construct problem

solutions together. This is why you work in groups in this class. Although it may seem difficult at first, s/he should try it. Tell the individual to put his pencil away and ask the Recorder/Checker to explain to the loner what they have done so far to solve the problem.

Example 3: A Non-participant. You observe a group in which one member does not appear to be engaged in the group problem-solving process.

Try to determine why the student appears to be disengaged. For example, if the students are sitting in a row and not facing each other, have the students to get up and rearrange the chairs so they sit facing each other. Ask the non-participating student to explain what the group is doing and why. [This emphasizes the fact that **all** group members need to be able to explain each step in solving a problem.] If the student can describe what the group is doing and why, then s/he may be a quiet student who pays attention, but does not speak as often as the others. You may not need to intervene further.

If the student does not have a clear idea of what the other group members are doing, s/he *may* be what is called a "free-rider" -- a person who leaves it to others to solve the problem. Ask the free rider: "What is your group role? What should you be doing to help your group solve this problem?" [If necessary, have the free rider read the description from the *Problem Framework Role* sheets.] If the free rider is not the Manager, ask the Manager what s/he could do to make sure everyone, including the free rider, participates in solving the problem.

Example 4: Dominant Student.
You observe a group in which one member is doing almost all of the talking, while the other members appear somewhat disengaged and lethargic (Rich-get-richer effect? Free-riders?

In this case, all members are failing in their roles. First tell the group: "I notice that one person appears to be doing all the talking in this group." Then ask: Manager, what could you be doing to make sure that all members of your group contribute their ideas?" If the manager has no ideas, then tell that Manager that: "In each step in your problem-solving framework, ask each member of your group what they think." Point to the last part of the group's solution and have the Manager

read questions from the *Problem Framework Sheet* that he/she could be asking individuals in the group.

Repeat this procedure with each group member. Ask: "Checker/Recorder, what could you be doing to make sure that all members understand and can explain everything that is written down?" [Periodically ask each member if they understand and agree with everything written down. Point to the last part of the group's solution and have the Checker/Recorder read questions from the *Problem Framework Sheet* that he/she could be asking individuals in the group. Ask: "Skeptic, what could you be doing to make sure that all possibilities and alternative ideas are being considered by the group?" [Be sure to ask for a justification for an idea, and suggest alternative ideas.] Point to the last part of the group's solution and have the Checker/Recorder read questions from the *Problem Framework Sheet* that he/she could be asking individuals in the group.

Example 5: Conflict Avoidance or Destructive Conflict.

You observe a group that is either struggling to come to a decision, but does not appear to have any strategy to reach a decision (conflict avoidance), or is arguing loudly, but does not appear to be resolving their conflict (destructive conflict). Ask the group: "Who is the Skeptic/Summarizer? I noticed that you are having difficulty deciding _____. What could you be doing to help the group come to a decision that is agreeable to all of you? [Stop and summarize your different ideas. Then discuss the merits/justification of each idea.] If the Skeptic/Summarizer has no idea, then either have the her/him read the *Problem Framework Role* sheet again (early in course) or give some suggestions, such as: "Stop and summarize your different ideas. Then discuss the merits of each idea. For example, you could . . . ." The specific suggestions you give will depend on the exact nature of the decision that led to the original conflict.

Group Processing

One of the elements that distinguish traditional groups from cooperative groups is structuring occasional opportunities for students to discuss how well they are solving the problems together and what actions they should take next time to work better together. You could do this informally (as Karl Smith demonstrated), or you could use the *Group Functioning Evaluation* form shown on the next page. After the group has discussed and completed the evaluation, spend a few minutes in a class discussion of the answers to Question 6, so students can consider a wider range of ways groups could function better. Common answers include: "Come better prepared; Listen better to what people say; Make better use of our roles (e.g., "Be sure the Manager watches the time so we can finish the problem." or "Be sure the Skeptic doesn't let us decide too quickly.").

At the beginning of the first semester, structure group processing *at least on alternate* class sessions. After 2 - 4 weeks (i.e., after students have worked in two different groups), you can reduce group processing to about once every two to three weeks, as it seems necessary (usually the first time new groups are working together).

Group Evaluation Sheet

Date: _____   **Group #:** _____

Complete the following questions as a team.

	Low				High
1. Did all the members of our group contribute ideas to solve the problem?	1	2	3	4	5
2. Did all the members of our group listen carefully to the ideas of other group members?	1	2	3	4	5
3. Did we *encourage* all members to contribute their ideas?	1	2	3	4	5

4. What are two **specific** actions we did today that helped us solve the problem?

5. What is a specific action that would help us do even better next time?

Group Signatures: **Manager**: _____.

Skeptic/Summarizer: _____.

Recorder/Checker: _____.

Skeptic/Summarizer: _____.

Remember the 2nd Law of Education: Don't change course in midstream. It is better to impose a structure early then fade. This means it is very difficult to start group processing when you finally discover that you need it. As students become more comfortable and competent with CPS, the group roles slowly and naturally "fade" away from students' minds, except when you coach students.

Random Calling on Students

In both discussion sections and lab, randomly call on individual students in a group to present their group's results. **This person is *not* usually the Recorder/Checker for the group**. In the beginning of the course, you can call on the individuals who seem most enthusiastic or involved. After students are familiar with CPS, you can either call on the Skeptic/Summarizers or Managers, or call on individuals who seemed to be the least involved. This technique helps avoid both dominance by one student and the free-rider effect.

Grading

The Zeroth Law of Education is:

If you don't grade it, students won't do it.

One consequence of the Zeroth Law of Education is that your students will work more effectively in cooperative groups when group problem solutions are occasionally graded. Group problem solutions are usually only 10% - 15% of a student's grade in the course. There are many ways that your team may grade the group problem solutions. For example, your team might assign 10% - 15% of each student's grade to a fixed number of group problem solutions. That is, groups occasionally turn in one problem solution for grading, and each group member gets the same grade for the group solution.

In some teams, each test has a group part and an individual part. The first part of the test is a group problem that students complete in their discussion sections. The following day students complete the individual part of the test. The group problem is usually about 25% of a student's total score for each test. When the final exam is added, the group problems are only about 15% of their total test scores. When other parts of the grade are added (e.g., individual laboratory reports), group problems are 10% or less of the students' course grade. [The advantage of this presentation of grading lies in the way students interpret their test scores. When groups are well managed, the highest score that students receive on a test is almost always for the group problem, which is also the most difficult problem on the test.[1] This reinforces the advantages of cooperative-group problem solving.]

To avoid the free-rider effect, your team may decide to set the rule that group members absent the week before the graded group problem (i.e., s/he did not get to practice with her/his group) cannot take part in solving the graded group problem. Towards the end of the first semester, you could let the rest of the group members decide if the absent group member can take part in solving the graded group problem.

To encourage students to work together in lab, your team could decide that each member of the group receives bonus points if all group members earn 80% or better on their individual lab reports.

MANAGER

Understand the Problem

Problem Statement

Construct a mental image of the sequences of events described in the problem statement.

- What's going on?
- What objects are involved?
- What are they doing? Where are they relative to each other?
- What is important and what is not?

Sketch a picture that represents this mental image; include given information.

- How should we draw the spatial relations between the objects?
- How should we draw the objects in motion?
- How should we draw the sequence of events?
- What information is given?

Determine the question/ physical quantities that will solve the problem .

- What can we calculate that will answer this question?
- What physical quantities do we need to solve this problem?

Select approach(es) that you think will lead to a solution of the problem.

- What physics concepts and principles might be useful to solve this problem? What kind of problem is it?
- How might these concepts and principles be used?
- Are different approaches useful for different time intervals?
- What approximations or assumptions are needed to use our approaches?
- Do we need to add information from our general knowledge or assume information that is not provided in the problem statement?

Analyze the Problem

Analyze the Problem

Understand the Problem	**Questions and Actions**

Construct motion diagram(s) to show important space and time relationships of each object.

- What coordinate axes are useful? Which direction should we call positive?
- Relative to the coordinate axes, where is (are) the object(s) for each important time?
- Are other diagrams necessary to represent the interactions of each object or what happens to the object over time?

Construct diagram(s) to show forces on each obect (when appropriate).

- Which object should we isolate in our fee-body diagram?
- What are the forces acting on this object?
- What coordinate axes should we use for our force diagram?
- Do we need separate diagrams showing the forces acting on another object?

Make sure all symbols representing quantities shown on diagram(s) are defined.

- What quantities are needed to define the problem mathematically using our approach(es)?
- Which symbols represent known quantities? Which symbols represent unknown quantities?
- Are all quantities having different values labeled with unique symbols?
- Do the diagrams have all of the essential information from the picture?

Declare a target quantity (unknown that answers the question).

- Which of the unknowns defined on the diagram(s) answers the question?

State mathematical relationships from principles, concepts, and specific constraints.

- What equations represent the fundamental concept(s) specified in our approach using the specific symbols for the physics quantities defined in the diagram?
- During what time intervals are those relationships either true or useful?
- Are there any equations that represent special conditions that are true for some quantities in this problem?

Construct a Solution

Construct a Solution

Questions and Actions

Analyze the Problem

Chose one of the quantitative relationships that involves the target variable.

- Which of the useful equations includes the target quantity?
- For what object does that equation apply?
- For what time interval does that equation apply?

Are there additional unknowns?

No

yes

- Are there any unknowns in the equation other than the target quantity?
- Are there any unknowns that we think will cancel out in the algebra?

Choose a new equation that involves the new unknown; substitute specific variable symbols.

- Which of the useful equations that have not already been used includes an unknown quantity? If there is more than one, which one shall we use?
- For what object and time interval does that equation apply?
- If there is no equation that involves the unknown quantity, can we make a different equation choice in the previous steps?

Solve the equation for the desired unknown and substitute into the previous equation.

- Are there as many different equations used in this process as unknowns?
- What unknown is the target of this last equation?
- Let's solve this equation for the unknown.
- Which previous equations have that unknown?
- Let's substitute our expression for this unknown into all of these equations.
- Are there any quantities that cancel out in the algebra?

Solve for the target quantity and check the units of the result.

- After all the substitution for unknowns, is the only unknown left the target quantity?
- If not, where did we make our mistake?
- Are the units the same on both sides of the equation?

Calculate the Answer

RECORDER/CHECKER

Understand the Problem

Problem Statement

Construct a mental image of the sequences of events described in the problem statement.

- Do we all agree that these are the important objects and this is the sequence of events?

Sketch a picture that represents this mental image; include given information.

- Sketch the important objects and sequence of events as discussed by your group. Show it to the other group members.
- Do we agree that this picture represents the situation accurately?
- Write down the information that the group decided might be important. Put it on the picture and show it to the other group members.
- Do we all agree on the useful information?

Determine the question/ physical quantities that will solve the problem .

- Write down the question that your group decided on.
- Do we all understand the question and what quantity we need to calculate?

Select approach(es) that you think will lead to a solution of the problem.

- As the group discusses the possible approaches to the problem, write them down. Write down the approach(es) that are chosen for this problem..
- Do we all understand why we are choosing the(se) approach(es)?
- Write down all approximations or assumptions that your group believes are necessary to solve the problem. Make sure everyone agrees.

Analyze the Problem

Analyze the Problem

Understand the Problem

Construct motion diagram(s) to show important space and time relationships of each object.

- Using a coordinate system chosen by your group, draw idealized objects at positions corresponding to all the important times.
- Draw vectors representing the velocity and acceleration associated with the idealized objects at each position chosen.
- Label all quantities with different symbols if they have different values.
- Show the diagram to other group members and get agreement.

Construct diagram(s) to show forces on each obect (when appropriate).

- While your group discusses the forces, draw a free-body diagram for each important object based on the discussion.
- Using a coordinate system chosen by your group, draw a force diagram for each important object.
- Label all forces so that forces with different values have different symbols.
- Show the free-body and force diagrams to the other group members for agreement.

Make sure all symbols representing quantities shown on diagram(s) are defined.

- While your group discusses the knowns and unknowns for the problem, write down the numerical value (with units) of each known quantity based on the discussion.
- Indicate which quantities are unknown.
- Make sure everyone agrees that all useful quantities have been identified and labeled.

Declare a target quantity (unknown that answers the question).

- Write down the target quantity that your group decides on.
- Is the target quantity clearly defined on a diagram.
- Make sure everyone in your group agrees that solving for the target quantity answers the question.

State mathematical relationships from principles, concepts, and specific constraints.

- Write down the equations that your group decided might be useful to solve this problem.
- Write down equations that your group agrees represent conditions which are only true for this problem (e.g., $v_1 = v_2 = v = $ constant)
- Make sure everyone in the group understands and agrees on the meaning of all the symbols in these equations.

Construct a Solution

Construct a Solution

Analyze the Problem

Questions and Actions

Chose one of the quantitative relationships that involves the target variable.
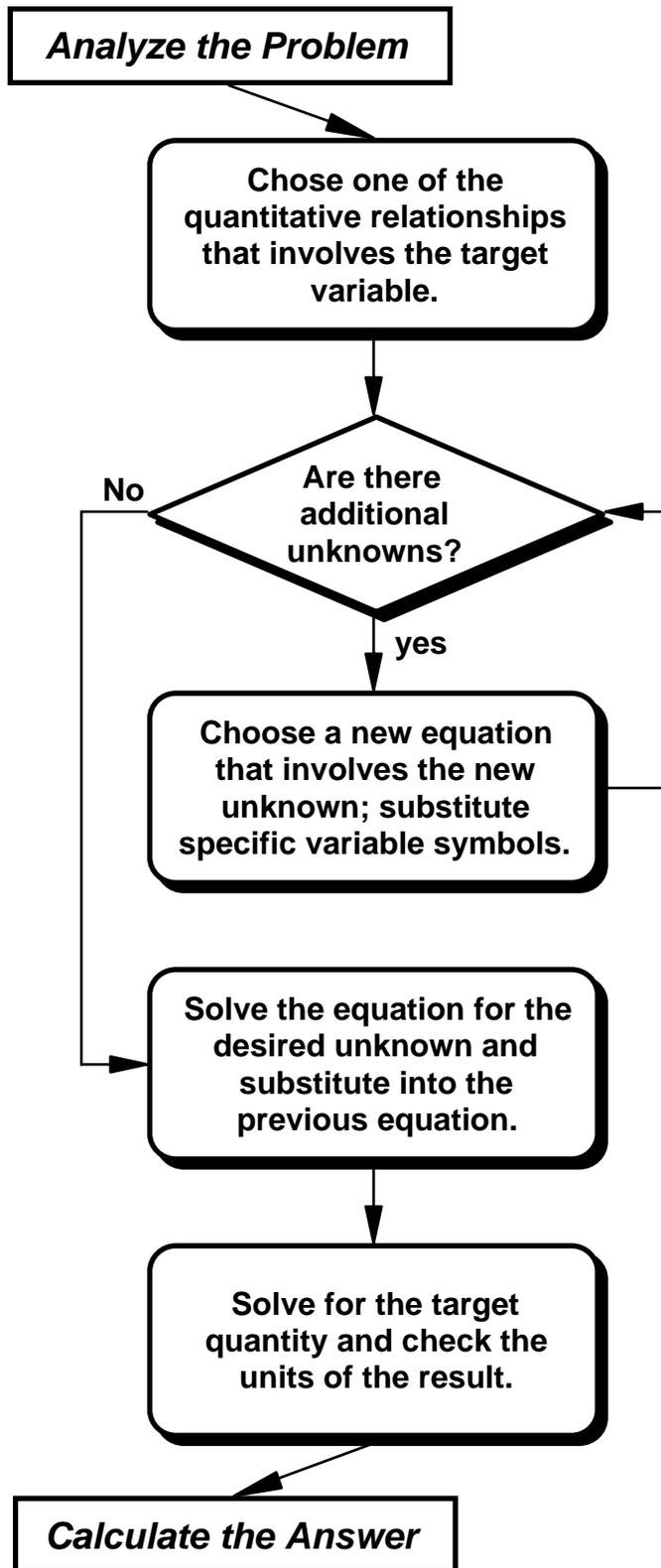
- Write down the equation that your group decides to start with. Make sure this equation includes the target quantity (as well as the object and/or time interval for which it is applicable).
- Write down how your group decides to solve for the target quantity.
- Number the equation

Are there additional unknowns?

No

yes

- Write down any additional unknowns (other than the target quantity).
- Write down any unknowns that your group thinks will cancel out in the algebra.

Choose a new equation that involves the new unknown; substitute specific variable symbols.

- Write the new equation chosen by your group that includes the next unknown quantity (as well as the object and and/or time interval for which it is applicable).
- Number the equation.
- Write down how your group decides to solve for the unknown.
- Make sure that everyone agrees on the mathematics.

Solve the equation for the desired unknown and substitute into the previous equation.

- Write down how your group decides to solve for the last unknown and substitute this unknown into previous equation(s) with this unknown.
- Make sure that everyone agrees with the mathematics.
- Check to see if any of the unknowns cancel out in the algebra.

Solve for the target quantity and check the units of the result.

- Write down how your group decides to solve for the target quantity.
- Check that the units of both sides of the equation are the same and make sure that everyone agrees.
- Make sure that everyone agrees on all the mathematical steps and on the answer.

Calculate the Answer

SKEPTIC/SUMMARIZER

Understand the Problem

Problem Statement

Construct a mental image of the sequences of events described in the problem statement.

- Where in the problem statement does it say what you claim?
- Give your group another interpretation of the problem situation and discuss why it is not as good as the one decided on.

Sketch a picture that represents this mental image; include given information.

- Have we left out any important objects? Make sure your group gives you good reasons why they are not important for this problem.
- Are there other times when the motion of the object(s) changed?
- Is there a better perspective to show the motion? How about from overhead? The front? The side?
- If one picture has been drawn, ask if it too complicated and propose a several pictures. If several pictures have been drawn, ask if one picture would be better.
- Describe to the group what you think the picture shows and see if they agree.

Determine the question/ physical quantities that will solve the problem .

- What does it say in the problem statement that leads you to that question?
- Is there any other physical quantity we could calculate that would also solve the problem and might be easier?

Select approach(es) that you think will lead to a solution of the problem.

- Do we have enough information to use this approach? Propose some information that might be missing.
- [If group decides there is information missing] Why don't we need this information? Make sure the group justifies why it is not needed.
- Can we break up the problem into simpler sub-problems?
- Make sure the group justifies every approximation or assumption made.
- Summarize the group's decision about the approach(es) and how the approach(es) lead(s) to a solution.

Analyze the Problem

Analyze the Problem

Questions and Actions

Understand the Problem	• Does our motion diagram show everything that is important in our picture? Show me.
	• Are these coordinate axes the most convenient? Propose a set that might be easier to work with
Construct motion diagram(s) to show important space and time relationships of each object.	• Are the spatial relations and/or vectors roughly to scale? If not, have the Recorder redraw them.
	•Are the velocity and acceleration vectors pointing in the right direction? Explain.
	• Ask someone to justify every force *by identifying the other object that causes that force*. Propose other forces and ask why they are not included.
	• Are the forces pointing in the right direction?
Construct diagram(s) to show forces on each obect (when appropriate).	• Are these forces roughly to scale? Have the Recorder change them if they are not.
	• Is each object's motion what is expected from the free-body diagram? Show me.
	• Are these coordinate axes the most convenient for the force diagram? Suggest a different set and discuss why they should not be used.
Make sure all symbols representing quantities shown on diagram(s) are defined.	• Are the known values clearly stated in the problem? Show me where.
	• Can the value of some of our unknowns be inferred from the information in the problem, even if not clearly stated? Show me how.?
	• Have we used the same symbol to represent different values? Have we used two different symbols to represent the same values?
Declare a target quantity (unknown that answers the question).	• Have someone explain how knowing the target quantity will answer the question.
State mathematical relationships from principles, concepts, and specific constraints.	• Ask the group how each equation follows the group's decision about the approach(es).
	• Do these equations apply only in special cases? If so, are those cases true in this problem?
	• Can we use some of these equations only in certain time intervals?
Construct a Solution	

Construct a Solution

Analyze the Problem

Questions and Actions

Chose one of the quantitative relationships that involves the target variable.

- Are there any reasons why we should not use this equation for this object at this time?
- Is there another equation from our list that also has the target quantity in it? Why not use it?

No

Are there additional unknowns?

- Did we miss any additional unknowns?

yes

Choose a new equation that involves the new unknown; substitute specific variable symbols.

- Have we used this equation already?
- Are all the quantities in this equation defined in our diagram or in our list of known and unknown quantities?
- Do all references to the same quantity use the same symbol?

Solve the equation for the desired unknown and substitute into the previous equation.

- Are we sure that we have substituted for this unknown whenever it occurs in all other equations?
- Is the mathematics correct?

Solve for the target quantity and check the units of the result.

- Has the target quantity been isolated in terms of known quantities only?
- Ask someone to justify that the units of each term is correct.

Calculate the Answer

EVERYONE

Calculate the Answer

Construct a Solution

Put in the numerical value and units for each quantity in your equation for the target variable.

- What values (numbers with units) from your list of known quantities should be put into the equation for the target quantity?

Does each additive term in the solution have the same units?

Yes

No
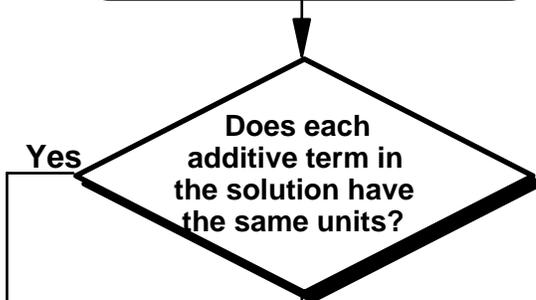
- Do we need to convert units?

Change additive terms to same units by multiplying the term to be changed by 1 expressed as ratio of units.

- What ratio of units equals 1?
$$\left(e.g., \ \frac{100 \ cm}{1 \ m} \ = 1 \right)$$

Calculate the numerical value of target quantity by combining the numbers with arithmetic and the units with algebra.

- Use a calculator for the numbers and algebra for the units.
- Do any units cancel?

Convert units as necessary to simplify the equation for the target quantity in terms of an understandable set of units.

- Do we need to convert any units?
- What is the most reasonable set of consistent units for this problem?

Answer the Question

- Does the quantity we have calculated answer the question?

Footnotes

[1]   Redish, E. F. (2003). *Teaching Physics With the Physics Suite*, NJ: John Wiley and Sons

[2]   Schoenfeld, A. H. (1985). *Mathematical problem Solving*, Academic Press.

[3]   Heller, P., Keith, R., & Anderson, S. (1992). Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. *American Journal of Physics*, 60, 627-636.

[4]   Heller, P., & Hollabaugh, M. (1992). Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups. *American Journal of Physics*, 60, 637-644.

[5]   Johnson, D. W. and Johnson, R. T. (1989). *Cooperation and Competition: Theory and Research*, Edina, MN: Interaction.

Chapter 3

Teaching a Laboratory Section

I. Cooperative Problem Solving Labs in Operation

The Cooperative Problem Solving (CPS) labs at the University of Minnesota are different from any labs you have experienced. This section describes the goals of the labs, the structure of the labs, and the structure of individual lab problems.

Goal of University of Minnesota Labs

Joe Redish (2003, page 162) describes a variety of different possible goals for a laboratory, from confirmation (demonstrating the correctness of theoretical results presented in the lecture) through inquiry (empiricism) (to help students understand the empirical basis of science) to attitude goals (to help students gain an appreciation of the role independent thought and coherence in scientific thinking). It is impossible to satisfy all of these goals with a single laboratory design. Because University of Minnesota courses follow the traditional structure of learning physics through solving problems, **the goal of the laboratory is to provide students with practice and coaching in using a logical, organized problem solving process to solve problems.** IN OTHER WORDS, THE GOAL OF THE LABS IS THE *SAME* AS THE GOAL OF THE DISCUSSION SECTION -- to help students slowly abandon their novice problem-solving strategies (e.g., plug-and-chug or pattern matching) and adopt a more logical, organized problem-solving procedure that includes the qualitative analysis of the problem. Since one reason that our students cannot solve physics problems is that they have misconceptions about the physics, a second goal is to confront some of those misconceptions in the laboratory.

Instructions for problem-solving labs are different from the instructions for other labs with different goals. A comparison of problem-solving labs with traditional confirmation 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 lecture and the text.

What Are Problem Solving Labs

The student lab manuals are divided into about 5-7 two-to-three-week topics, called *Labs*. For example, part of the Table of Contents from the lab manual for the course for scientists and engineers (Physic 1301) is shown in Figure 2 on page 59. The labs/topics for the first 9-10 weeks of the course are: Laboratory I: Description of Motion in One Dimension, Laboratory II: Description of Motion in Two Dimensions, Laboratory III: Forces, and Laboratory IV: Conservation of Energy. The manual also includes an technique and equipment appendices. For example, the appendices for Physics 1301 are:

Appendix A: Significant Figures   Appendix D: Video Analysis of Motion
Appendix B: Accuracy, Precision, and   Appendix E: Sample Laboratory Reports
        Uncertainty   Appendix F: Simulation Programs.
Appendix C: Graphing

Figure 1. Comparison of Different Types of Labs

TRADITIONAL CONFIRMATION LABS	U OF MN PROBLEM-SOLVING LABS	INDUCTIVE OR "INQUIRY" LABS
MAJOR GOAL: To illustrate, support what is being learned in the course and teach experimental techniques	**MAJOR GOAL:** To illustrate, support a logical, organized problem-solving process	**MAJOR GOAL:** 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 2. First Page of Phys 1301 Table of Contents

The Labs themselves are comprised of an introduction page and several lab problems. *Notice that we do not do experiments in our "laboratory."* Students typically use the same equipment for a Lab topic. There are more problems than can be taught in the available time. The teaching team for each course section selects 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 you the flexibility to select the problems that 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 and problem solving skills. [This also keeps these groups from becoming bored.] On the other hand, some groups will have difficulty applying their knowledge to solve the problems, and may need to concentrate on a specific difficulty by doing a second, very similar problem.

Structure of the Lab Problems

Skim the two lab problems for the calculus-based course for scientists and engineers (Physics 1301) at the end of this section: Lab I Problem #3: Motion Up and Down an Incline (page 65), and Lab III Problem #1: Forces and Motion (page69). Notice that each lab problem has eight sections (the problem, Equipment, Prediction, Warm-Up Questions, Exploration, Measurement, Analysis, and Conclusion). Students read the first four sections of the assigned lab problems (the problem, *Equipment*, Prediction, and *Warm-Up Questions*) **before** class. These sections are designed to help students solve the problem. They hand in their problem solutions one or two days before the lab session. During the lab sessions, students collect and analyze data to check their solution (that is, to see if they solved the problem correctly). The *Exploration*, *Measurement*, *Analysis and Conclusion* sections guide students through the process of checking their solution. 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 discuss and work on the next assigned problem.

Before a Lab Session

The lab problems are similar to the ones found at the end of a textbook chapter or in a discussion session. There are two different types of lab problems, as shown in Figure 3 on the next page. That is, the problem may require a **qualitative** solution (educated guess) or a **quantitative** (algebraic or calculus) solution. There are two types of qualitative problems. Students may be asked to predict a relationship and/or the shape of a graph. Lab I Problem #3 (page 65) is an example of this type of qualitative problem. For the second type of qualitative problem, students usually predict the value (or range of values) of a physical quantity, such as the coefficient of sliding friction for different surfaces.

After Lab I, qualitative problems are usually found only at the beginning of a Lab. The majority of the problems are quantitative. Lab III Problem #1 (page 69) is an example of a quantitative problem. Students solve the problem for a target quantity (e.g., velocity). The physical quantities on the right side of the prediction equation (e.g., mass of the object A, the mass of the cart, and the distance object A falls) are called the *independent* variables. To check their algebraic solution (prediction equation) during lab, students:
1. measure the target quantity   2. measure the independent variables and substitute these values into their prediction equation to calculate the target variable.

Figure 3. Types of Laboratory Problems
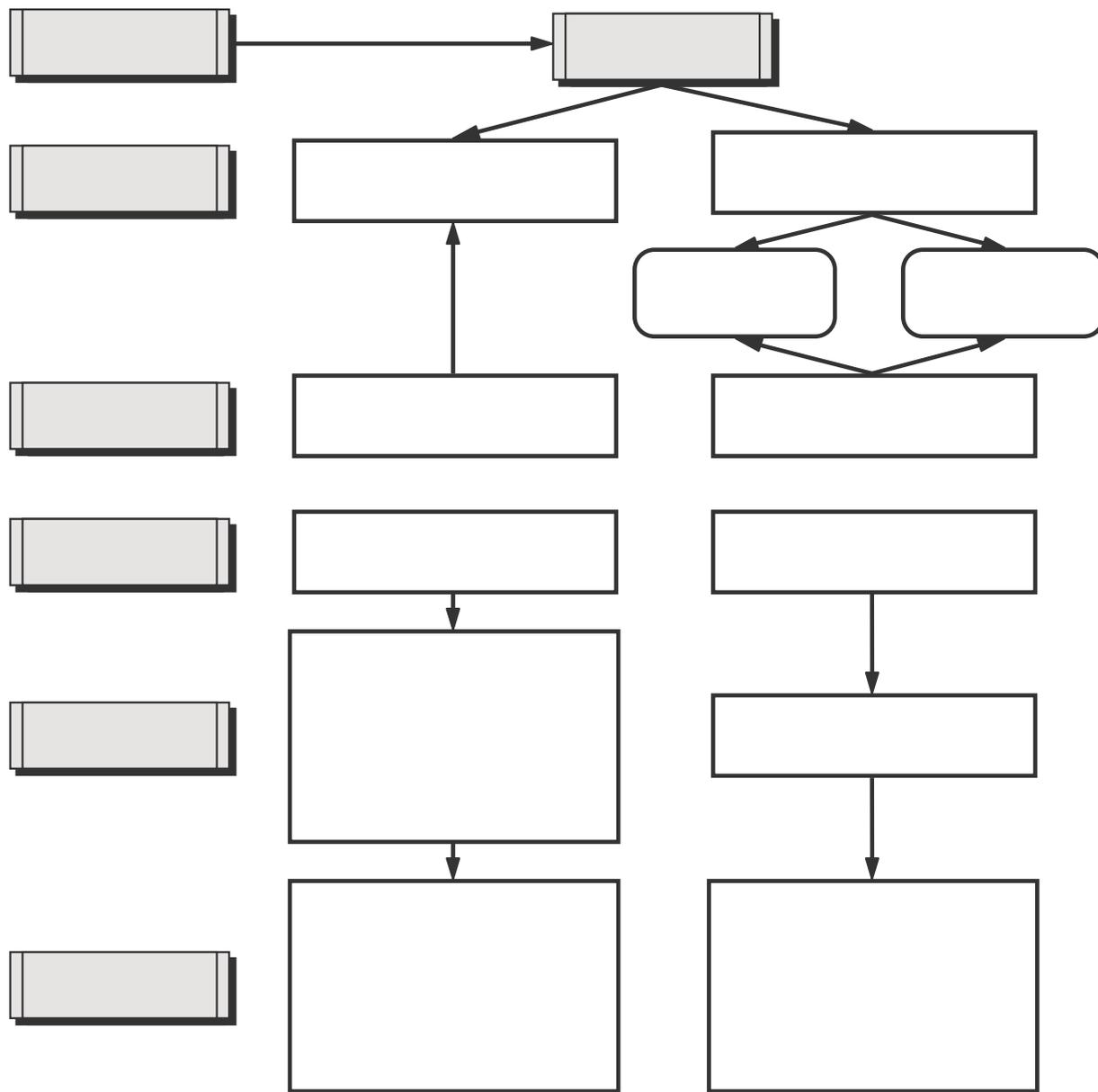
This allows students to determine if they solved the problem correctly (see Figure 3 above).

Look at the **_Warm-Up Questions_** for Lab I Problem #1 (page 65) and Lab III Problem #1 (page 70). Method questions are designed to coach students through a logical, organized problem-solving process to arrive at the problem solution. The warm-up questions are the only _individual_ "coaching" students receive for solving problems in our introductory courses. Notice that each warm-up question corresponds to a specific part of the problem-solving framework that you designed for students to use during discussion sessions.

Look at the ***Prediction*** sections for Lab I Problem #3 and Lab III Problem #1. Notice that this section restates of the problem question *in terms of the lab equipment and measurements*. In the course for scientists and engineers (Physics 1301), the prediction section changes at beginning in Lab 5 (Conservation of Momentum). At this point, students are required to restate or reformulate the problem themselves. Some examples of the *Prediction* section, starting in Lab 5, are shown below.

> Example Prediction A. "Restate the problem to identify your target and get the relationships useful for the three cases considered in the problem."
>
> Example Prediction B. "What are you trying to calculate? Restate the problem to clearly identify your objective."
>
> Example Prediction C. Reformulate the problem in your own words to understand its target. What do you need to calculate?

At his point, solving a lab problem is analogous to solving a problem in a discussion session or for homework. Good problem solving requires informed decision-making. The first decisions students must make are: What is the question? What physical quantity (target quantity) do I need to calculate to solve the problem?

The *Prediction* section comes before the *Warm-Up Questions* section so that students will understand the language of the warm-up questions. But students tend to do things in the order presented, so you will have to remind students to follow the problem-solving framework outlined in the warm-up questions to solve the problem (complete the prediction). Of course, if a student can solve the problem in a logical and organized manner, the *Warm-Up Questions* serve as a check of their problem solving process.

During a Lab Session

Unlike a confirmation or inquiry lab, the **purpose of collecting data in problem-solving labs is to allow students to check their problem solution** (answers to Warm-up Questions and Prediction**)**. Examine the *Exploration*, *Measurement*, and *Analysis* sections for Lab I Problem #3 (page 66) and Lab III Problem #1 (page 71). Notice that these sections provide students with minimal guidance -- they are not the step-by-step instructions found in confirmation laboratories. 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."

The ***Exploration*** section encourages the students to become familiar with the experimental set-up so they will understand the range over which valid measurements can be made. This is the most important section of the lab, and the one that students tend to skip. **Don't let them.** This is where students develop a "feel" for the real world that is a crucial guide in solving problems. This is also where students can qualitatively test their alternative conceptions about the physical process occurring. The outcome of the *Exploration* should be an organized plan for making the measurements.

The **Measurement** section asks the students to collect the data needed to check their problem solution. This usually involves collecting the data necessary to determine the values of a target quantity (e.g., velocity) and/or make one or more graphs. During the first semester, students use a camera and computer program called VideoRECORDER to make one or more digital movie(s) of the motion of an object. For <u>quantitative</u> problems (like Lab I Problem #3), students collect additional data -- they measure the independent variables (e.g., mass of the object A, the mass of the cart, and the distance object A falls) on the right side of their prediction equation (problem solution).

In the **Analysis** section, students analyze the data so it is in a form that will allow them to compare experimental results with their prediction. In the first semester, the computer program called VideoTOOL is used for part of the analysis. For <u>quantitative</u> problems (like Lab III Problem #1, students also use their measurements of the independent variables to calculate the value of the target quantity using their prediction equation (problem solution).

Examine the **Conclusion** sections for Lab I Problem #3 (page 68) and Lab III Problem #1 (page 72). Notice that there are usually two or three parts of the conclusion. In the first part, students compare their results with their predicted problem solution. If their results do not match their predicted problem solution, then they know that their solution was incorrect. Students are asked to explain why their solution was incorrect.

> Lab I Problem #3. How do your position-versus-time, velocity-versus-time, and acceleration-versus-time graphs compare with your answers to the warm-up questions and the prediction? …If there are any differences between your predictions and your experimental results, describe them and explain why they occurred.

> Lab III Problem #1. How does the velocity from your prediction equation in each case compare with the two *measured* velocities (measured with video analysis, and also with stopwatch / meterstick measurements)? Did your measurements agree with your initial prediction? If not, why?

For some problems, the second set of questions are designed to have students think about the solution of the original problem:

> Lab I Problem #3. Did the cart have the same acceleration throughout its motion? Did the acceleration change direction? Was the acceleration zero at the top of its motion? Describe the acceleration of the cart through its entire motion **after** the initial push. Justify your answer with kinematics arguments and experimental results.

> Lab III Problem #1. Does the launch velocity of the car depend on its mass? The mass of the block? The distance the block falls?

Finally, students answer a set of question designed to help them address common alternative conceptions:

> Lab I Problem #3. Did the cart have the same acceleration throughout its motion? Did the acceleration change direction? Was the acceleration zero at the top of its motion? Describe the acceleration of the cart through its entire motion **after** the initial push. Justify your answer with kinematics arguments and experimental results.

> Lab III Problem #1. If the same block falls through the same distance, but you change the mass of the cart, does the force the string exerts on the cart change? Is the force of

the string on object A *always* equal to the weight of object A? Is it *ever* equal to the weight of object A? Explain your reasoning.

Notice that in Lab I Problem #3, the same set of questions serves two purposes – to think about the answer to the original problem AND address common alternative conceptions.

Pre-lab Computer Quiz

For some courses, students are required to pass a pre-lab quiz before every lab session (your professor will decide whether this quiz is required). The quiz questions are designed to make sure that students have read the relevant sections of the text *before* the lab. 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 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. The minimum score required is determined in the first team meeting of the semester.

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 report file for your use. 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. See Chapter 5 for details of how to access the quiz and the quiz report.

LABORATORY I. DESCRIPTION OF MOTION IN ONE DIMENSION

Problem #3. Motion Up And Down an Incline

A proposed ride at the Valley Fair amusement park launches a roller coaster car up an inclined track. Near the top of the track, the car reverses direction and rolls backwards into the station. As a member of the safety committee, you have been asked to describe the acceleration of the car throughout the ride. (The launching mechanism has been well tested. You are only concerned with the roller coaster's trip up and back down.) To test your expectations, you decide to build a laboratory model of the ride.

EQUIPMENT

For this problem, you will have a stopwatch, a meter stick, an end stop, a wood block, a video camera and a computer with a video analysis application written in LabVIEW™ (VideoRECORDER and VideoTOOL applications). You will also have a cart to roll up an inclined track.

PREDICTION

Make a rough sketch of how you expect the acceleration vs. time graph to look for a cart with the conditions discussed in the problem. The graph should be for the entire motion of going up the track, reaching the highest point, and then coming down the track.

*Do you think the acceleration of the cart moving up an inclined track will be **greater than**, **less than**, or **the same as** the acceleration of the cart moving down the track? What is the acceleration of the cart at its highest point? Explain your reasoning.*

WARM-UP QUESTIONS

The following questions should help you examine the consequences of your prediction.

Read: Fishbane Chapter 2, Sections 2.1-2.4

1. Sketch a graph of the *instantaneous acceleration vs. time graph* you expect for the cart as it rolls up and then back down the track **after** an initial push. Sketch a second *instantaneous acceleration vs. time graph* for a cart moving up and then down the track <u>with the direction of a constant acceleration always down along the track</u> **after** an initial push. On each graph, label the instant where the cart reverses its motion near the top of the track. Explain your reasoning for each graph. Write down the

equation(s) that best represents each graph. If there are constants in your equations, what kinematic quantities do they represent? How would you determine these constants from your graphs?

2. Write down the relationship between the acceleration and the velocity of the cart. Use that relationship to construct an *instantaneous velocity vs. time graph* just below each of acceleration vs. time graph from question 1, with the same scale for each time axis. (The connection between the derivative of a function and the slope of its graph will be useful.) On each graph, label the instant where the cart reverses its motion near the top of the track. Write an equation for each graph. If there are constants in your equations, what kinematic quantities do they represent? How would you determine these constants from your graphs? Can any of the constants be determined from the constants in the equation representing the acceleration vs. time graphs?

3. Write down the relationship between the velocity and the position of the cart. Use that relationship to construct an *instantaneous position vs. time graph* just below each of your velocity vs. time graphs from question 2, with the same scale for each time axis. (The connection between the derivative of a function and the slope of its graph will be useful.) On each graph, label the instant where the cart reverses its motion near the top of the track. Write down an equation for each graph. If there are constants in your equations, what kinematic quantities do they represent? How would you determine these constants from your graphs? Can any of the constants be determined from the constants in the equations representing velocity vs. time graphs?

4. Which graph do you think best represents how position of the cart will change with time? Adjust your prediction if necessary and explain your reasoning.

EXPLORATION

What is the best way to change the angle of the inclined track in a reproducible way? How are you going to measure this angle with respect to the table? (Think about trigonometry.)

Start the cart up the track with a gentle push. **BE SURE TO CATCH THE CART BEFORE IT HITS THE END STOP ON ITS WAY DOWN!** Observe the cart as it moves up the inclined track. At the instant the cart reverses direction, what is its velocity? Its acceleration? Observe the cart as it moves down the inclined track. Do your observations agree with your prediction? If not, discuss it with your group.

Where is the best place to put the camera? Which part of the motion do you wish to capture?

Try different angles. **Be sure to catch the cart before it collides with the end stop at the bottom of the track.** If the angle is too large, the cart may not go up very far and will give you too few video frames for the measurement. If the angle is too small, it will be difficult to measure the acceleration. Take a practice video and play it back to make sure you have captured the motion you want (see the "Exploration" section in Problem 1, and appendix D, for

hints about using the camera and VideoRECORDER / VideoTOOL). *Hint: To analyze motion in only one dimension (like in the previous problem) rather than two dimensions, it could be useful to rotate the camera!*

What is the total distance through which the cart rolls? How much time does it take? These measurements will help you set up the graphs for your computer data taking, and can provide for a check on your video analysis of the cart's motion.

Write down your measurement plan.

MEASUREMENT

Follow your measurement plan to make a video of the cart moving up and then down the track at your chosen angle. Record the time duration of the cart's trip, and the distance traveled. Make sure you get enough points for each part of the motion to determine the behavior of the acceleration. *Don't forget to measure and record the angle (with estimated uncertainty).*

Work through the complete set of calibration, prediction equations, and fit equations for a single (good) video before making another video.

Make sure everyone in your group gets the chance to operate the computer.

ANALYSIS

From the time given by the stopwatch and the distance traveled by the cart, calculate its average acceleration. Estimate the uncertainty.

Look at your graphs and rewrite all of the equations in a table, but now matching the *dummy letters* with the appropriate kinematic quantities. If you have constant values, assign them the correct units, and explain their meaning.

Can you tell from your graph where the cart reaches its highest point?

From the velocity vs. time *graph,* determine if the acceleration changes as the cart goes up and then down the ramp. Use the *function* representing the velocity vs. time graph to calculate the acceleration of the cart as a function of time. Make a graph of that function. Can you tell from this *instantaneous acceleration-versus-time graph* where the cart reaches its highest point? Is the average acceleration of the cart equal to its instantaneous acceleration in this case?

Compare the acceleration function you just graphed with the average acceleration you calculated from the time on the stopwatch and the distance the cart traveled.

<div style="border: 1px solid black; padding: 20px; text-align: center;">

CONCLUSION

</div>

How do your position-versus-time, velocity-versus-time, and acceleration-versus-time graphs compare with your answers to the warm-up questions and the prediction? What are the limitations on the accuracy of your measurements and analysis?

Did the cart have the same acceleration throughout its motion? Did the acceleration change direction? Was the acceleration zero at the top of its motion? Describe the acceleration of the cart through its entire motion **after** the initial push. Justify your answer with kinematic arguments and experimental results. If there are any differences between your predictions and your experimental results, describe them and explain why they occurred.

SIMULATION
If your data did not match your expectations, you may use the simulation to explore what could have happened. A scheme for doing so is outlined at the end of Problem 2 in this lab.

LABORATORY III. FORCES

Problem #1: Force And Motion

You are a volunteer in the city's children's summer program. In one activity, the children build and race model cars along a level surface. To give each car a fair start, another volunteer builds a special launcher with a string attached to the car at one end. The string passes over a pulley and from its other end hangs a block. The car starts from rest when the block is allowed to fall. After the block hits the ground, the string no longer exerts a force on the car and it continues along the track. You decide to calculate how the launch velocity of the car depends on the mass of the car, the mass of the block, and the distance the block falls. You hope to use the calculation to impress other volunteers by predicting the winner of each race.

EQUIPMENT

Released from rest, a cart is pulled along a level track by a hanging object as shown below:
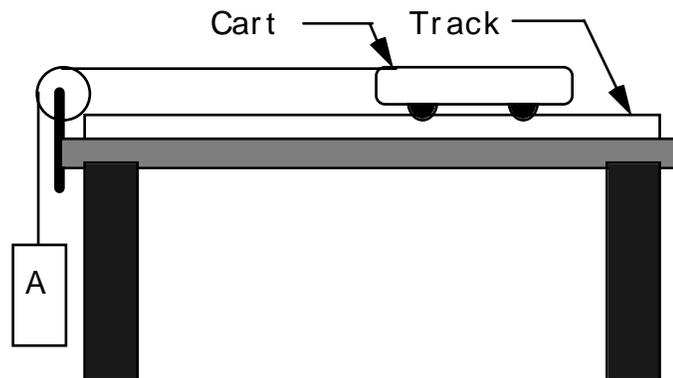
You can vary the mass of Object A and the Cart. A light string connects them. Object A falls from a height shorter than the track's length. You will have a meter stick, a stopwatch, a mass hanger, a mass set, cart masses, a pulley, a pulley clamp, a piece of string and the video analysis equipment.

PREDICTION

Calculate the cart's velocity <u>after object A has hit the floor. Express it as an equation, in terms of quantities mentioned in the problem, and draw graphs to show how the velocity changes with each variable.</u>

WARM-UP QUESTIONS

Read: Fishbane Chapter 4. Read carefully Sections 4-5 and 4-6 and Examples 4-9 and 4-12.

To figure out your prediction, it is useful to have an organized problem-solving strategy such as the one outlined in the following questions. You might also find the Problem Solving techniques in the Competent Problem Solver useful.

1. Make three sketches of the problem situation, one for each of three instants: when the cart starts from rest, just <u>before</u> object A hits the floor, and just <u>after</u> object A hits the floor. Draw vectors to show the directions and relative magnitudes of the two objects' velocities and accelerations at each instant. Draw vectors to show all of the forces on object A and the cart at each instant. Assign appropriate symbols to all of the quantities describing the motion and the forces. If two quantities have the same magnitude, use the same symbol but write down your justification for doing so. (For example, the cart and object A have the same magnitude of velocity when the string pulls the cart. Explain why.) Decide on your coordinate system and draw it.

2. The "known" quantities in this problem are the mass of object A, the mass of the cart, and the height above the floor where object A is released. Assign a symbol to each known quantity. Identify all the unknown quantities. What is the relationship between what you really want to know (the velocity of the cart after object A hits the floor) and what you can calculate (the velocity of the cart just before object A hits the floor)?

3. Identify and write the physics principles you will use to solve the problem. (Hint: forces determine the objects' accelerations, so Newton's 2nd Law may be useful. You need to relate the magnitudes of forces on different objects to one another, so Newton's 3rd Law is probably also useful. Will you need any kinematics principles?) Write down any assumptions you have made which are necessary to solve the problem and justified by the physical situation. (For example, why will it be reasonable to ignore frictional forces in this situation?)

4. Draw one free-body diagram for object A, and a separate one for the cart after they start accelerating. Check to see if any of these forces are related by Newton's 3rd Law (Third Law Pairs). Draw the acceleration vector for the object next to its free-body diagram. Next, draw two separate coordinate systems; place vectors to represent each force acting on the cart on one coordinate system, and those acting on Object A on the second one (force diagrams). [The origin (tail) of each vector should be the origin of the coordinate system.] For each force diagram, write down Newton's 2nd law along each axis of the coordinate system. Make sure all of your signs are correct in the Newton's 2nd law equations. (For example, if the acceleration of the cart is in the + direction, is the acceleration of object A + or -? Your answer will depend on how you define your coordinate system.)

5. You are interested in the final velocity of the cart, but Newton's 2nd Law only gives you an acceleration; write down any kinematics equations, which are appropriate to this situation. Is the acceleration of each object constant, or does it vary while object A falls?

6. Write down an equation, from those you have collected in steps 4 and 5 above, which relates what you want to know (the velocity of the cart just before object A hits the ground) to a quantity you either know or can find out (the acceleration of the cart and the time from the start until just before object A hits the floor). Now you have two new unknowns (acceleration and time). Choose one of these unknowns (for example, time) and write down a new equation (again from those collected in steps 4 and 5), which relates it to another quantity you either know or can find out (distance object A falls). If you have generated no additional unknowns, go back to determine the other original unknown (acceleration). Write down a new equation that relates the acceleration of the cart to other quantities you either know or can find (forces on the cart). Continue this process until you generate no new unknowns. At that time, you should have as many equations as unknowns.

7. Solve your mathematics to give the prediction.

Make a graph of the cart's velocity <u>after object A has hit the floor</u> as a function of the mass of object A, keeping constant the cart mass and the height through which object A falls.

Make a graph of the cart's velocity <u>after object A has hit the floor</u> as a function of the mass of the cart, keeping constant the mass of object A and the height through which object A falls.

Make a graph of the cart's velocity <u>after object A has hit the floor</u> as a function of the distance object A falls, keeping constant the cart mass and the mass of object A.

8. Does the shape of each graph make sense to you? Explain your reasoning.

EXPLORATION

Adjust the length of the string such that object A hits the floor well before the cart runs out of track. You will be analyzing a video of the cart *after* object A has hit the floor. Adjust the string length to give you a video that is long enough to allow you to analyze several frames of motion.

Choose a mass for the cart and find a useful range of masses for object A that allows the cart to achieve a reliably measurable velocity before object A hits the floor. Practice catching the cart <u>before</u> it hits the end stop on the track. Make sure that the assumptions for your prediction are good for the situation in which you are making the measurement. Use your prediction to determine if your choice of masses will allow you to measure the effect that you are looking for. If not, choose different masses.

Choose a mass for object A and find a useful range of masses for the cart.

Now choose a mass for object A and one for the cart and find a useful range of falling distances for object A.

Write down your measurement plan. (Hint: What do you need to measure with video analysis? Do you need video of the cart? Do you need video of object A?)

MEASUREMENT

Carry out the measurement plan you determined in the Exploration section.

Complete the entire analysis of one case before making videos and measurements of the next case. *A different group member should operate the computer for each case.*

Make sure you measure and record the masses of the cart and object A (with uncertainties). Record the height through which object A falls and the time it takes to fall (measured with the stopwatch).

ANALYSIS

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*Make sure a **different** person in your group operates the computer for each case you are analyzing.*

Determine the cart's velocity just after object A hits the floor from your video.

From the time and distance object A fell in each trial, calculate the cart's velocity just after object A hits the floor (assuming constant acceleration). Compare this value to the velocity you measured from the video. Are they consistent with each other?

What are the limitations on the accuracy of your measurements and analysis?

CONCLUSION

How does the velocity from your prediction equation in each case compare with the two *measured* velocities (measured with video analysis, and also with stopwatch / meterstick measurements)? Did your measurements agree with your initial prediction? If not, why?

Does the launch velocity of the car depend on its mass? The mass of the block? The distance the block falls?

If the same block falls through the same distance, but you change the mass of the cart, does the force the string exerts on the cart change? Is the force of the string on object A *always* equal to the weight of object A? Is it *ever* equal to the weight of object A? Explain your reasoning.

SIMULATION

Use the simulation "Lab4Sim" (See *Appendix F* for a brief explanation of how to use the simulations) to explore the effects of a very wide range of masses for the hanging object and the cart. When the hanging object is *much more massive* than the cart, does the system have the

acceleration you would expect? When the hanging object is *much less massive* than the cart, does the system have the acceleration you would expect? Explain.

If your results did not completely match your expectations, you may use the simulation to explore what might have happened. First, set the simulation to approximate the conditions of your experiment. Can you get the behavior, and the graphs of position and velocity, that you expect?

If you believe friction may have affected your results, explore its effects with the simulation. Does it affect the behavior, and the graphs of position and velocity, in the ways you expect? Explain

If you believe that your prediction was incorrect because it did not take into account the effects of the mass of the string or the mass of the pulley, explore their effects with the simulation. Do they affect the behavior, and the graphs of position and velocity, in the ways you expect? Explain.

If you believe uncertainty in position measurements may have affected your results, use the simulation to compare the results with and without error. Can you more easily see the effect in the position vs. time graph or in the velocity vs. time graph? Did you see the effects of measurement uncertainty in your VideoTOOL measurements?

NOTES:

II. Grading the Labs

*A*t 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 answers to Warm-Up Questions and Prediction for the assigned lab problem(s). The Warm-Up Questions are graded quickly as either 0 points or the maximum points (usually 3).

2. Each student is also graded once on his or her lab procedure during the 2 - 3 session of a Lab topic.

3. At the end of a Lab topic, you randomly assign *a different lab problem for each student in a group* to write a Lab Report. (You will grade only about 4 lab reports per semester.) Students should never know ahead of time which Lab problem they will write up as a report.

Each of the three grading procedures is described below.

Grading the Warm-Up Questions

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

- **The Warm-Up Questions are graded for <u>REASONABLE EFFORT</u>, 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 problem *before* the lab is for students to learn how to figure out for themselves *at what location in the problem they get stuck and why*. This metacognitive 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 warm-up questions, *and clearly indicate where they got stuck and why*.

Students receive no points (0) if they:
- did not attempt to answer the warm-up questions (even if they solved the problem); or
- answer some of the warm-up questions, *but do not indicate why they did not finish (why they got stuck)*.

Guidelines for Grading Warm-Up Questions

Before you grade students' *Warm-Up Questions*, solve the problem yourself by answering the questions. Then read the ***Instructor's Laboratory Guide***. You should have a good idea of students' alternative conceptions and what aspects of the qualitative analysis of the problem are the most important for students to learn in the lab.

1. Don't spend more than 30 - 60 seconds looking at a student's answers to the warm-up questions.

2. Look at the student's work *in general*: Are they using the correct physics concept(s) and principles? Have they made a reasonable effort to answer the questions? If they did not answer all the questions, did they explain why they got stuck?
   - It is usually quicker to look first at the questions that require students to draw a physics diagram (e.g., motion or free-body force diagram) or generate a graph,.
   - Then look at the first equations students write to apply the fundamental principles (e.g., kinematics, Newton's 2nd Laws). Look only at the first equation(s) they write down.

3. Decide on the number of points to give the student. Do not mark anything as "wrong" on the students' papers. Give "hints" if you feel information would be helpful for students, or if it might spark discussion among group members.

When you have finished the grading a section, you will have enough information to decide on the learning focus of the lab session for this section. [See VI. Preparations for Teaching a Lab Session, page 89.]

Grading Lab Procedures

Grade each students' lab procedure and journal *at least once* during the 2 – 3 sessions of a Lab topic. Observe whether:
- students spend adequate time completing the Exploration;
- a measurement plan is recorded in the journal **before** students begin making measurements;
- observations/measurements are written in the journal;
- data tables and graphs are made in the journal **as the data is collected**;
- analysis is completed before students discuss conclusions;
- conclusion includes answers to all questions AND a correct solution to the problem (if they did not answer the Warm-Up Questions correctly).

Grading the 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. To meet the Writing Intensive requirement, students must be allowed to rewrite their lab report at least once.

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 *Warm-Up 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.

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 on the next page. You fill out this form and return it to students with their graded Problem Report

GRADING CHECKLIST	Points
LABORATORY JOURNAL:	
WARM-UP QUESTIONS AND PREDICTIONS (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.

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 warm-up questions.

III. Overview of Teaching a Lab Session

*T*he usual Cooperative Problem Solving (CPS) routine, like a game of chess, has three parts -- Opening Moves, a Middle Game, and an End Game. As in chess, both the opening moves and the end game are simple, and can be planned ahead of time. The middle game – checking the problem solution -- has many possible variations.

Opening Moves (~ 20 minutes)

Opening moves determine the mind-set that students should have during the Middle Game – checking their problem solution. The purpose of the opening moves is to answer the following questions for students.

♦ What should we be learning while discussing and checking our solution?

♦ How much time will we have to check our solution?

Typically, your opening moves begin when you ask the members of each group to arrive at a consensus about one or two of the *Warm-Up Questions*. You will know which warm-up question(s) to have students discuss and put on the board from your examination of the answers your students turned in before lab (see the Grading section, page 75). Make sure to give an explicit time limit for this group discussion. The discussion of for straightforward lab problems should take no more than 5 - 10 minutes. [The discussion for the more difficult problems may take longer. See Section VI, page 91.]

At the end of the group discussion time, have one representative from each group put their group's answers to the assigned warm-up question(s) on the board. Ask each group to give their reasons for their answers. Then conduct a class discussion comparing and contrasting the answers and reasons. Remember that one purpose of the opening moves is to increase students' active engagement in the lab [see Redish, 2003, page 163]. ***The discussion need not arrive at the correct answers to the questions.*** In fact, more learning occurs in a lab session when there are unresolved disagreements. Wait to resolve the disagreement in the closing discussion, after students have completed checking their solution.

Finally, discuss *briefly* the measurements they will make to check their solution. For quantitative problems, discuss the direct measurement(s) of the target quantity as well as the measurements of the independent variables in the Prediction equation. The Instructor's Lab Manual often includes suggestions for what to discuss at this point.

Middle Game (~ 35 minutes)

The purpose of collecting and analyzing data in problem-solving labs is to allow students to check their problem solution (answers to the Warm-Up Questions and Prediction). The

Exploration, Measurement, and Analysis sections give minimal guidance (they are not the step-by-step instructions) and require the group to make several decisions).

During this time, your role is one of observer, listener and coach. You circulate around the room, observing what the groups are doing, listening to what students are saying, and observing what the groups are writing in their lab journals. Observing groups' incorrect decisions allows you to coach each group when they need it. You intervene when a group needs to be coached on an aspect of physics or the Exploration, Measurement, or Analysis procedure.

At the end of the allotted time, have a representative from each group put their group's *corrected* answers to the warm-up questions on the board (if possible, below their original answers).

End Game (~ 10 - 20 minutes)

The end game determines the mind-set students have when they leave the class -- do they think they learned something or do they think it was it a waste of their time (see Redish, 2003, page 163). The purpose of the end game is to help students answer the following questions.

- ♦ What have I learned that I didn't know before?
- ♦ What did other students learn?
- ♦ What should I concentrate on learning next?

A good end game helps students consolidate their ideas about the qualitative analysis of a problem and produces discrepancies that stimulate further thinking and learning.

Give students a few minutes to examine what other groups wrote on the board. Then lead a whole-class discussion of the results. You may decide to discuss some of the answers to the other warm-up questions. The time for this discussion depends on:
- the scheduled time of your lab session.
- whether the lab session is the first or second in a Lab topic;
- the type of lab problem (qualitative or quantitative)
- the difficulty of the problem; and
- the learning focus of the lab session (see Section VI, page 89).

We will also discuss leading lab discussions in the TA Orientation and the seminars.

IV. Outline for Teaching a CPS Lab Session

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

- ❑ assign new roles (and groups when appropriate)
- ❑ answer *Warm-Up Questions* to solve the problem
- ❑ grade students' *Warm-Up Questions*

- ❑ decide which Warm-Up Questions to have students put on board and the learning focus of the session
- ❑ review comments and suggestions in *Lab Instructor's Guide*
- ❑ check pre-lab quiz scores (if 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 answers to *Warm-Up Questions*.
	  b) selecting one person from each group to write/draw on board answers to your selected *Warm-Up 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 cooperatively.
		
		• 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 corrected Warm-Up Questions on board.
		• Check their group prediction:
		  - explore equipment
		  - 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 (as necessary). 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 Teaching a Lab

You should notice a lot of repetition of the same advice given for teaching a discussion session (page 101) because the goal of the labs and discussion sessions are the same – for students to improve their problem solving skills.

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 write their answers to the Warm-Up Questions you selected. If you have changed groups, list or project the new groups and roles. (Remember to follow the guidelines for forming groups and rotating roles (page 31).

- 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 answers to the *Warm-Up Questions*, set aside a small but necessary piece of equipment. Pass this out only after the discussion is finished. [After the students are used to the lab routine, you will not need set aside a piece of equipment.]

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

If students are working in the same groups, remind them to rotate roles.

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

a) ***Focus on what students should learn (~ 1 minute).*** Tell your students which Warm-Up Question(s) they should discuss and put on the board, and what aspect of problems solving they should learn in the lab.

b) ***Diagnose student difficulties (~ 5 minutes).*** While the students are discussing the assigned Warm-Up 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 your groups are having coming to consensus on the answers to the warm-up question(s). This is easier to do for some lab problems than others.

No matter how severe students' conceptual difficulties seem to be, **<u>DO NOT LECTURE</u>** about the physics concepts of the problem. 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. Some 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 warm-up questions before the lab. In other cases, you can treat the beginning of the lab like a discussion session (see Section VI: Preparation for Teaching a Lab Session, page 89).

c) ***Posting group answers (~ 2 minutes).*** Select one person from each group to write their group answers to the warm-up question(s) on the board.

d) ***Lead a class discussion (~ 10 minutes).*** Many students can come up with reasonable looking graphs or a correct prediction equation 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 warm-up questions on the board give you an easy way to have students discuss the physics involved in solving the problem

   (i) Give students a few minutes to read all the answers on the board. Then ask the representatives of each group to give their reasons for each of their answers. Ask questions about the similarities and differences in what's on the board. Do the differences reflect different physics, or different ways or representing the same physics?

   DO NOT TELL THE STUDENTS WHETHER THEIR ANSWERS ARE CORRECT! This would spoil the whole purpose of the labs. Tell the students that at the end of the lab, they will be asked to write on the board any corrections to their warm-up questions.

   (i) Discuss briefly the measurements they will make to check their prediction. For quantitative problems, discuss the more direct measurement(s) of the target quantity as well as the measurements of the independent variables in the prediction equation.

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 warm-up 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 17 – 20 and 23 - 25.

a) ***Diagnose initial difficulties with the Exploration.*** 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 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 what decisions they are making. 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, check their conclusions before you let them 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 your students are:
- students spend adequate time completing the Exploration;
- a measurement plan is recorded in the journal **before** students begin making measurements;
- observations/measurements are written in the journal;
- data tables and graphs are made in the journal **as the data is collected**;
- analysis is completed before students discuss conclusions;
- conclusion includes answers to all questions AND a correct solution to the problem (if they did not answer the Warm-Up Questions correctly).

If, after a few reminders, a student (or group) is not following these procedures, then tell the student(s) that they have lost their journal point(s). Losing a point *once* will prompt almost any student to improve his or her journal keeping. [Losing one point will not jeopardize a student's final lab grade for the course.]

In <u>computer labs</u>, 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 have finished grading journals. Also, pass out group-functioning forms at this time (as necessary, about every 2 - 3 weeks).

When you were an undergraduate, your laboratory instructor probably did not stop you to have a class discussion. Doing this is one of the hardest things you will have to do as a TA. You may be tempted to either 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. But students do not learn from their laboratory experiences unless they are actively engaged in figuring out what they have learned (see Redish, 2003, page 163).

In the beginning, a few students may try to keep working. If it is necessary, you can make obstinate 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 Warm-Up Questions.*** Tell one person in each group to write their corrected answers to the warm-up questions on the board.

End Game (~ 10 - 20 minutes)

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

The whole-class discussion is always based on the groups, with individuals only acting as representatives of a group. This avoids putting one student "on the spot." The trick is to conduct a discussion about a specific aspect of problem solving without (a) **telling** the students the "right" answers or becoming the final "authority" for the right answers, and (b) without focusing on the "wrong" results of one group and making them feel stupid or resentful. To avoid these pitfalls, start with general, open-ended questions.

♦ What is similar about the position versus time graphs?
♦ Which part represents the cart slowing down? How can you tell that the cart is slowing down?

In the beginning of a course, students naturally do not want to answer questions. They unconsciously play the *waiting game:* "If we wait long enough, the instructors will answer his/her own question and we won't have to think." Try counting silently up to at least 30 after you have asked a question. Usually students get so uncomfortable with the silence that

somebody speaks out. If not, call on a group by number and role: "Group 2 Skeptic, what do you think?"

After the general questions, you can become more specific. Of course, the specific question you ask will depend on what your groups write/draw on the board. For the rolling up and down an incline:

♦ What function represents how the position changes with time while the cart is slowing down?

♦ How can you estimate the constants in this function from the graph?

Remember to count silently up to 30, then call on a group if necessary. Always encourage an individual to get help from other group members if he or she is "stuck."

Encourage groups to talk to each other by redirecting the discussion back to the groups. For example, when a group reports their answer to a question, ask the rest of the class to comment: "What do the rest of you think about that?" This helps avoid the problem of you becoming the final "authority" for the right answer.

Step ⑦. Group Processing (as necessary, ~ 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 pages 42-43). Randomly call on one member of from each group to report their group answer to the following questions:

♦ What is one difficulty your group encountered working together?

♦ What specific action did your group decide would help you work together 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 in some groups, one person is doing most of the work. 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(s) to solve for next week.** You will decide what lab problems all students should solve in your team meetings.

b) ***Assign students problems to write up (if last session of Lab/topic).*** Each student will write a lab report for one problem from each Lab/topic. If there is one student in a group who was not participating as well as you would like in a particular problem, you might consider assigning that problem to the student. This way either the group will help the student catch up with the important information, or the student will learn to participate in the future. [A lower grade on one written lab report will not jeopardize a student's lab grade for the course.]

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 (e.g. which equipment did not work). The sheet is on the wall near the door.

VI. Preparation for Teaching a Lab Session

*T*he overall goal of the CPS labs is to help students slowly abandon their novice problem-solving strategies (e.g., plug-and-chug or pattern matching) and adopt a more logical, organized problem-solving procedure that includes the qualitative analysis of the problem. The *Warm-Up Questions* (WUQs) are designed to "coach" students through the qualitative analysis of the lab problem. *The learning focus of a particular lab session will **always** be on some aspect of the analysis of the problem and/or the application of the fundamental principles.*

The learning focus of a lab session is established and carried out in your opening moves and end game (see Section III, page 75). So before you teach a lab session, there are several (at least six) decisions you need to make.

Opening Moves

1. Which WUQs should I have the groups answer on the board?

2. Do groups need extra time to solve the problem before they begin to check their solution?

3. If so, then how much extra time do groups need and what do I tell my groups to do during this time?

4. What should I discuss/tell students, before they start, about the equipment and measurements for checking their solution?

End Game

5. Besides the discussion of the corrected WUQs, should we spend extra time discussing how to solve the problem?

6. If so, then how much extra time should we spend and what should we discuss (what questions should I ask)?

You can plan the opening moves and the end game for a lab session when you have finished grading the *Warm-Up Questions* for the section and read the *Lab Instructor's Guide* for the lab problem. Guidelines for planning are given below. An outline of the planning procedure is on page 95. [Note: This planning procedure is repeated a second time if you teach two lab sessions. For example, if you teach one lab session Monday afternoon and a second lab session Thursday afternoon, your plan for the two lab sessions may be very different.]

I. Background Questions to Answer

Your decisions about how to focus a lab session on problem solving are based on your answers to seven background questions.

❶ When is session scheduled?	❷ Which session is it in the Lab topic sequence?	❸ What is the lab problem type?	❹ How difficult is the lab problem?
☐ Early in Week ☐ Later in Week	☐ 1st Lab Session ☐ 2nd or 3rd Lab session	☐ Qualitative ☐ Quantitative	☐ Easy/Medium ☐ Difficult

❺ Which of the WUQs did your students have the most difficulty answering? Common alternative conceptions? Which ones?	Warm-Up Questions: _____
❻ Count the number of students who were able to solve the problem (even if the solution was incorrect). Is this the majority of the students?	____ students solved the problem out of ____.
❼ Look at the students' final solution (Prediction). How many students got the right answer for the wrong reasons? That is, how many students arrived at a correct (or almost correct) prediction, but had several alternative conceptions in their answers to the WUQs.	____ students got the right (or close to right) answer for the wrong reasons.

You will probably find that the *majority* of your students get the right answer for the wrong reasons. There are several explanations for this:

- Many students persist in their plug-and-chug or pattern-matching strategies for solving problems. They will solve the problem first using these novice strategies, and then try to answer the *Warm-Up Questions*.

- Sometimes the students' textbook has an example solution to a similar problem (or even the same problem). Some students can arrive at a correct prediction from pattern-matching these example solutions, with very little understanding of the physics concepts or principles.

- For some students, you may notice that the correct prediction seems to appear from nowhere – with very few answers to the WUQs. In this case, the student may have gotten the answer (graph/function or algebraic solution) from a friend who did the lab earlier in the week or took the course last year.

II. Decisions About How to Focus a Lab Session on Problem Solving

The following decisions are based on your answers to Questions ❶ – ❼ above.

Opening Moves

1. Which Warm-Up Questions should I assign groups to answer on the board?

Your answer to background question ❺ will tell you which WUQs to have your groups answer on the board -- the parts of the qualitative analysis of the problem that were the most difficult for your students.

- Qualitative Problem. Usually a few graphs and/or a function.
- Quantitative Problem. Usually the physics diagram(s) [e.g., motion diagram(s) and/or free-body force diagram(s)].

2. **Do groups need extra time to solve the problem before they start checking their solution?**

Base your decision (YES or NO) on your answer to background question ❻, taking into consideration your answers to questions ❶ through ❹. Here are four examples of how these factors can influence your decision.

Example 1: NO. The problem is an easy/medium difficulty quantitative problem, but in 3ʳᵈ session of the Lab session. The majority of your students were able to arrive at a prediction (although many were incorrect).

Example 2: NO. The problem is an easy/medium difficulty qualitative problem, and is the first in the sequence of a new Lab topic. The *majority* of your students did not get very far in the warm-up questions, and did not arrive at a prediction. On the other hand, the lab problem is a very good conceptual introduction to the topic. You decide that having students discover the answers to the WUQs and prediction in lab is a better learning experience than you coaching them through the answers.

Example 3: YES. The problem is a difficult quantitative problem, and is the first in the sequence of new Lab topic (e.g., Forces in Motion). The students have had only a few lectures on the topic, and have done no homework problems or had any practice solving this type of problem in a discussion session. So the *majority* of your students did very far in the qualitative analysis of the problem, and most did not arrive at a prediction equation. Without a prediction equation (even a wrong one), they cannot check their solution in lab.

Example 4: YES. The problem is a difficult quantitative problem, and is in the 2ⁿᵈ session in the Lab topic sequence. The *majority* of your students did not get very far in the qualitative analysis of the problem, and most did not arrive at a prediction equation. Without a prediction equation (even a wrong one), they cannot check their solution in lab.

3. **If YES, then how much extra time do groups need and what do I tell my groups to do during this time?**

Use your answers to background questions ❶ – ❹ to help you decide how much extra time and how much structure your students will need. Two examples are given below.

Example 1. The problem is a difficult quantitative problem, and is in the 2nd session of the Lab sequence. Your lab session is on Wednesday afternoon. You decide that your students should have sufficient physics background (collectively, as a group) to solve the problem. You decide to give students enough time to solve the problem in groups, like in discussion sessions. You plan to tell your students:

a) They can NOT start checking their solution until they have solved the problem.

b) They should follow the problem-solving framework outlined in the *Warm-Up Questions* to solve the problem as a team, just like they do in discussion sessions; and

c) When they think they have a problem solution, you will randomly check group member's solution (written in journal). If the solution is adequate (not necessarily correct), they can start checking their solution.

Note: An alternative to this last step is to have one student from each group put on the board physics diagram(s) and a list of the equations they used to solve the problem. Then lead a whole-class discussion.

<u>Example 2</u>. The problem is a difficult quantitative problem, and is in the 1st session of a new Lab topic. Your lab session is early in the week. You decide that your students do **not** have sufficient physics background (collectively, as a group) to solve the problem. You decide that you will need to spend a lot of time doing a combination of combination of modeling and coaching *of the whole class*. [Remember, students should have read the textbook before the lab! You can NOT start from ground zero.]

a) Have the groups work on the first warm-up question (or first few warm-up questions). Randomly call one student from each group to write/draw their answers on the board.

Discuss similarities and differences. You may need to show students how to do something (model). For example, you may need to model how to draw vector components on their motion diagrams, or how to determine what forces are acting on an object, how to label the forces, how to draw a free-body diagram, the meaning of Newton's 2nd Law, how to draw an energy diagram, and so on.

b) Repeat Step a) for the next Warm-Up Question (or next few warm-up questions). Call on different students in each group to put answers on board. Discuss and model-coach as necessary.

c) Keep repeating this procedure until the students have arrived at an answer.

4. What should I discuss/tell students about checking their solution before they start?

The *Lab Instructor's Guide* and your own experience with the lab equipment (TA Orientation and TA seminars) will help you decide what to discuss/tell your students about the equipment, measurements and analysis for checking their solution.

End Game

5. Besides the groups' corrected answers to the assigned WUQs, do we need to spend more time discussing how to solve this problem?

Base your decision (YES or NO) on your answer to background question ❼ *and* your Decisions 2 and 3.

YES. About one-half or more of your students arrived at the correct (or close to the correct) solution *for the wrong reasons* AND you did not spend time coaching students on how to solve the problem in the Opening Moves.

NO. Either the majority of your students had only a few difficulties answering the WUQs OR you spent extra time coaching the students on how to solve the problem in the opening moves.

6. **If YES, then how much time and how should I structure this extra time?**

There are different ways to structure this discussion. One suggestion is given below.

After you have discussed the warm-up questions on the board, have a different student from each group put their answers to the next Warm-Up Question (or few warm-up questions) on the board. Discuss the similarities and differences in the answers. Hopefully, students recognize the best answers. If not, you may need to model (show) students an easy or efficient way to answer one of the WUQs. **Stop short of solving the problem**. Get far enough so students recognize what they did wrong in their initial solution.

NOTES:

Lab Preparation

Name _____   Date: _____.

Lab Problem: _____   Section _____

I. Solve the problem yourself by answering the warm-up questions. Then read the **Lab Instructor's Manual**. Finally, grade the Warm-Up Questions for this section.

II. Answer the following background questions.

❶ When is session scheduled?	❷ Which session is it in the Lab topic sequence?	❸ What is the lab problem type?	❹ How difficult is the lab problem?
☐ Early in Week ☐ Later in Week	☐ 1st Lab Session ☐ 2nd or 3rd Lab session	☐ Qualitative ☐ Quantitative	☐ Easy/Medium ☐ Difficult

❺ Which of the WUQs did your students have the most difficulty answering? Common alternative conceptions? Which ones?	Warm-Up Questions: _____
❻ Count the number of students who were able to solve the problem (even if the solution was incorrect). Is this the majority of the students?	_____ students solved the problem out of _____.
❼ Look at the students' final solution (Prediction). How many students got the right answer for the wrong reasons?	_____ students got the right (or close to right) answer for the wrong reasons.

III. Based on the answers to these questions, make the following decisions about opening moves and the end game for the lab session.

Opening Moves		
1. Which WUQs should I assign groups answer on board?	Use answer to Question ❺:	Warm-Up Questions: _____
2. Do groups need extra time to solve the problem before they start collecting data?	Use answer to Question ❻, taking into account Questions ❶ to ❹	☐ YES ☐ NO because:
3. If YES, then how much time extra time and how should I structure this extra time?	Use answers to Questions ❶ to ❹	Plan:
4. What do I need to discuss/tell students about how to check their solution before they start?	Use information in *Lab Instructor's Guide* and your own experience	Discuss:

End Game		
5. (Besides corrected answers to assigned WUQs), do we need to spend extra time discussing how to solve the problem?	Use answer to Question ❼ and your previous decisions 2 & 3	☐ YES ☐ NO because:
6. If YES, then how much time and how should I structure this extra time?		Plan:

IV. List some possible questions to ask groups during whole-class discussion (opening moves and/or end game) that you think would promote a discussion.

a.
b.
c.
d.
e.
f.
g.

Chapter 4

Teaching a Discussion Section

I. Overview of Teaching a Discussion Session

The usual Cooperative Problem Solving (CPS) routine, like a game of chess, has three parts -- Opening Moves, a Middle Game, and an End Game. As in chess, both the opening moves and the end game are simple, and can be planned in detail. The middle game - collaborative problem solving -- has many possible variations.

Opening Moves (~5 minutes). Opening moves determine the mind-set that students should have during the Middle Game -- the collaborative solving of a problem. The purpose of the opening moves is to answer the following questions for students.

♦ Why has this particular problem been chosen?

♦ What should we be practicing and learning while solving this problem?

♦ How much time will we have?

♦ What is the product we should have at the end of this time?

Educational research indicates that providing students this simple information before they start leads to better learning and higher achievement. Here is an example of an opening move for the Skateboard problem, shown in Figure1 on the next page.

"We have been studying two conservation principles in class -- the conservation of energy and the conservation of momentum. The problem you will solve today was selected to help you learn how to decide *when and how to apply these principles.*

You will have 30 minutes to work on the problem. At the end of that time, you will be asked to draw on the board your diagrams and write a numbered list of the equations you used to solve the problem."

Middle Game (~30 - 35 minutes). This is the learning activity -- students work collaboratively to solve the problem. During this time, your role is one of listener and coach. You circulate around the room, listening to what students in each group are saying and observing what the Recorder/Checker is writing. You intervene when a group needs to be coached on an aspect of physics (see Chapter 2, page 13).

At the end of the allotted time, you have your groups draw and write on the board the parts of the solution that you specified in your opening moves.

In most CPS sessions (except for a group test problem), students may not have time to complete the problem solution before you stop them to conduct the whole-class discussion. This makes some students anxious or uncomfortable, and it is very difficult to get groups to stop solving the problem. Because the class discussion cannot go over the entire problem solution, many students need reassurance that their solution is correct (or at least on the right track). Anxiety is relieved when they know they will get a complete solution when they leave class, and it is then easier to stop the groups and have them participate in the whole-class discussion.

Figure 1. The Skateboard Problem

You are helping your friend prepare a skateboard exhibition. The idea is for your friend to take a running start and then jump onto a heavy duty 15-lb stationary skateboard. Your friend, on the skateboard, will glide in a straight line along a short, level section of track, then up a sloped concrete wall. The goal is to reach a height of at least 6 feet above the starting point before rolling back down the slope. The fastest your friend can run and safely jump on the skateboard is 20 feet/second. Can this program work as planned? Your friend weighs in at 125 lbs.

End Game (~10 - 15 minutes). The end game determines the mind-set students have when they leave the class -- do they think they learned something or do they think it was it a waste of their time. The purpose of the end game is to help students answer the following questions.

- ♦ What have I learned that I didn't know before?
- ♦ What did other students learn?
- ♦ What should I concentrate on learning next?

That is, a good end game helps students consolidate their ideas and produces discrepancies that stimulate further thinking and learning. Typically, the instructor gives students a few minutes to examine what each group produced, then leads a whole-class discussion of the results. Your role as the instructor is to *facilitate* the discussion, making sure students are actively engaged in consolidating their ideas. Here is a short example of a few end-game questions for the Skateboard problem.

“Look at the momentum vector diagrams on the board. How are they the same and how are they different?

Is there different physics represented in the momentum diagrams, or the same physics?

Look at the momentum diagrams for group #1 and #5. What is missing in these diagrams?

Does the order – x direction first or y direction first – make any difference to the final solution?”

At the end of this discussion, you may need to model some parts of a solution – like how to draw a good physics diagram (motion, force, energy, or momentum), how to apply Newton's Laws to the problem, how construct a solution that helps you keep track of the unknowns, and so on. [See page 105 for some tools that will help you model and coach these aspects of a logical, organized problem solving procedure.

II. Outline for Teaching a CPS Discussion Session

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

Preparation Checklist

❑ New Group/Role assignments (if necessary, written on board)

❑ Photocopies of Problem & Useful Information *(one per person)* OR Problem and list of useful information to put on board

❑ Photocopies of Answer Sheet (or later, blank sheets of paper) *(one per group)*

❑ Photocopies of problem solution *(one per person)*

❑ Group Evaluation forms *(optional one per group)* and extra photocopies of Problem Solving Roles sheets

	Instructor Actions	What the Students Do
Opening Moves ~3-5 min.	⓪ Be at the classroom early ① Introduce the problem by telling students: 　a) what they should learn from solving problem; 　b) the part of the solution you want groups to put on board ② Prepare students for group work by: 　a) showing group/role assignments (and classroom seating map if necessary); 　b) passing out Problem, (& Useful Information) and Answer Sheet.	• Students sitting and listening • Students move into their groups, and begin to read problem. • Checker/Recorder puts names on answer sheet.
Middle Game ~35 min.	③ Coach groups in problem solving by: 　a) monitoring (diagnosing) progress of all groups 　b) helping groups with the most need. ④ Prepare students for class discussion by: 　a) giving students a "five-minute warning" 　b) selecting one person from each group to put specified part of solution on the board. 　c) passing out Group Evaluation Sheet (as necessary)	• Solve the problem: 　- participate in group discussion, 　- work cooperatively, 　- check each other's ideas. • Finish work on problem (many will not finish the solution). • Write part of solution on board • Discuss their group effectiveness
End Game ~10 min.	⑤ Lead a class discussion focusing on what you wanted students to learn from solving the problem ⑥ Discuss group functioning (as necessary) ⑦ Pass out the problem solution as students walk out the door.	• Participate in class discussion

III. Detailed Advice About Teaching a Discussion Section

Y ou should notice a lot of repetition of the same advise given for teaching a lab session (page 83) because the goals of the discussion sessions and labs are the same – practice and coaching in a logical, organized problem solving process.

Opening Moves

Step ⓪. Be at the Classroom Early

The classroom will probably need some preparation, so it is best to go in and lock the door, leaving your early students outside. [The best time for informal talks with students is **after** the class or during your office hours.]

Early in the course, arrange the chairs for group work (see page 38). Then write on the board:

    (a) group assignments (if new) and roles;

    (b) the part of the solution you want groups to write on the board (see example below);

    (c) early in course, a seating map for the groups.

Step ①. State the Purpose of This CPS Session *(~ 2 minutes)*

Introduce the problem by telling students:

a) **What They Should Learn.** Tell your students why the group problem was selected and *what they should learn from solving the problem*. For example: "For the past few weeks we have been studying the conservation of energy and the conservation of momentum. The problem you will solve in your groups today was designed to help you think about the difference between the two conservation laws and when to apply a conservation law."

b) **The Part of the Solution You Want Groups to Put on the Board.** For example, For example, for the Skateboard problem: "After about 30 minutes, I will randomly select one person from each group to write two things on the board, first your conservation diagram(s) with defined symbols; and second a list of the specific equations that you need to solve the problem. [It is helpful to write this on a board, as shown below] Then we will discuss the features of a good diagrams that are useful for solving problems."

> 1. Conservation Diagram(s) & Defined Symbols.
>
> 2. List of specific equations needed to solve the problem

DO NOT have students write their mathematics solutions on the board. You can tell by a list of equations whether the students have the right equations to solve the problem. Students will see the detailed mathematics solution when you hand out the solution at the end of class.

Step ②. *Prepare Students for Group Work* *(~ 1 minute)*

a) ***Group Role Assignments.*** If students are working in the same groups, remind them to rotate roles. If you have assigned new groups, show students their group assignments and roles. Then tell your students to move the chairs for their group.

b) ***Pass Out Materials.*** While the students are getting into their groups, *pass out the Problem/information Sheet **and** Answer Sheet (or blank pages)* to each group. As you do this, make sure all groups are seated according to your map -- facing each other, close together but with enough space between groups for you to easily observe and circulate between groups.

If you do not have equations on the problem sheet, write the equations on the board. **NEVER LET STUDENTS USE THEIR TEXTBOOKS.**

Middle Game (~ 30-35 minutes)

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

Step ③. *Coach Groups in Problem Solving* *(~ 25-35 minutes)*

Below is a brief outline of coaching groups. For detailed suggestions for coaching and intervening techniques, see pages 13 - 27.

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 drawing conservation diagrams. Be sure to draw and label a diagram. . . .").

b) ***Monitor groups and intervene to coach when necessary.*** Establish a circulation pattern around the room. Stop and observe each group to see how easily they are solving the problem and how well they are working together. 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.

Step ④. Prepare Students for Class Discussion *(~ 5 minutes)*

a) **Five-minute Warning.** About five minutes before you want students to stop, warn the class that they have only five minutes to wind up their solution. Then circulate around the class once more to determine the progress of the groups. Make a mental note of what you need to discuss with the class.

b) **Posting Partial Group Solution.** Tell one person in each group, who is *not* the Recorder/Checker, to write the (previously specified) part of their solution on the board (or butcher paper if there is not enough board space). In the beginning of the course, select students who are obviously interested and articulate. Later in the course, it is sometimes effective to occasionally select a student who has not participated in their group as much as you would like. This reinforces the fact that *all* group members need to know and be able to explain what their group did.

c) **Pass out Group Functioning Evaluation form (as necessary).** If you decided to have your groups evaluate their effectiveness, pass out the forms (one per group) and have groups complete the form.

End Game (~ 10 - 15 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. We will discuss leading a class discussion in TA Orientation and in the seminars throughout the year.

The end-game discussion focuses on what you told students they would learn from solving this problem. After group pictures, diagram, and/or equation lists are posted (on board, whiteboards, butcher paper) for all to see, give students a few minutes to compare the results from each group. Then lead the class discussion

Step ⑤. Lead a Class Discussion *(~ 10 minutes)*

The whole-class discussion is always based on the groups, with individuals only acting as representatives of a group. This avoids putting one student "on the spot." The trick is to conduct a discussion about the problem solution without (a) **telling** the students the "right" answers or becoming the final "authority" for the right answers, and (b) without focusing on the "wrong" results of one group and making them feel stupid or resentful. To avoid these pitfalls, you could try starting with general, open-ended questions. Examples of some questions for the Skateboard problem are:

♦ How are the representations of the conservation of energy and conservation of momentum similar? [Need to consider initial and final states of the system, and whether there is a transfer into or out of the system]

♦ How are the representations different? [momentum is a vector; energy is not.]

In the beginning of a course, students naturally do not want to answer questions. They unconsciously play the *waiting game* -- "If we wait long enough, the instructors will answer

his/her own question and we won't have to think." Try counting silently up to at least 30 after you have asked a question. Usually students get so uncomfortable with the silence that somebody speaks out. If not, call on a group by number and role: "Group 3 Manager, what do you think?"

After the general questions, you can become more specific. Of course, the specific question you ask will depend on what you observed while groups were solving the problem and what your groups write on the board. For the skateboard problem, some example questions might include:

♦ How are the representations of the conservation of energy and conservation of momentum similar? [Need to consider initial and final states of the system, and whether there is a transfer into or out of the system]

♦ How are the representations different? [momentum is a vector; energy is not.]

Remember to count silently up to 30, then call on a group if necessary. Always encourage an individual to get help from other group members if he or she is "stuck."

Encourage groups to talk to each other by redirecting the discussion back to the groups. For example, when a group reports their answer to a question, ask the rest of the class to comment: "What do the rest of you think about that?" This helps avoid the problem of you becoming the final "authority" for the right answer.

Step ⑥. Discuss group functioning (as necessary, ~ 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. 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 ⑦. Pass out the solution.

Passing out the solution is important to the students. They need to see good examples of solutions to improve their own problem solving skills. Again, it is important to pass them out as the last thing you do -- as students leave the room. If you pass them out earlier, your students will ignore anything that you say after you have passed them out.

IV. Preparation for Teaching a Discussion Session

*T*he overall goal of the CPS discussion section is to help students slowly abandon their novice problem-solving strategies (e.g., plug-and-chug or pattern matching) and adopt a more logical, organized problem-solving procedure that includes the qualitative analysis of the problem. *The learning focus of a particular lab session will **always** be on some aspect of the analysis of the problem and/or the application of the fundamental principles.*

The learning focus of a discussion session is established and carried out in your opening moves and end game (see Section I, page 97). So before you teach a discussion session, there are two decisions you need to make.

Opening Moves

1. What will I tell my students the learning focus is? Which part(s) of the problem solution will I tell groups to draw/write on the board during the end game?

End Game

2. How much time should I set aside for the end game?

The following is a guideline for making these decisions.

Step 1. Browse through the *Competent Problem Solver* for examples of (a) how to draw the physics diagram for the group problem (e.g., motion, free-body, energy, and/or momentum diagram), (b) how to apply fundamental concepts and principles to solve problems, and (c) how to keeping track of the unknowns while constructing a solution.

Step 2.   Solve the group problem in the way you would like students to solve the problem, so you know what to look for while coaching your students. Use the notation that is in the students' textbook. [If kinematics is involved, try to use only three kinematics equations in your problem solution. See the next section, Useful Information.]

Step 3. Decide the **learning focus** for the discussion session. What part(s) of the problem solution do you want groups to draw/write on the board?

One factor that influences your choice of learning focus is the timing.

- Has a new fundamental principle been introduced (e.g., Newton's Laws, Conservation of Energy)?

- Have new concepts been introduced? NO (e.g., students in last week of projectile motion) or YES (e.g., students just starting circular motion).

You should know this information from your team meeting and from teaching the lab session earlier in the week.

Decision Table

Timing	Rule of Thumb for Learning Focus What to Tell Groups to Draw/Write on The Board
New fundamental principle just introduced (e.g., forces, conservation of energy)	Learning focus is on how to draw **new** physics diagram(s) (where most alternative conceptions show up)
New concept has been introduced (e.g., independence of motion in the horizontal and vertical directions.	Learning focus is on how to incorporate the new concept in physics diagram(s), but you can often have students list equations as well.
No new concept has been introduced (or new concept is easy)	Learning focus is usually on the list of equations students need to solve the problem (indicates difficulties students continue to have in applying a principle and concepts)

Another factor that influences your choice of learning focus is the difficulties students had with solving the last lab problem. What aspect of solving problems with this principle and associated concepts are still difficult for your students? The Decision Table above gives only a general rule of thumb for deciding what part of the solution to have groups draw/write on the board.

Step 4. The two factors above (timing and your knowledge of the difficulties students are having solving problems) also influence your decision of how much time to spend on the end game, as well as your coaching of your groups while they solve the problem.

The one thing you can count on is that when a new fundamental principle or difficult concept has just been introduced, the discussion of your group's partial solution will take longer. At the end of the discussion, you may need to show students how to do something (model). For example, you may need to model how to draw vector components on their motion diagrams, or how to determine what forces are acting on an object, how to label the forces, how to draw a free-body diagram, the meaning of Newton's 2nd Law, how to draw an energy diagram, and so on.

V. Some Other Teaching Tools

You have several teaching tools available for CPS discussion sessions, including the Problem Solving Framework and Answer sheets, the *Group Roles* (page 16), and the *Problem Framework Roles* (page 46).

Three additional tools, which will make your teaching role easier and more rewarding, are discussed in this section: list of useful information, the *Competent Problem Solver*, and a Table of Interactions and Forces.

List of Useful Information

Many students believe that solving a physics problem requires them to know the right equation for that particular problem. So part of their plug-and-chug and pattern-matching strategies is the memorization of *all* the equations in each chapter of their textbook. These equations are of equal importance to students. They do not distinguish the mathematical formulations of fundamental principles (e.g., Newton's Laws, conservation of energy and momentum) from equations that are applicable only in specific circumstances or for specific types of interactions (e.g., equations for the gravitational interaction, spring interaction, friction). Worse yet, the equations memorized for one chapter are promptly forgotten while memorizing the formulas for the next chapter.

The use of a list of useful equations (written with the problem statement or on the board) is an example of applying the 3rd Law of Instruction -- Make it *easier* for students to do what you want them to do than to do what you don't want. In this case, you don't want students to spend time searching a textbook (or their memory) for appropriate equations or a matching example problem, so you supply them with the information they need to solve the problem. Then groups **must** spend their time discussing what the equations mean and how the concepts and principles should be applied to solve the problem.

There are three features of a list of useful equations that can help promote student development of a coherent knowledge base and reinforce logical analysis of a problem using fundamental concepts and principles.

1. Separate the *Fundamental Concepts and Principles* from the concepts that apply *Under Certain Conditions*, as shown in the list on the next page.

2. Have the list of useful equations grow with time. For example, the list on the next page is near the end of the first semester.

3. Supply *only* the equations that state the fundamental principles that are stressed in the course. Students are not allowed to use any other equations to solve a problem.

List of Useful Equations

Fundamental Concepts and Principles:

$$v_{x \ av} = \frac{\Delta x}{\Delta t} \qquad s_{ave} = \frac{dist}{\Delta t} \qquad a_{x \ av} = \frac{\Delta v_x}{\Delta t} \qquad E_f - E_i = \Delta E_{transfer} \qquad \vec{p}_f - \vec{p}_i = \Delta \vec{p}_{transfer}$$

$$v_x = \frac{dx}{dt} \qquad s = \frac{dr}{dt} \qquad a_x = \frac{dv_x}{dt} \qquad KE = \frac{1}{2}mv^2 \qquad \vec{p} = m\vec{v}$$

$$\frac{d\theta}{dt} = \frac{v}{r} \qquad \Sigma F_x = ma_x \qquad F_{12} = F_{21} \qquad E_{transfer} = \int F_x dx \qquad \vec{p}_{transver} = \int \vec{F} dt$$

Under Certain Conditions:

$$x_f = \frac{1}{2}a_x(\Delta t)^2 + v_{ox}\Delta t + x_o, \quad a_r = \frac{v^2}{r}, \quad F = \mu_k F_N, \ F \le \mu_s F_N, \ F = k\Delta x, \ PE = mgy, \quad PE = \frac{1}{2}kx^2$$

Feature 1 is easy for you to carry out. Feature 2 is more difficult if you write the list of useful equations on the board. It is easier to write the list once below the group problem *before* you photocopy the problem for your class.

You cannot implement Feature 3 unless your team (professor and other TAs) agrees. Feature 3 is another example of applying the 3rd Law of Education: Make it what you want students to do easier than what you don't want students to do. For example, if students are allowed to use all of the derived equations in kinematics, then they can solve most of the kinematics problems using their plug-and-chug and pattern-matching strategies. By limiting the kinematics equations they can use, students must think about what each equation means and how they can use these equations to solve the problem.

Most kinematics problems can be solved with only three equations: the definition of average velocity, the definition of average acceleration, and one derived formula that applies only when the acceleration is constant. Using only three equations increases the number of steps in the solution. But an advantage is that the equations are independent. Students know that when they have the sane number of equations as unknowns, they can solve the problem – the rest is just mathematics.

In a calculus-based course that limits the number of equations, the derived formula is usually

$$x_f = \frac{1}{2}a_x\Delta t^2 + v_{ox}\Delta t + x_o$$

because it is directly connected to the solution of the differential equation defining acceleration. In the algebra-based course, the derived equation is often replaced by

$$\bar{v}_x = \frac{v_i + v_f}{2}$$

because this equation is easier for students to understand.

The Competent Problem Solver

The *Competent Problem Solver – Calculus Version* contains explanations and examples of:
- pictures and motion diagrams [pages 1-4 to 1-5; pages 1-8 to1-9, pages 2-4 and 2-12; pages 2-6 and 2-14; and pages 3-6 to 3-13, 3-18 to 3-19]
- free-body and force diagrams [pages 4-1 through 4-21]
- conservation of energy and conservation of momentum diagrams [pages 5-1 through 5-31]

You have seen how *Competent Problem Solver* can help you in your preparation for a lab session. You may also want to photocopy some of the pages to hand out to your students. For example, you may want to copy and hand out one or two examples that include the use of motion diagrams (e.g., pages 1-8 to1-9). You could white out the labels of the steps and write in the new labels). If your students are having difficulty with free-body diagrams, you may want to photocopy pages 4-1 though 4-7. And so on.

Table of Interactions and Forces

You learned from your reading that students have many alternative conceptions about the nature of forces, particularly the passive normal and tension forces. If you notice that many of your students have misconceptions about the nature of forces, you may want to hand out the Table of Interactions and forces. Allow the students to use this table while they are solving problems in groups.

The information in the table is spread out in their textbook. The table organizes the information in a way that is easy to use.

Table of Interactions and Forces

Contact Interaction	Description of Contact Interactions	Empirical Approx.	When Is the Contact Interaction Present?
Normal	This interaction occurs when two objects are "pressed" together. The surfaces of the objects exert forces on each other where they are in contact. These forces are called "normal" forces. A normal force on an object is always a **push** directed at a right angle from the pushing surface. (In mathematics, the word *normal* means *perpendicular*.) The normal force has no force law or empirical approximation; you must calculate the magnitude of the normal force from the acceleration of the system and the other forces acting on it.	None (must use $\Sigma \mathbf{F} = m\mathbf{a}$ to calculate normal force)	Whenever two objects are in contact, each will exert a normal force on the other. A normal force on an object will assume whatever value is required to keep the object from going "through" the surface of the other object. For example, a book does not fall through a table because of the normal force the table exerts on the book.
Tension	Another type of contact interaction occurs when a cord (rope, wire, or string) pulls on another object or system of objects. The force exerted by the cord is often called the "tension" force. A cord cannot push, so a tension force always a **pull** in the direction the cord is pulling. Like the normal force, the tension force has no force law or empirical approximation; you must calculate the magnitude of the tension force from the acceleration of the system and other forces acting on it.	None (must use $\Sigma \mathbf{F} = m\mathbf{a}$ to calculate tension force)	Whenever a cord is attached to an object, the cord will exert a tension force (unless the cord is slack). For most problems, the cord is much lighter than the object(s) it is pulling, so the mass of the cord can be ignored. For most problems, you can also assume that the cord does not stretch, deform or break.
Spring	A spring interaction occurs whenever a spring attached to an object is stretched or compressed. The force of the spring on the object is called the spring force. Empirically, the spring force is proportional to the displacement (Δx) of the object from the spring's relaxed or unstretched position. The constant of proportionality, k, is the same for compression and extension and depends on the "stiffness" of the spring being used. The minus sign in the empirical approximation (called Hooke's Law) indicates that the direction of the spring force is always towards the relaxed position of the spring. That is, a **stretched spring** *pulls* on an object attached to its end, and a **compressed spring** *pushes*.	$\mathbf{F_S} = -k\Delta\mathbf{x}$ or $F_S = k\Delta x$	A spring force will be present any time an object is attached to a spring that is stretched or compressed. Hooke's law is only accurate when the spring is neither stretched nor compressed too far from its relaxed length.
Air Resistance	Another type of contact interaction occurs when an object is moving relative to the air. The resulting force on the object is called air resistance. At speeds we normally encounter, the magnitude of the air resistance force is approximately proportional to the square of the object's velocity <u>relative to the surrounding air</u>. Thus, if wind is present, an object may experience air resistance without moving! The constant of proportionality, A, is called the shape parameter. It depends on the size and shape of the object and on the density of the air. The direction of the air resistance force is the same as the direction of the air relative to the object. Air resistance is <u>not</u> a type of friction. The empirical relationship is more approximate than those for friction, springs and gravity close to the Earth's surface	$F_{AIR} = Av^2$	An object experiences air resistance whenever it moves through air (or through any other gas), or if there is a wind blowing on the object. In many problems, the object is either small enough (so that A is very small) or moving slowly enough relative to the air that air resistance is much smaller than the other forces in the problem and you can ignore it. In other problems, air resistance is ignored to make the problem simple to solve while still maintaining the main features of the motion.

| Contact Interaction	Description of Contact Interaction	Empirical Approx.	When Is the Contact Interaction Present?
Friction	<u>Kinetic</u>: When the surfaces of two objects slide over each other, each surface exerts a force (push) on the other called the kinetic friction force. The direction of a kinetic friction force on an object is parallel to its sliding surface and opposite from the direction the object is sliding. Empirically, the magnitude of the kinetic friction force that a surface exerts on a sliding object is approximately proportional to the normal force the surface exerts. The value of the proportionality constant μ_k, called the coefficient of kinetic friction, depends on the types of materials of the two surfaces and the roughness of the surfaces. It does not depend on the surface area in contact or the velocities of the objects in contact.	Kinetic: $F_k = \mu_k F_N$	<u>Kinetic</u> frictional forces will be present whenever two surfaces slide against each other (including an object on a large surface like a ramp or table, or two objects in contact, like a book sliding over another book).
	<u>Static</u>: Even when two objects are <u>not</u> <u>sliding</u> over each other, they may exert a "static friction" force on each other to keep from sliding. They act as though they are "stuck" together. For example, a car parked on a hill remains stationary because the road exerts a static friction force on the tires; if the hill were icy, the static friction force might not be large enough to keep the car from slipping.	Static: $F_s \le \mu_s F_N$	<u>Static</u> frictional forces will be present whenever two objects move as though they are "stuck" together. They become "unstuck" when the net force due to all the other interactions exceeds $\mu_s F_N$ and the friction becomes kinetic.
	Empirically, the magnitude of the static friction force that a surface exerts on an object has a *maximum* value that is proportional to the normal force the surface exerts. As with kinetic friction, the proportionality constant μ_s, called the coefficient of static friction, depends on the types of materials of the two surfaces and the roughness of the surfaces. The exact value of the static friction force will be whatever is necessary to keep the object from sliding; it is always <u>less than or equal to</u> the maximum value ($\mu_s F_N$). The direction of the force is parallel to the surface and opposite from the direction the object would slide if there were no static friction.		<u>General Comments</u>: Only one kind of friction acts between any two surfaces at one time: it must be *either* kinetic *or* static friction. A friction force is sometimes so small that it makes no difference and you can ignore it (for example, objects sliding on an icy surface). For some problems, the surfaces are treated as ideal ($\mu_k = 0$, $\mu_s = 0$), and they exert no frictional forces. We refer to surfaces as *frictionless* when the friction is small enough to be ignored.
	<u>General Comments</u>: For any particular pair of surfaces in contact, the value of μ_s is always larger than μ_k. Static and kinetic friction forces always push; they can never pull.		

Long-Range Interaction	Description of Long-range Interaction	Force Law	When Is the Long-range Interaction Present?
Gravitation	A long-range gravitational interaction occurs between any two objects having mass. The gravitational force on each interacting object is proportional to the product of the two masses (m_1 and m_2), and inversely proportional to the square of the distance r between the centers of mass of the objects. The proportionality constant, G, is a called a universal constant because it does <u>not</u> depend on any other properties of the objects such as chemical composition, shape, texture, etc. The gravitational force is always attractive: the force on one mass is always directed *toward* the other mass. The magnitude of gravitational forces is extremely small (compared to common, everyday forces) unless both interacting objects are very massive (such as the sun and the Earth) or one is very massive and they are very close to each other (such as an object near the surface of the Earth). Weight: For objects that are relatively close to the surface of a planet, the gravitational force of the planet on an object is called its "weight." If the distance the object moves from the center of the planet does not change appreciably, then r is approximately equal to the radius of the planet (R_P), and we can define a new variable, $$g = \frac{GM_P}{r^2} \approx \frac{GM_P}{R_P^2}$$ which is very nearly a constant. Then the gravitational force of the planet on an object is approximately equal to the object's mass times the gravitation "constant" g: $$F_g = mg.$$ The average value of g close to the surface of the Earth is 9.81 N/kg.	$$\mathbf{F_g} = \frac{Gm_1 m_2}{r^2}\,\hat{\mathbf{r}}$$	Objects with mass always exert a gravitational force on each other. However, in everyday situations, the gravitational forces between ordinary-sized objects are so extremely small that they can be ignored. For example, the gravitational force exerted by a 100 lb woman on a 200 lb man standing 3 feet away is only 0.000000074 lbs. If both interacting objects are very massive (e.g., sun, planets), then the gravitational forces are large and the force law should be used to calculate the forces. If one of the interacting objects is very massive (e.g., a planet like the Earth), then the gravitational force on an ordinary-sized object is large and must be calculated. If the object remains close to the surface of the planet, then the gravitational force exerted by the planet on the object (the object's weight) can be found using the approximation: $$F_g = W = mg$$ However, if the object's change of position from the center of the planet is an appreciable fraction of the radius of the planet (e.g., rockets, satellites, objects deep inside the Earth), then the gravitational force law should be used.

Long-Range Interaction	Description of Long-range Interaction	Force Law	When Is the Long-range Interaction Present?
Electric	A long-range electric interaction occurs between any two objects that are electrically charged. For point charges, the force law (called Coulomb's Law) states that the electric force on each charge is proportional to the product of the two charges (q_1 and q_2), and inversely proportional to the square of the distance r between the centers of the charges. The value of the proportionality constant, k_e, depends on the conducting properties of the medium between the charges. When the two charges are different (one positive and one negative), then the electric force is attractive: the force on one charge is directed *toward* the other opposite charge. When the two charges are the same (i.e., both positive or both negative), then the electric force is repulsive: the force on one charge is directed *away from* the other charge.	$\mathbf{F_e} = \dfrac{k_e q_1 q_2}{r^2}\hat{\mathbf{r}}$	Charges always exert an electric force on each other. However, Coulomb's Law only holds for point charges like electrons and protons. For these subatomic particles, the electric force is very large compared to the gravitational force. For ordinary objects that are charged, the electric forces between the objects depend on how the charge is distributed on the objects. If the objects have a spherically symmetric charge distribution, then they behave as if all the charge were at the center of the spheres. In such cases, the electric force has the same form as the Coulomb force for point charges: $$\mathbf{F_e} = \dfrac{k_e q_1 q_2}{r^2}\hat{\mathbf{r}}$$ However, ordinary spherical objects cannot hold a large charge (the range is about 10^{-9} to 10^{-7} Coulombs). If the charged spherical objects are *heavy*, then the electric forces will be very small compared to the other forces acting on the objects, and can be ignored. If the objects with spherically symmetric charge distributions are light (e.g., ping pong balls, pith balls, balloons, small pieces of foil or paper) and close together (e.g., a few inches apart), then the electric forces will be comparable in size to the other forces acting on the charged objects. In such cases, the mathematical form of Coulomb's law can be used to calculate the forces.

NOTES:

VI. What are the Characteristics of a Good Group Problem?

*G*ood group problems encourage students to use an organized, logical problem-solving framework instead of their novice, formula-driven, plug-and-chug or pattern-matching strategy. Specifically, they should encourage students to (a) consider physics concepts in the context of real objects in the real world; (b) view problem-solving as a series of decisions; and (c) use their conceptual understanding of the fundamental concepts of physics to qualitatively analyze a problem *before* the mathematical manipulation of formulas.

In other words, good group problems place barriers (fences) on all solution paths that do not involve using a logical and organized problem-solving framework.

1. It is difficult to use a formula to plug numbers to get an answer.

2. It is difficult to find a solution pattern to match to get an answer. [A solution pattern is a memorized procedure for solving "inclined plane problems", "free fall problems," and son on.]

3. It is difficult to solve the problem without first analyzing the problem situation.

4. Physics words such as "inclined plane," "starting from rest," or "inelastic collision" are avoided as much as possible.

5. Logical analysis using fundamental physics concepts is reinforced.

Consider the following problem.

Traffic Accident Problem. You have a summer job with an insurance company and are helping to investigate a tragic "accident." At the scene, you see a road running straight down a hill that is at 10° to the horizontal. At the bottom of the hill, the road widens into a small, level parking lot overlooking a cliff. The cliff has a vertical drop of 400 feet to the horizontal ground below where a car is wrecked 30 feet from the base of the cliff. A witness claims that the car was parked on the hill and began coasting down the road taking about 3 seconds to get down the hill. Your boss drops a stone from the edge of the cliff and, from the sound of it hitting the ground below, determines that it takes 5.0 seconds to fall to the bottom. You are told to calculate the car's average acceleration coming down the hill based on the statement of the witness and the other facts in the case. Obviously, your boss suspects foul play.

The application of some of these criteria to the Traffic Accident Problem is shown on the next page.

Feature 1. It is difficult to use a formula to plug in numbers to get an answer.

The student "knows" that acceleration is velocity divided by time, but no velocity is given and there are two different times in the Traffic Accident problem. OK, the student also "knows" that velocity is distance divided by time, so one time is to get the velocity and the other is to get the acceleration. Unfortunately for the student, there are two distances in the problem. Which one should be used? There is also an angle given. Does the student need to multiply something by a sine or cosine?
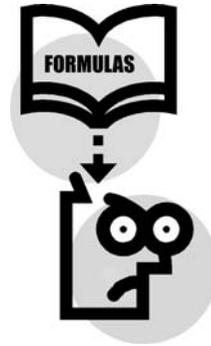
Feature 2. It is difficult to find a matching solution pattern to get an answer.

In the Traffic Accident problem, going down the hill this looks like an "inclined plane problem." Is the acceleration just g sinθ? But what about the other numbers in the problem? When the car goes off the cliff, this is a "projectile problem." You can calculate an acceleration from the distance (which one?) and the time the car falls. Why would that be the acceleration down the hill?

Feature 3. It is difficult to solve the problem without first analyzing the problem situation.

It is difficult to understand what is going on in the Traffic Accident problem without drawing a picture and designating the important quantities on that picture.

♦ Making the situation as real as possible, including a plausible motivation, helps students in the visualization process.

♦ Making the student the primary actor in the problem also helps the visualization process. This also avoids gender and ethnic biases that can inhibit learning. The other actors in the problem are as generic as possible, so the student's visualization is not hampered by unfamiliar names or relationships.

♦ Students are forced to practice visualization because *no picture is given to them.* What path does the car travel when it goes off the cliff? What are the velocity and acceleration of the car at interesting positions in its motion? What are those positions?

♦ The visualization of a realistic situation gives the student practice connecting "physics knowledge" to other parts of the student's knowledge structure. This makes the physics more accessible, and so more easily applied to other situations. What does a car going off a cliff have to do with dropping a stone? Does physics really apply to reconstructing accidents?

♦ In real situations, assumptions must always be made. What are reasonable assumptions? What is the physics that justifies making those assumptions? Can friction be ignored? Where? Is the acceleration down the hill constant? Do you care? This gives students practice in idealization to get at the essential physics behind complex situations.

Feature 4. Physics cues, such as "inclined plane", "starting from rest", or "projectile motion", are avoided as much as possible.

Avoiding physics cues not only makes it difficult for students to find a matching pattern, it encourages students to find connections and apply their physics knowledge.

♦ Using common words helps students practice connecting "physics knowledge" to other things they know. This makes the physics more capable of being applied to other situations. In the Traffic Accident problem, the car goes down a hill (instead of an inclined plane) and begins by being parked (instead of starting from rest).

♦ Physics cues automatically set students thinking along a single path. They do not require students to re-examine many of their physics concepts to determine which are applicable. In the Traffic Accident problem, the student must apply physics knowledge to decide on where the acceleration of the car is constant and where the velocity, or a component of the velocity of the car is constant.

Feature 5. Logical analysis using fundamental concepts is reinforced.

Logical analysis is reinforced because there is no obvious path from the information given to the desired answer. Each student must examine his or her own knowledge to determine that path.

♦ Using a logical analysis helps to determine which information is relevant and which is not. The extra information is not simply chaff to confuse the student. It is information that they would likely have in that situation, and it might be used if the student has incorrect or fragile physics knowledge.

♦ After a logical analysis using the most fundamental physics concepts, the answer can be arrived at in a straightforward manner. In this case, the fundamental concepts are (a) the definition of average acceleration (b) the definition of average velocity, (c) the connection between average and instantaneous velocity for constant acceleration; and (d) the independence of horizontal and vertical motion).

♦ A logical analysis is necessary because this question cannot be answered in one step.

Problems like the Traffic Accident Problem are called context-rich problems   Context-rich problems have the following characteristics:

- The problem is a short story in which the major character is the student. That is, each problem statement uses the personal pronoun "you."

- The problem statement includes a plausible motivation or reason for "you" to calculate something.

- The objects in the problems are real (or can be imagined) -- the idealization process occurs explicitly.

- No pictures or diagrams are given with the problems. Students must visualize the situation by using their own experiences.

- The problem requires more than one step of logical and mathematical reasoning. No single equation that solves the problem.

In addition, most context-rich problems have a few characteristics that make them more difficult to solve

- The unknown quantity is not explicitly specified in the problem statement (e.g., Will this design work?).

- More information is given in the problem statement than is required to solve the problems.

- Unusual ignore-or-neglect assumptions are necessary to solve the problem.

- The problem requires more than one fundamental principle for a solution (e.g., kinematics and the conservation of energy).

- The context is very unfamiliar (i.e., nuclear interactions, quarks, galaxies, etc.)

VII. Level of Difficulty of a Good Group Problem

*G*roup problems should have an appropriate *level of difficulty* for its intended use as either a group practice problem or graded/test problem. All group problems should be more difficult to solve than easy problems typically given on an individual test. But the increased difficulty should be primarily conceptual, not mathematical. **Individuals, not groups, best accomplish difficult mathematics.** So problems that involve long, tedious mathematics but little physics, or problems that require the use of a shortcut or "trick," which only experts would be likely to know, do not make good group problems. In fact, the best group problems involve the straight-forward application of the fundamental principles (e.g., the definition of velocity and acceleration, the independence of motion in the vertical and horizontal directions) rather than the repeated use of derived formulas (e.g., $v_f^2 - v_o^2 = 2ad$).

There are many characteristics of a problem that can make it more difficult to solve than a standard textbook exercise. Thirteen of these difficulty characteristics are described below.

Analysis of Problem

Problem analysis is the translation of the written problem statement into a complete physics description of the problem. It includes a determination of which physics concepts apply to which objects or time intervals, specification of coordinate axes, physics diagrams (e.g., a vector momentum diagram), specification of variables (including subscripts), and the determination of special conditions, constraints, and boundary conditions (e.g., $a_1 = a_2 =$ constant). The next 8 traits are all examples of how problems that require a careful and complete qualitative analysis are more difficult for students to solve.

1. ***Choice of useful principles.*** The problem has more than one possible set of useful concepts that could be applied for a correct solution. For example, consider a problem with a box sliding down a ramp. Typically either Newton's Laws of Motion or the conservation of energy will lead to a solution, but deciding which principles to use can be difficult for students.

2. ***Two general principles.*** The correct solution requires students to use two or more major principles. Examples include pairings such as Newton's Laws and kinematics, conservation of energy and momentum, conservation of energy and kinematics, or linear kinematics and torque.

3. ***Excess numerical data.*** The problem statement includes more data than is needed to solve the problem. For example, the inclusion of both the static and kinetic coefficients of friction in a problem requires students to decide which frictional force is applicable to the situation

4. ***Numbers must be supplied.*** The problem requires students to either remember a common number, such as the boiling temperature of water, or to estimate a number, such as the height of a woman.

5. **Uncommon assumptions.** The problem requires students to generate an *uncommon* simplifying assumption to eliminate an unknown variable. *All* problems require students to use their common sense knowledge of how the world works (e.g., boats move through water and not through the air!). Typically, assumptions, such as frictionless surfaces or massless strings, are explicitly made for the students in class or in textbooks. Therefore, asking students to make their own simplifying assumptions is a new and difficult task. Problems that require students to make their own simplifying assumptions are more difficult to solve. To be included as a difficulty trait, the simplifying assumption must be *uncommon*, such as ignoring a small frictional effect when it is not obvious to do so. The two categories of uncommon simplifying are neglect and ignore. The first category includes situations where the students must *neglect* a quantity, such as neglecting the mass of a flea when compared to the mass of a dog. The next category of assumptions involves *ignoring* effects that cannot be easily expressed mathematically, such as how a yo-yo's string changes its moment of inertia.

6. **Special conditions or constraints.** The problem requires students to generate information from their analysis of the conditions or constraints. An example is the generation of the relationship $a_1 = a_2$ for the two masses in an ideal Atwood machine.

7. **Diagrams.** The problem requires students to extract information from a spatial diagram. A simple example is when students must express the cosine of an angle between *forces* in terms of known and unknown *distances*, as in the Safe Ride problem you solved (Homework #3)

8. **Two directions (vector components).** The problem requires students to treat principles (e.g., forces, momentum) as vectors. This requires both the decomposition of the physics principle and the careful subscripting of variables. Some students are still tripped up taking vector components even after weeks of using vectors.

Mathematical Solution

Mathematical difficulty is last category of traits. A teacher can put into a problem some simple mathematical hurdles that prevent some students from reaching a final answer. Some of these are included in the last five traits.

9. **No numbers.** The problem statement does not use any numbers. Many students use numbers as placeholders to help them remember which variables are known and which are unknown. Therefore, if a problem is written without numbers, it is more difficult for the students.

10. **Unknown(s) cancel.** Problems are more difficult to solve when an unknown variable, such as a mass, ultimately factors out of the final solution. The students must not only decide how to solve the problem without all the cues they expect, but keep symbolic track of all the variables.

Decision Table

Type of Problem	Timing	Diff. Ch.
Group Practice Problems should be shorter and mathematically easier than graded/test group problems.	• just introduced to concept(s) • just finished study of concept(s)	2 - 3 3 - 4
Graded/Test Group Problems can be more complex mathematically.	• just introduced to concept(s) • just finished study of concept(s)	3 - 4 4 - 5

11. ***Simultaneous equations.*** The solution requires solving simultaneous equations. Simultaneous equations are difficult for the students not only because of the algebra involved, but because there are at least two unknowns in each equation and they need to keep track of these variables. A typical circuit-analysis problem best illustrates this trait.

12 ***Calculus or vector algebra.*** The solution requires the students to use sophisticated vector algebra, such as cross products, or calculus. Most students are still learning these skills in their math courses and have not learned how to transfer these skills from their math class to their physics class.

13. ***Lengthy or Detailed Algebra.*** A successful solution to the problem is not possible without working through lengthy or detailed algebra. While these calculations are typically not difficult, they require careful execution. A typical example is a problem that requires students to solve a quadratic equation.

Of course, other factors contribute to whether a problem is a good group problem. One factor is whether the problem is intended for a group practice problem or a graded/test problem. Students have only about 25 - 30 minutes to solve a group practice problem, but they have 45 - 50 minutes to solve a graded/test problem. So practice problems should be shorter and the mathematics should be easier. Graded/test problems can be more difficult (have more difficulty characteristics), and involve more detailed or complex mathematics. Another factor is the timing of the problem – whether the problem is given just after students learn the physics concepts, or just as they are finishing a topic. A problem given at the end of a topic should be more difficult than a problem given just after students have been introduced to the concepts.

The table above shows how these factors influence a judgment about whether a problem is a good choice for a group problem.

NOTES:

VIII. How to Change an Unsuitable Textbook Exercise into a Good Group Problem

Occasionally, you may be given a problem for your discussion session that is not a suitable group problem. For example, consider the three problems below.

1. A ball starts from rest and accelerates at 0.500 m/s² while moving down an inclined plane 9.00 m long. When it reaches the bottom, the ball rolls up another plane, where, after moving 15.0 m, it comes to rest.

    (a) What is the speed of the ball at the bottom of the first plane?

    (b) How long does it take to roll down the first plane?

    (c) What is the acceleration along the second plane?

    (d) What is the ball's speed 8.00 m along the second plane?

2. A merry-go-round has a circular platform which turns at a rate of one full rotation every 10 seconds. A passenger holds himself to the surface with a pair of very sticky shoes with a coefficient of static friction of 0.4. Determine how far away from the center he can go before falling down to the platform?

3. As shown in the diagram, mass M_1 rests on an inclined plane with a rope tied to it. The rope goes through a frictionless, massless pulley, and is connected to another mass, M_2, which hangs off the edge of the table. There is a coefficient of friction, μ_k, between mass M_1 and the inclined plane. The angle of the inclined plane is θ.
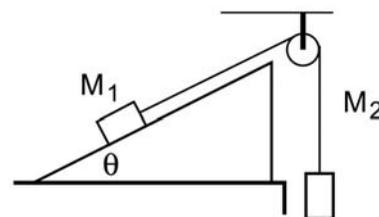
    (a) Draw a free body diagram showing all forces (solid lines) and the acceleration (dotted line).

    (b) Write a general solution for the acceleration of the masses in terms of the variables given plus any other you need to define.

    (c) What is the expression for the acceleration if μ_k goes to zero?

    (d) What is the expression for the acceleration if $\theta = 0$?

    (e) What is the acceleration if $M_1 = 10$ kg, $M_2 = 4$ kg, $\mu_k = 0.2$, and $\theta = 30$ degrees?

None of these problems have the features of a good group problem (see page 115). They can all be solved with one equation (or one equation at a time) using novice plug-and-chug or pattern-matching strategies. There are no decisions to make, so there is no physics to discuss. There is no advantage to working in a group to solve these problems. The best student in the group would solve any of these problem in a few minutes.

How could you change an unsuitable problem to make it an appropriate group problem? It is difficult and time-consuming to change a textbook problem into a context-rich problem. But

you can make several other changes that would make the problem suitable for a practice or graded/test group problem. The guidelines for doing this are given below.

Step 1. Take out any diagram in the original problem. If necessary, reword the problem so students can draw a picture of the situation from the description.

Step 2. As far as possible, make idealized objects real objects. Take out as many physics cues as possible. For example, "an inclined plane" can be a ramp, and a "block" could be a package or a car with its brakes on. "At rest" can be stopped, parked, not moving, and so on. "Free fall" can be simply falling.

Step 3. Change the problem so it requires at least two equations to solve. Some ways to accomplish this are:

A. For problems with a series of questions, select **one** target variable. This is often, but not always, the target variable in the last question in the series.

B. Change the given quantities in the problem.

C. Change the target variable for the problem (e.g., change the target variable from velocity to a time, or from an acceleration to a force).

Step 4. Make sure the problem can be solved with the information given in the problem. At the same time, determine if the changes from Step 3 added any difficulty characteristics to the problem.

Step 5. Change some other features of the problem to make it more difficult to solve. The easiest difficulty traits to add are:

A. ***Uncommon assumption.*** Take out or change a statement of an assumption or idealization. For example, replace "frictionless" with "low friction surface" or "massless" with "very light."

B. ***Excess data.*** Add information to the problem statement that is not needed to solve the problem. But be careful. This information **must** be the type of information that would be natural to have in the given situation.

Analysis
___ 1. Choice of principle
___ 2. Two principles
___ 3. Excess data
___ 4. Numbers required
___ 5. Assumptions
___ 6. Special constraints
___ 7. Diagrams
___ 8. Vectors
Mathematical Solution
___ 9. No numbers
___ 10. Unknown(s) cancel
___ 11. Simultaneous eqns.
___ 12. Calc/vector algebra
___ 13. Lengthy algebra

C. ***Numbers must be supplied.*** Take out some relevant information. But be careful. Groups **must** be able to estimate this information from their collective general knowledge (e.g., the height of a baseball bat above the ground when a batter swings and hits the ball; the boiling temperature of water).

Decision Table

Type of Problem	Timing	Diff. Ch.
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Graded/Test Group Problems can be more complex mathematically.	• just introduced to concept(s) • just finished study of concept(s)	3 - 4 4 - 5

D. ***Diagrams.*** Change the information given in the problem so students must extract information from a spatial diagram. A simple example is when students must express the cosine of an angle between *forces* in terms of known and unknown *distances*.

Step 6. Use the Decision Table (above) to decide if the problem now makes a good group practice problem. If so, solve the problem again (to check that you haven't added or taken out too many things, so the problem can't be solved). Make a final edit of the problem. You may need to write a new example solution.

Note: You should not change a graded/test problem unless you receive it early enough to discuss with your professor or in a team meeting.

You may be asked (once a semester) to write a group practice problem. Don't start from scratch! Several faculty members at different colleges and universities have written context-rich problems for individual and cooperative groups. These problems are available at our web site:

http://groups.physics.umn.edu/physed/Research/CRP/on-lineArchive/ola.html

But be sure to check the difficulty of the problem. The collection includes easy, medium, and difficult problems for use both on individual tests and for group practice and graded/test problems.

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NOTES:

Discussion Preparation

Name _____   Date: _____ .

Timing	**Rule of Thumb for Learning Focus** **What to Tell Groups to Draw/Write on The Board**
New fundamental principle just introduced (e.g., forces, conservation of energy)	Learning focus is on how to draw **new** physics diagram(s) (where most alternative conceptions show up)
New concept has been introduced (e.g., independence of motion in the horizontal and vertical directions.	Learning focus is on how to incorporate the new concept in physics diagram(s), but you can often have students list equations as well.
No new concept has been introduced (or new concept is easy)	Learning focus is usually on the list of equations students need to solve the problem (indicates difficulties students continue to have in applying a principle and concepts)

I. Browse through *Competent Problem Solver* for examples of (a) how to draw the physics diagram for the group problem (e.g., motion, free-body, energy, and/or momentum diagram), (b) how to apply fundamental concepts and principles to solve problems, and (c) how to keeping track of the unknowns while constructing a solution.

Browse through textbook to see how similar problems are solved.

II Solve the group problem in the way you would like students to solve the problem, so you know what to look for while coaching your students. Use the notation that is in the students' textbook.

III Use Decision Table (above), your knowledge of difficulties your students had solving the last lab problem, and information from your team meeting to answer the following questions

Opening Moves	
1. What is the learning focus of this session that I will tell students?	
2. What part(s) of the problem solution do you want groups to draw/write on the board?	
End Game	
3 Do we need to spend extra time?	☐ YES ☐ NO because:
4. If YES, then how much extra time? What should I be prepared to coach and/or model?	Plan:

IV. List some possible questions to ask groups during whole-class discussion (end game) that you think would promote a discussion.

a.	
b.	
c.	
d.	
e.	
f.	
g.	

Chapter 5

Other Teaching Resources

I. Top 20 TA Traps

This list has been compiled by mentor TAs to help you avoid some common pitfalls of being a TA. These are the top twenty things TAs do that interfere with the work of teaching.

General Management

- ❑ Helping groups too much.
- ❑ Not comprehending or ignoring student questions.
- ❑ Not interacting with students at their eye level.
- ❑ Not discussing the main point(s) of each class meeting with the students in the form of a lesson summary at the end of class.
- ❑ Not managing your class time wisely. For example: no end discussion in lab or discussion session because your class ran out of time.
- ❑ Not managing the chalkboard space appropriately / asking groups to show mathematical solutions rather than physics decisions on the board.

Cooperative Groups

- ❑ Not circulating while listening and watching all groups before interacting with one.
- ❑ Not assigning group roles or not using them to help dysfunctional groups.
- ❑ Not assigning groups according to a plan based on gender and past performance.
- ❑ Not having introductions when new groups are formed.
- ❑ Not calling on individual students to explain what their groups have written on the board. Note that one way to avoid this is by asking all of the skeptics (or some other group role) to explain their group's answer.
- ❑ Not assessing your class and diagnosing which group(s) are having the most problems either with the physics concepts or cooperating with one another.

Discussion Sessions

- ❑ Too much or too little presentation of problem to the class.
- ❑ Not having read the discussion problem and checked the solution beforehand.
- ❑ Allowing students to use their books in discussion and not giving them an equation sheet (or writing the fundamental equations on the board).

Lab Sessions

- ❑ Being unfamiliar with new lab equipment.
- ❑ Not reading the assigned lab problems and solving the predictions and warm-up questions ahead of time.
- ❑ Letting groups that finish a problem leave early rather than checking their learning with questions and increasing their learning by assigning an additional challenging problem.
- ❑ Not grading predictions for intellectual content.

TA Duties

❑   Not actively participating in team meetings.

Periodically, you should review this checklist and examine your teaching habits. What do you need to work on? Your mentor TAs can help you with any troubles you have.

Notes:

II. Team Meeting Guidelines

First Team Meeting

1. Duties: TA, faculty, lead TA

TA office hours.

➢ TAs have office hours in Physics 320. This room is a 'drop-in center' for the students where they can go for help.
➢ You will decide the schedule of your office hours at the first team meeting.

Setting the agenda and running meetings

➢ One way to effectively integrate the TAs into the team is to have a TA set the agenda for each team meeting. This duty could be the responsibility one TA or rotated amongst all members of the team.

Expectations of TAs

➢ Make sure the TAs know if they are expected to attend lectures and how often they will proctor and grade?
➢ TAs need to know what is expected of them beyond meeting their sections.

Expectations of lecturer

➢ Where will the lecturer be during the exams? Will the lecturer grade any questions?
➢ Another way to make TAs feel a part of the team is for the lecturer to participate to some extent in all of their duties.
➢ Sometimes issues arise when proctoring or grading (e.g. cheating) that only the lecturer is qualified to deal with. If the lecturer is helping in these duties, then the issues can be handled when they arise.

Writing problems

➢ Who will create the problems and solutions for discussion sections and for exams? How will these questions be communicated to everyone in the team? How will the writer get feedback and corrections before they are given to students?
➢ Creating and checking problems for the students is a duty that can be shared.

Other issues

➢ Create a fair schedule of everyone's duties for the semester? Remember that half time TAs have the same "overhead" (e.g., preparation, meetings) as full time TAs. The other assignments of half time TAs must be less than half those of full time TAs.
➢ What problem-solving framework will be used by the lecturer?
➢ What will be the first lab assignment? What will be done on the first day of discussion?
➢ Who is in charge of switching students into different sections and adding new students? Students **must** register for the appropriate section on the web. Teaching Assistants are **not** allowed to let students attend sections that they are not registered for.

2. TA Support

Will the professor visit TA classes? What is the role of the mentor TAs?

One of the hot issues at the TA meetings has been the issue of autonomy.
➢ It must be made clear that the TA is not free to teach anyway they please. The team must agree on a basic emphasis and mode of operation.
➢ The Lecturer is ultimately responsible for everything that happens in the course.

➢ Since effective teaching depends on the characteristics of the TA and their students, the teaching of each section will vary. Each team needs to agree on guidelines to address the issue of what level of variance is acceptable.

3. Policies

Cheating

➢ In the Activity Guide, there is a section on what the TA should do if cheating is suspected. This should be reviewed by the team.
➢ Any statement that the lecturer makes to the students about cheating should be reviewed for the team.
➢ This will ensure that the entire team is familiar with the same cheating policy.

Syllabus - Grading scheme

➢ Zeroth Law - students value their grade, so if you want the students to do something, grade them for it. However, grading adds stress and can inhibit learning so don't overuse grading.
➢ Special grading policies: What to do:
   ♦ about regrades?
   ♦ about late assignments?
   ♦ when a student misses a discussion section during non-quiz weeks?
   ♦ about lab computer prep quiz?

Lab Grading

➢ Discuss lab a report grading outline based on the one provided in the lab manual.

4. Respecting the party line and the team

➢ Discuss all class policies and come to a definite conclusion.
➢ Make sure everyone supports the policies even though there may be disagreement. Inconsistencies in grading, assignments, or other policies make students frustrated and angry.
➢ Everybody in the team should present a unified front to the students. Students have been known to try to play the TA off the instructor and vice versa.
➢ In front of the students, provide positive support for the other TAs, the lecturer, and the course material. Students will easily loose confidence in the course and in their own learning if they believe the instructors "don't know what they are doing." If you can't make sense of an action of another instructor as reported by a student, it is most likely that the student has misinterpreted that action or you do not understand the entire background. Give the impression that the action must make sense and tell the student you will check into it. Discuss your difficulties with what another instructor had said or done in private with that instructor or in your team meeting, not in front of the student. Mutual support of all instructors in the course is essential for student morale and ultimately for student learning.
➢ Listen, pay attention, and contribute during the team meetings.

5. General

➢ What is the copy code number?
➢ When will the team meeting be held? Where?
➢ As a team, you should decide upon contingency lesson plans for lab and discussion sections. What will you do if you do not have enough equipment? If you can't make it to your teaching sections? You should decide upon a plan as a team during the first team meeting.

Each Team Meeting

Lecture

- ❑ Where is the class? What topics are covered in lecture?
- ❑ How far do you plan to get?
- ❑ Any demonstration related to lab or discussion section problem?

Lab

- ❑ What problem(s) will be done this week?
- ❑ What should TAs expect from student predictions?
- ❑ What are some discussion topics related to the problems this week?
- ❑ What problem(s) will be assigned for next week?
- ❑ What constitutes an acceptable answer for the prediction to receive points?
- ❑ Allow some prep time for the team - review instructor's guide
- ❑ How did the students do in last week's lab: problems, observations, concerns?

Discussion section

- ❑ What is the problem for this week? Proof-read the solution!!!
- ❑ How did the students do in last week's problem?
- ❑ What type of questions did students raise?
- ❑ What type of mistakes did students make?
- ❑ Who is creating next week's problem? When will it be submitted for comments?
- ❑ What equations will be given to the students? Should the equations be written on the board or will they be included on the problem sheet?

General

- ❑ How many hours are TAs spending related to class?
- ❑ Is this where you expected them to spend their time?
- ❑ Is enough being done to ensure that every TA is contributing to the team meeting?

Last Team Meeting

- ❑ Discuss how student evaluations will be conducted.
- ❑ Any post class measures?
- ❑ Evaluate your team.

Team Meetings Prior To Quizzes

1. For group quiz problem:
- ❑ Proof-read problem and solution.
- ❑ What level of intervention should be expected (see below for levels of intervention) and when should the intervention take place?
- ❑ Who will grade group problems?
- ❑ What will be done about students who missed the previous week's practice problem?

<u>Three Types of Intervention During Group Quizzes</u>: One concern about group quizzes is how much help the TA gives during the group problem. In the past, when one TA gave more help than other TAs, the students found out and became angry - with good reason. This issue needs to be clearly addressed before every group quiz.

Another concern about the group quizzes is that it is a very intense learning situation. To be effective, good group problems are needed and TAs should be allowed to intervene in an agreed upon way to ensure necessary learning occurs without unfairly influencing grades.

Apart from no intervention (TA sits in front and lets groups work), which is NOT recommended, there are three levels of intervention, in order from lowest to highest:

Level	What it means	What it sounds like
Group Functioning	TA intervenes at the group functioning level to ensure the students work effectively.	"Manager or summarizer, does everyone understand the problem?" "Who is the skeptic in this group?"
Problem Solving	TA uses the problem solving framework to offer hints to a group of students.	"Did you re-read the problem?" "You might want to spend some more time working on your force diagram."
Physics	The TA gives physics related hints, usually to the entire class to ensure fairness.	"Does the car accelerate?" "What is the effect of the wind?"

2. Who will proctor?
- ❑ Any special instructions?

3. Who will Proof-read quiz?
- ❑ The proctors need to see the quiz beforehand. Who else sees the quiz before it is given?

4. Grading
- ❑ Who will grade?
- ❑ Will all the grading be done all at once or can TAs take tests home?
- ❑ How will the lecturer's expectations and standards of grading be communicated?
- ❑ When is the deadline for the grades to be entered into the computer?
- ❑ How will the quizzes be returned to the students?

III. TA Office Hour

1. Duties:

- The TAs are expected to hold their office hours in Physics 230. You will have one office hour a week for each your section. You need to decide the schedule of your office hours at the first team meeting. Also, you might want to check which room will be used as the TA office hour room because the room might be changed every semester.
- This is your chance to interact one-on-one with your students, and it is your students' chance to get some personal tutoring. So, you need to be serious about your office hour as well as your Lab or Discussion section.
- The office hour room is a "drop-in center" for the students where they can go for help. So, you will tutor not only your students but also other sections' (sometimes other classes') students in your office hour.

2. Details for Mentoring in your office hour:

As well as Lab or Discussion section, we focus the office hours toward Problem Solving. Many of the strategies of tutoring are similar with those you use in those sections.

i. Make sure that students know where they are having difficulties

The first thing you have to do is to determine the source of a student's difficulty. Often the student cannot tell you this directly. Remember some students come to the office hour to just get the correct answers without really doing problems. You need make sure that they have made an honest attempt to do the problem before you give them any help. Always ask to see their work.

Students might ask you about problems for another classes. Because you might be not familiar with the other classes, you will have to read their Lab manual or textbook. Make sure that the student shows you what they have done. If you have only one student in your office hour, you have time to do that. However, if you have several students in your office hour, you might not be able to spend much time with one student. If this happens, explain to the student that you must help the others and that they might get more effective help from a TA who is more familiar with their class. Do not turn a student away just because you are not teaching their class. This is demoralizing to student who interpret this action as rejection of them as a person.

ii. Give some hints to their questions

After determining the student's difficulty, give the student some hints instead of just telling them how you would proceed toward the correct answer. If you determine that the student has a misconception, you could ask her/him some questions to try to get them to see a contradiction with something else they believe (like the 'skeptic' in the group solving). Again, do not just give the correct answer. Give the students the chance to go through their own thought processes. One suggestion is that you do not write anything down. Let the student do all of the writing. This help make the student a more active participant. If the TA does all the writing, the student tends to be just an observer.

iii. Do not show the entire procedure to the final answer

After giving some hints and/or questions and finding the student is on 'the right track', you can leave him/her and tutor the next student who is waiting for you. Our duty is not to give the correct final answers but to help each students learn problem-solving that fits their own thinking. Your procedure to the final answer is not likely to be the exact one that the student would use. You will not be there when the student takes a test.

IV. Proctoring and Record Keeping

1. Proctoring Exams

The purpose of proctoring is to make the students as comfortable as possible in the stressful environment of taking an exam. You can achieve this goal by:

- being familiar with the test and prepared to be fast, friendly and helpful when students have questions;
- going over the exam with the professor before it is given to determine what help you may or may not give;
- announcing to the whole class any answer for an individual student's question that you feel might be generally helpful. It must appear to all students that you are not showing any favoritism;
- being helpful in explaining the meaning of words or situations to foreign students;
- walking around the class so that it is easy for shy students to ask you a question;
- protecting the students from the small minority of students who try to cheat.

Before the exam starts:

- TAs given the assignment of proctoring will pick up exams from Office Room 148.
- If the course to be proctored is 1xxx level, the TA must pick up exams 15 minutes before the class begins; 3xxx and 5xxx class exams should be picked up 10 minutes prior to class time. Distribute tests according to the professor's instructions.
- Also, be sure that you are clear about what the professor wants you to do if you feel that cheating is occurring during the test.

At the start of the exam:

- Read any special instructions from the professor to the class.
- Explicitly tell the students what materials they may use and may not use (i.e. calculator, textbooks, etc.). This may mean reading the exam's instructions aloud to the class.
- Be sure the students are sitting every other seat. Watch for people who insist on sitting diagonally behind someone else. You may want to explicitly state where the students can store their backpacks, books, etc...(for example: underneath the chair.)
- After you are sure all student materials are properly stored, you should pass out the exams as efficiently as possible. Students are very frustrated if it takes more than two or three minutes to distribute the tests to the entire class. One very efficient system is to hand stacks of exams to students at multiple places in the class and have the students pass them around while you remind them to do so quickly.
- Announce when the exam is scheduled to end. You should also write it on the board.

During the exam:

- **Count the number of students in the room. Check your count with your partner.**
- Write the time remaining on the board at least every five minutes. Announce when there are 5 minutes left.
- It is important that you remain active. This will let the students know that you are not too busy to help them and it will discourage cheating. Quietly and unobtrusively, walk around the room watching the students work. Do not just sit in the front of the room.

- Try to answer a student's question as quickly and as quietly as possible. Try not to disturb the other students. If you get asked the same question several times, announce your answer to the class and write it on the board.

- Today's calculators can store an enormous amount of information and some can exchange information with other calculators over a short distance. Watch for students who are overusing their calculators.

- If you do suspect that someone is cheating, discretely explain your reasons to your proctoring partner and both of you should watch for the behavior.

- If you both are reasonably sure that cheating is occurring, carry out the instructions from the professor in charge of the class. (Prior to the exam, ask the professor what he/she wants you to do when cheating occurs.)

- If you both are not reasonably sure that cheating is occurring, but you still suspect that it might be, you can move the students involved.

- Do not engage in pleasant conversation with your proctoring partner. If you even smile, students think that you are laughing at them. *Many students have complained about proctors who are laughing during exams.* Remember exams are deadly serious for your students.

At the end of the exam:

- Watch for students who use the commotion of the end of the exam to cheat. It is effective to have the students remain in their seats and pass their papers to the end of each row for collection before any student is allowed to leave the class.

- Count the number of exams received and compare it to the number of students at the exam.

- Check the room for lost items - some of them might be "cheat sheets."

After the exam is complete, bring ALL tests back to Room 148. Count the number of tests again and enter the necessary information into the *Proctoring Book*. Place all extra exams in a separate pile to be picked up by the professor.

2. Grading Exams/Homework

TAs picking up exams to grade must count the number of assignments and fill out the necessary information in the *Grader Book* before taking them out of the Physics office. Upon returning the graded exams, they must again be counted and signed back into this book. Grades must be submitted electronically via the web. See page 141 for instructions for entering grades into the computers.

3. Keeping Lab Scores In the *Class Record Book*

TAs will record lab scores for each lab section they teach. Scores will be kept according to the professor's instructions in a green *Class Record Book*. These books, as well as red pens for grading, can be obtained in Room 148.

IMPORTANT:

These procedures have been used successfully in the Physics Department for years. While some steps may seem insignificant or redundant, they are necessary in safeguarding you and your students' work assignments in case of cheating, loss or error.

V. Grading Procedure

1. Look at the solution to the problem. Does the solution involve the application of more than one major principle (e.g., forces and kinematics, energy and kinematics)? If yes, decide how many points should be awarded for each approach. (Note: The answer may depend on when the problem is given -- quiz or final).

2. For *each* major approach needed for a solution: Decide how you will divide the points between Physics Approach and Logical Execution (mathematics) based on the answer to the question: Does the problem solution involve mathematics that is difficult for the students (e.g., quadratics, simultaneous equations, difficult integral, etc.)?

    If the answer is no, then you may want to assign most of the points (80% - 90%) to the Physics Approach. If the answer is yes, then you may want to assign fewer points to the physics (60 - 70%) and more points to the logical execution.

3. Start with at least 20 student solutions to examine in detail. Spend about 30 minutes sorting the solutions into about 5 stacks (roughly based on the grade, A, B, C, D, F, you would give for that solution), using the criteria below (see also the Grading Flow Chart). Then go through your piles briefly, make a list of the types of physics approaches you found, and decide on the number of points you will assign to each approach.

    Criteria:

    A. Communicates reasoning?

        Can you tell how student got their answer? If yes, then go on. If no, then student gets zero (0) points.

    B. Physics Approach (60% - 90%): Look at the combination of student's diagrams, general equation(s), and specific equation(s). Do **not** look at execution or numerical answers. Keep a list of the types of approaches you find, and how many points you assign each approach.

        i.   Correct Approach: 60% - 90%

        ii. Major mistake of some kind: There are two kinds of mistakes, quantity definition and conceptual mistakes.

             <u>Quantity definition</u> errors are translation errors from diagrams to equations:
             - sign errors (signs of quantities inconsistent with defined or inferred coordinate axes)
             - symbol errors (use same symbol for two different quantities, for example "m" for both m_1 and m_2)
             - component (trigonometry) errors (sines and cosines confused, etc.)
             - carelessness in writing terms (e.g., forget to include a force in equations that was clearly shown on the diagram, etc.)

GRADING FLOW CHART

```
        ┌─────────────┐
        │ Does solution│   NO      ┌──────┐
        │ communicate  │─────────→ │ STOP │
        │ reasoning?   │           └──────┘
        └─────────────┘
              │ YES
              ↓
     ┌─────────────────┐
     │    PHYSICS       │
     │   APPROACH       │
     │  (60% - 90%)     │
     └─────────────────┘
```

Correct (60% - 90%) · Major Mistake (20% - 85%) · Off-the-wall (0% - 20%)

Variable Def. Difficulty · Conceptual

Decide on consistent grades

Decide on consistent grades → STOP

```
     ┌─────────────────┐
     │    LOGICAL        │
     │   EXECUTION       │
     │  (10% - 40%)      │
     └─────────────────┘
```

Correct or Minor Error (10% - 40%) · Simpler Problem Solved (5% - 20%) · Use wrong physics to get answer (0%)

STOP

Major Math Error · Conceptual or Var. Def. Error

STOP

Decide on consistent grades → STOP

> Conceptual mistakes can take many forms -- omitting important physics (e.g., initial or final velocity, important force or energy term, etc.), wrong directions for vectors, etc.
>
> Decide how many points to assign each type of approach. Be sure to keep a brief list, so you can add to it later, and remain consistent.

    iii. Non-Physics Approaches: Student takes a totally wrong approach. For example, student assumes a constant velocity for free fall. Or student states that the unknown force (tension, normal, friction) is the sum of all the known forces, and so on.

> Depending on whether a student shows some understanding of the physics (e.g., a correct or nearly correct force diagram, a few energy terms correct), decide on the maximum amount of points to give. You probably will give no more than 20% for such solutions. Most weird solutions will get zero (0) points. Add to your brief list.

4. Now start assigning points to these solutions, one pile at a time. As you grade, look for the logical execution errors listed below (see also Grading Flow Chart). Add to your brief list.

Logical Execution (10% - 40%): How did the student execute the approach?

    A. Correct or Minor Error (full points, 10% - 40%): Minor math errors include a dropped sign late in the execution, or a calculator error.

    B. Simpler Problem Solved (5% - 20%): There are two kinds of errors that result in the students solving a much *simpler problem than intended*:

> Math Error: This includes any algebra or calculus mistake that greatly simplifies the problem, such as dropping a square so the quadratic equation does not have to be solved, etc.
>
> Conceptual or Quantity Definition Error: Some conceptual errors, such as the omission of certain forces, result in a much simpler problem solution. For example, if a student uses "m" for both m_1 and m_2 in some force problems, the mass may cancel out of the problem.

> Decide how many points to assign for each kind of execution error you find. Students who make a mathematical error trying to solve simultaneous equations or a difficult integral should get a higher score than the students who solve a different, simpler problem.

    C. Use wrong physics to get an answer (0%). This includes setting a variable to a constant or to zero to get an answer, or making other weird assumptions. This mistake is often seen when students have to solve simultaneous equations. These students should get zero (0) points for logical execution. They should receive no more points than a student who had the same physics approach, then quit (or said that they did not know how to do the mathematics).

Based on the above experience, grade the rest of the student solutions in two passes. First, quickly glance at each paper and assign it to an A, B, C, D, or F pile. This should take no more than 10 seconds/paper. You will make some mistakes but you will find them on the next pass. Each pile is more homogeneous than the entire class. Now go through each pile more carefully (it is usually easiest to start with the A pile) and assign a score to each paper in a manner consistent with your initial sample of 20. You will find some new physics approaches and combinations of errors you did not see in your initial sort. As you encounter these, decide on a reasonable number of points to assign compared to the other approaches/errors on your list. Be sure to add to your list, so you can remain consistent. When you find a paper that you misclassified, put it on the appropriate pile to be scored when considering that pile. In addition to being a faster and more consistent way to grade, this method allows you to take a break when you have finished scoring a pile without loosing consistency.

VI. Electronic Submission of Grades

Grades for the courses you will teach must be submitted to the Undergraduate Office via the web. If you have any problems, the telephone number of the office is 624-7375, and it is located in room 148.

- You could see the details of electronic grades submission on the website http://www.physics.umn.edu/resources/classes/gradebooks/help.html .
- This system is accessible <u>only</u> from registered hosts of the University of Minnesota.

1. DOWNLOADING THE COMPUTER TEMPLATE

The Undergraduate Office provides electronic grade book "templates" (in Microsoft Excel file format) on the web. To get a blank template,

go to the web URL http://www.physics.umn.edu/resources/classes/gradebooks/

The program will ask for your U of M X.500 username and Password. You'll only be able to access the files if your username is recognized in the department directory as a T.A.

You will see a list of all available templates at this time. Find the one that is yours and click on it. (If you cannot find the one that is yours, call the front office, and they will put one there for you. NEVER USE YOUR OLD TEMPLATES. SEE THE FRONT OFFICE IF YOU DO NOT SEE YOUR TEMPLATE.) If you are entering the Multiple Choice grades, please see the bottom of the page for more specific information.

The program will ask you whether to open it or save the file. SAVE this file to the desktop. Then double click the icon on the desktop to open the file in Excel to enter your grades.

2. ENTERING YOUR GRADES ONTO THE TEMPLATE

- **<u>NEVER</u>** change or alter in any way the order of the gradebook. Never delete any student from the list.

Enter the scores of the students. If a student is not listed yet on the template, enter the name (and score) at the BOTTOM of the list. If a student is listed in the template, but did not answer the problem, do not enter anything. If the student did answer the problem, but did not receive any points, enter a zero.

Once you finish entering the grades, save the file (while still in Excel). DO NOT CHANGE THE NAME OF THE FILE! Your gradebook file is now complete.

3. UPLOADING THE GRADEBOOK TO THE OFFICE COMPUTER

- <u>Never</u> upload a template more than once.
- See the front office if you need to add or change grades.

In the same page where you selected your blank gradebook to download, there is a textbox in which to enter the filename of your completed gradebook. Enter your filename and upload.

Enter the username and password. The username is "grades" and the password is "fall04". The password will be changed each semester (e.g. "fall04" in the fall semester in 2004). You will be linked to "File Upload to grades dropbox area." Follow the instructions given on the web page to upload the file.

(When you click on browse to find your file, remember that it's on your desktop. Change the "File of Type" to "All Files." Click on the correct file. Click on UPLOAD.)

Even though the computer will show you immediately whether the uploading was successful, telephone the front office to see if the file was indeed correctly uploaded and received.
- Do not keep a copy of the grades in a public computer. Keep a copy of the file in a secure account or keep a hard copy for your records.
- Do not keep the old templates. You will need a new one the next time you submit grades.

MULTIPLE CHOICE: SPECIFIC INFORMATION REGARDING TEMPLATE FILES AND ENTERING THE SCORES

When entering the multiple choice scores, there will be two files on the web for you. One, phys1xxxq1mc SCORES, is a list of names of students who took the test and their scores. The other, phys1xxxq1MC is the Excel gradebook for your class. You are to transfer scores FROM phys1xxxq1mc scores TO phys1xxxp1MC. DO NOT CHANGE THE ORDER OF q1MC.

Arrange the q1mc SCORES file to match the q1MC file. Add new blank lines to the q1mc SCORES file, if necessary, to make existing names correspond to the names on the q1MC file. (Example: When you have completed the process, "Smith, John" should have the same row number on both files.)

When all names match, Copy and Paste the scores FROM q1mc SCORES file TO the q1MC file.

After doing this, check your work to make sure students received their appropriate scores.
- Some students names on the q1mc SCORES file may have their first name first. Some may have misspelled their own name on the multiple choice sheet. Some students may have only recorded their ID#. Do a search of the q1MC file to find out the corresponding name. Look for these problems before you start, and rearrange when needed.

Some names may be on the q1mc SCORES file and not on the q1MC file. Add these names to the BOTTOM of the q1MC file. <u>Do NOT change the order</u> of the q1MC file for any reason!

VII. Downloading Class Lists

You are strongly recommended to make a class list because you need it when grading. You can make the class lists using the University of Minnesota web page.

A - To View Class Roster:

1. Access Netscape. (You can use only Netscape if you are using Win NT on the Physics Network.)
2. Enter the URL http://www.umreports.umn.edu.
3. Click on **User Login**. If you receive a warning text box, click on **continue**.
4. The next screen will ask for your Internet ID (X.500 username) and password. Enter these in the appropriate boxes and click on **Login**. A small screen appears, click on **continue**.
5. The next screen should be "home page" with your name at the top. Click on **Class List**.
6. Choose "my classes".
7. Select the class you want to see.
8. The class roster should appear.

B - To Download Class Roster as an xls file (Excel Workbook):

1. In the upper right corner, there are maroon buttons. Click on **Save to Excel.**
2. Click the link "**Click here to get the Excel file**".
3. Netscape will ask, "What do you want to do with this file?" Choose **Save it to disk** and click on **OK.**
4. Choose the folder where you want to save the file and click **Save** button.
5. You can open the file you have downloaded using the Excel. (It is better to change the column width.) Once the file is open, a gray box will appear. On Text Import Wizard-Step 1 of 3, check: **Delimited**. On the 2nd screen check: **Tab** and **Comma**. On the 3rd screen, check: **General** and click on the **finish** button. (It is better to change the column width.)

C1 - To Download Class Roster as a csv file (Comma delimited text):

1. In the upper right corner, there are maroon buttons. Click on **Save to CSV.**
2. Click the link "**Click here to get the CSV file**".
3. Choose the folder where you want to save the file and click **Save** button. (You might simply see the text file of the roster on the screen.)
4. You can open the file you have downloaded using the Notepad or any text file editor. (It is better to change the file name.)
5. To access the file using Excel, first open Excel. Then, click **open** button on the tool bar. Once the box appears, find the file you have downloaded. (Make sure to set "files of type: All files") Click **OPEN**.
6. Once the file is open, a gray box will appear. On Text Import Wizard- Step 1 of 3, check: **Delimited**. On the 2nd screen check: **Tab** and **Comma**. On the 3rd screen, check: **General** and click on the **finish** button. (It is better to change the column width.)

C2 - To Save a csv File As an xls File:

1. On the **file** menu, click **save as**. This allows you to rename the file and save it as Microsoft excel worksheet. Save it where you would like on your PC.
2. "Save in" is where you indicate where you would like your file to appear. Use the drop down arrow to select a place to save the file.
3. Change "File Name:"
4. Change "save as type: Microsoft excel workbook" (in pulldown).
5. Click on Save.

Once you have your class lists, click **exit** on the top of the page and use the logoff screen to exit Management Reporting. Also please do not forget to click on **Logout** button in the small login window appeared in A-4.

Example of the class list using Excel

ACCESSING CLASS LISTS WITH STUDENTS' PICTURES

It is recommended that you should have a class list with students' pictures, so that you will remember your students' names as soon as possible. On the **My Classes** page, click on **Class Pictures** link next to your section. Choose **Save to PDF** link from the upper right corner.

VIII. Reference Guide for Ultr@ VNC version 1.0.0

Ultr@ VNC is a computer program in the physics lab rooms that gives you the power to observe student computer screens and control a student's computer remotely via your keyboard and mouse. It is particularly useful for giving instructions about a program or displaying students' lab data.

To access Ultr@ VNC, log in to a lab computer with a TA username and password (most likely your physics department ID). If you would potentially like to broadcast a screen using the digital projector, log in to the instructor computer located near the printer. (Refer to the Digital Projector Reference for more information.) Access the program from the Start menu, Programs folder, UltraVNC, and UltraVNC Viewer. Refer to Figure 1.

You can also access the program from My Computer:
C:\Program Files\UltraVNC\UltraVNC Viewer

Fig. 1

The following pop-up window should appear, requesting the name of the display host:

Fig. 2
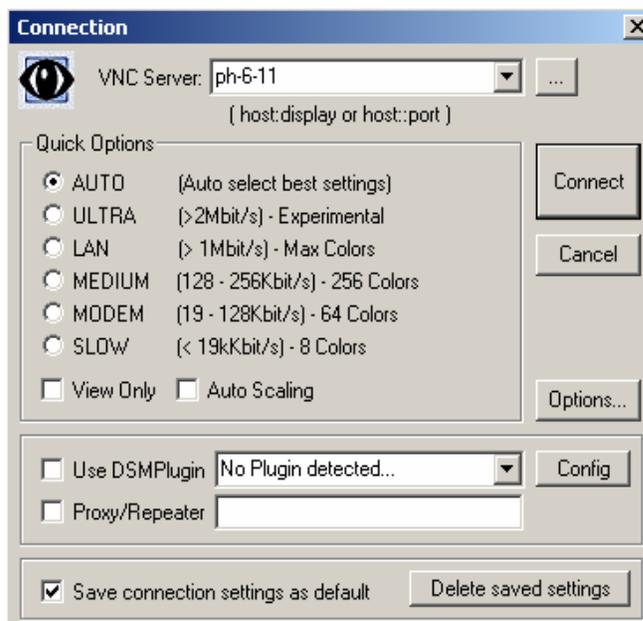
In the *VNC Server* drop-down field, type the number of the student's computer that you want to observe. The numbers are printed on each computer and should be in the format ph-#-##.

If you want to change connection options, click the **Options** button. Another pop-up window will appear (Figure 3). *Auto select best settings* is the default. From this window you can change *Mouse Cursor* options and select *Display* options.

Click **Connect** to begin viewing the selected Desktop. An Authentication pop-up window might appear, requesting you to enter your username and password. Type vnc and labvnc, click **Log On**.

Ultr@ VNC
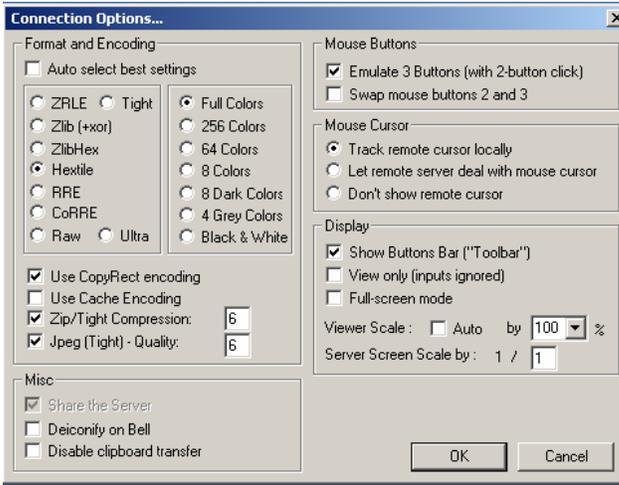

Fig. 3: Connection Options
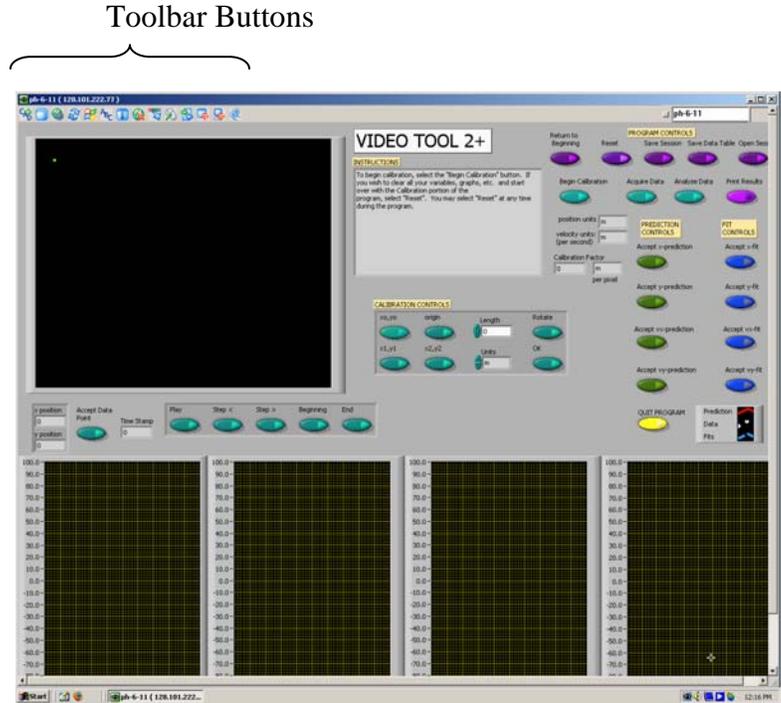
Toolbar Buttons

Fig. 4: Sample view of a student screen

Refer to Figure 4 for a sample view of a student screen. You can resize the window of the student screen using the arrows in the bottom right corner.

Use the toolbar buttons to navigate Ultr@VNC, as seen in Figure 5. Most buttons are self-explanatory, but selected descriptions are given on the next page.

Send Ctrl+Alt+Del to host

Show Connection Options

Send Custom Key

Show Status Window

Hide Toolbar Buttons

Open File Transfer

Select Single Window

Select Full Desktop

Host computer number

Fig. 5

Toggle Fullscreen mode (On/Off)

Refresh Screen

Send 'Start' (Ctrl+Esc) to host

Close Connection

Toggle Remote Input & Remote Blank Monitor (On/Off)

Open Chat
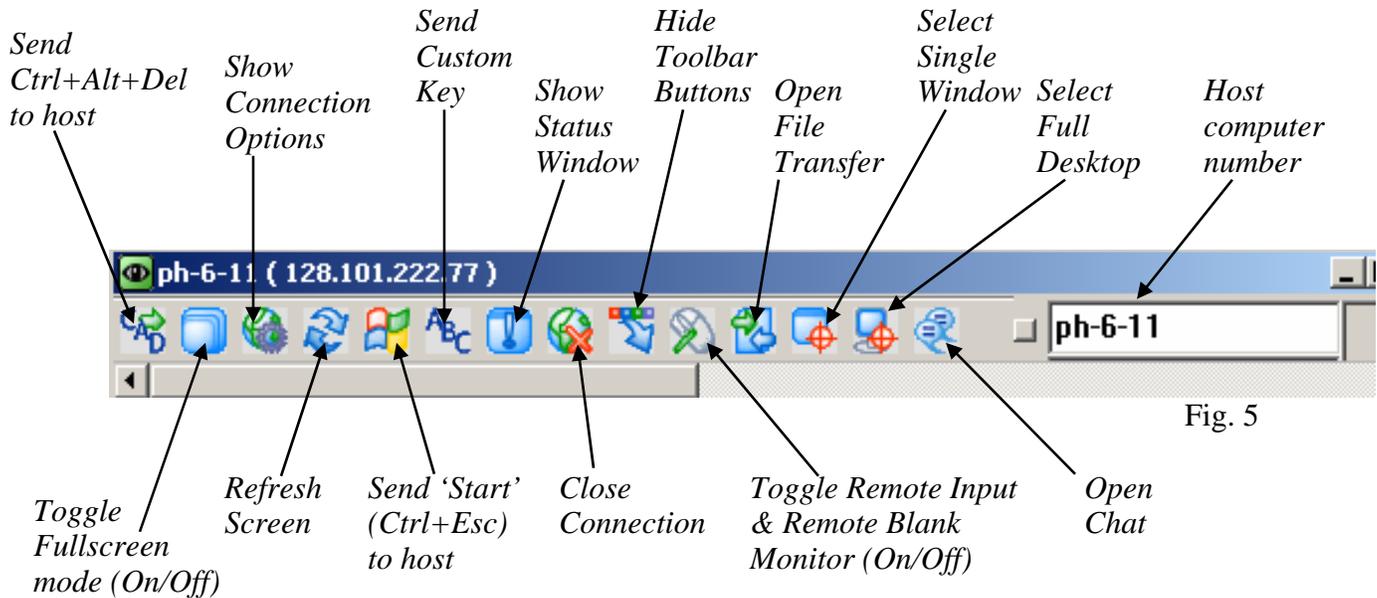
Selected Descriptions for Toolbar Buttons:

- ***Send Ctrl+Alt+Del to host*** will bring up the physics logout window on the student's computer.
- ***Send 'Start' (Ctrl+Esc) to host*** will depress the start button on the student's computer, giving you the power to access programs, etc. from the host computer.
- ***Show Connection Options*** will display the same pop-up window that is available from the ***Options*** button of the initial ***Connection*** window (Figure 3).
  - There are three options for the *Mouse Cursor*: Track remote cursor locally, Let remote server deal with mouse cursor, and Don't show remote cursor.
  - The first two options appear to be a shared-control option between the student and instructor computers, with slight differences between what is seen on each screen.
- ***Toggle Remote Input & Remote Blank Monitor (On/Off)*** gives total control to the instructor by disabling the student's computer mouse.
- ***Select Single Window*** gives you the option to select and view one window that is open on a student's screen, providing multiple windows are opened at the same time. When this toolbar button is depressed, a crosshair appears and you can use this to click on the window to be viewed. Any remaining windows are "blacked out". To return to the fullscreen view, click the ***Select Full Desktop*** toolbar button.
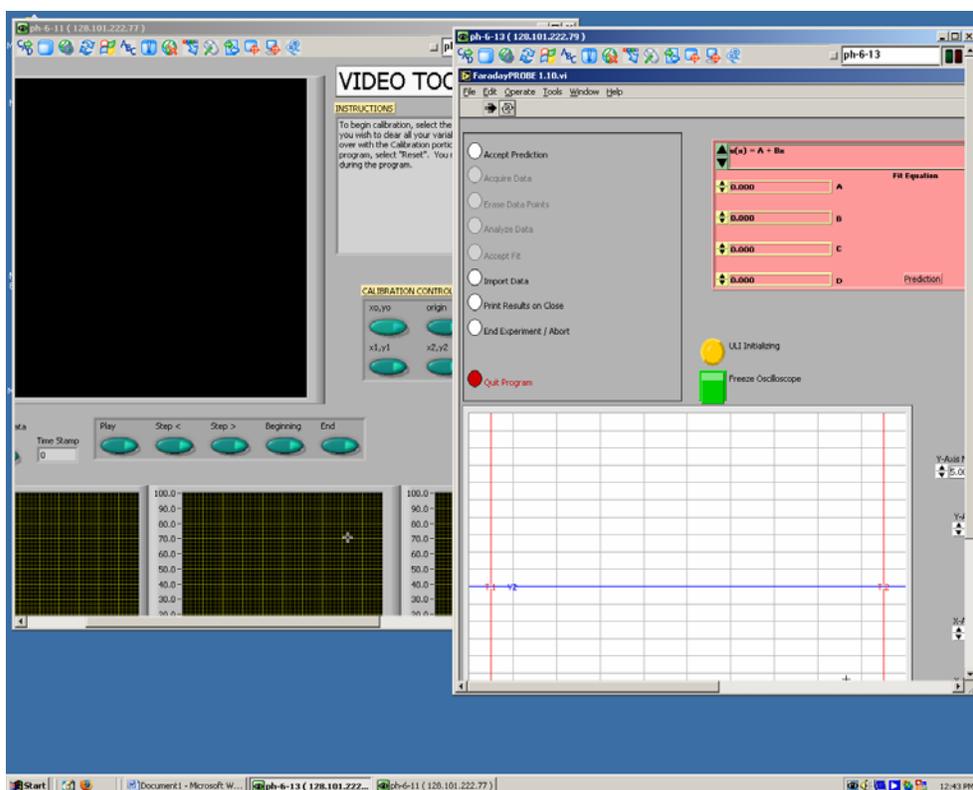
It is possible to display multiple student screens on an instructor desktop, but you must reopen the Ultr@ VNC program each time and resize the windows (or only view one screen at a time).

Fig. 6

To exit Ultr@ VNC, click ***Close Connection***.

For more information, the software developers' website is:
http://www.ultravnc.com/

Digital Projector Reference:

Every lab room has a Panasonic® projector fixed to the ceiling with connections to a wall unit. This is useful to project documents or programs onto a pull-down screen for easy viewing by the entire class.

To project the instructor computer, log in using either a student ID and password or a TA username and password.   This computer should have a serial cable connected from *Input 1* of the monitor to *Local Monitor* of the black Output box, and another cable from *Data Display* of the black Output box to *Computer* of the silver wall unit.

Turn on the Panasonic® projector by depressing the large *Power* button. You might need to use a meter stick to reach it. If the computer screen does not immediately display, cycle through the input by pressing the *RGB* button. Most will display on *RGB 1*. Turn off the projector by pressing *Power* twice.

Silver wall box:

Video   Computer

L-Audio-R   Computer audio

Computer Monitor

Input 1   Black box

Output

Local Monitor   Data Display
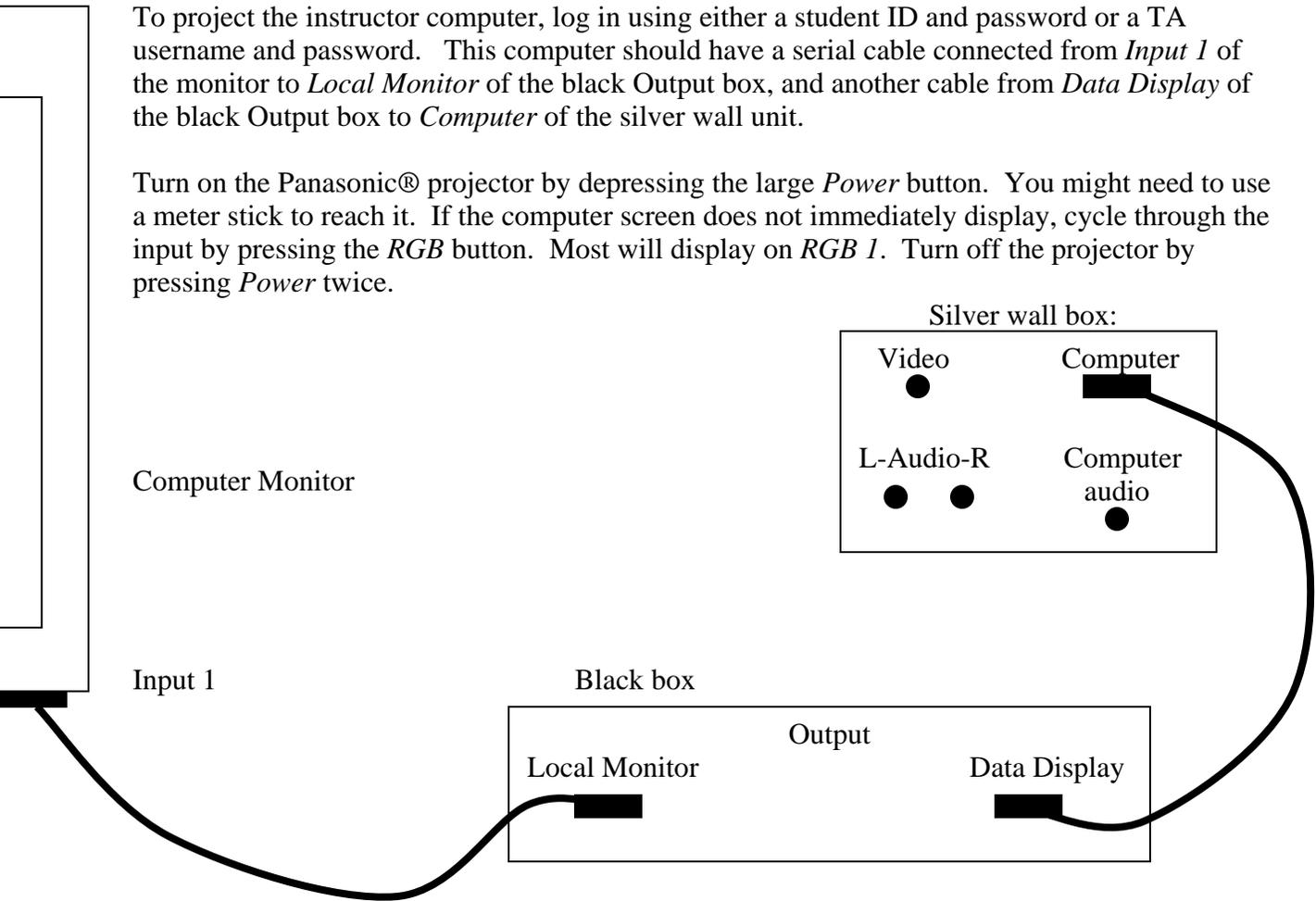
IX. To install a camera:

1. Hook up new camera to firewire cable.
2. Launch the "Measurement & Automation" application (icon on desktop)
3. On the left-hand panel *(shown below),* expand "Devices and Interfaces"
4. On the same panel, expand "NI-IMAQ IEEE 1394 Devices"

MAX has a generic camera setup initially; this needs to be switched to the Unibrain camera by right clicking on the device and selecting the NI-IMAQ driver using the menu. **If a device does not appear, you likely have a bad camera (see next page.)**
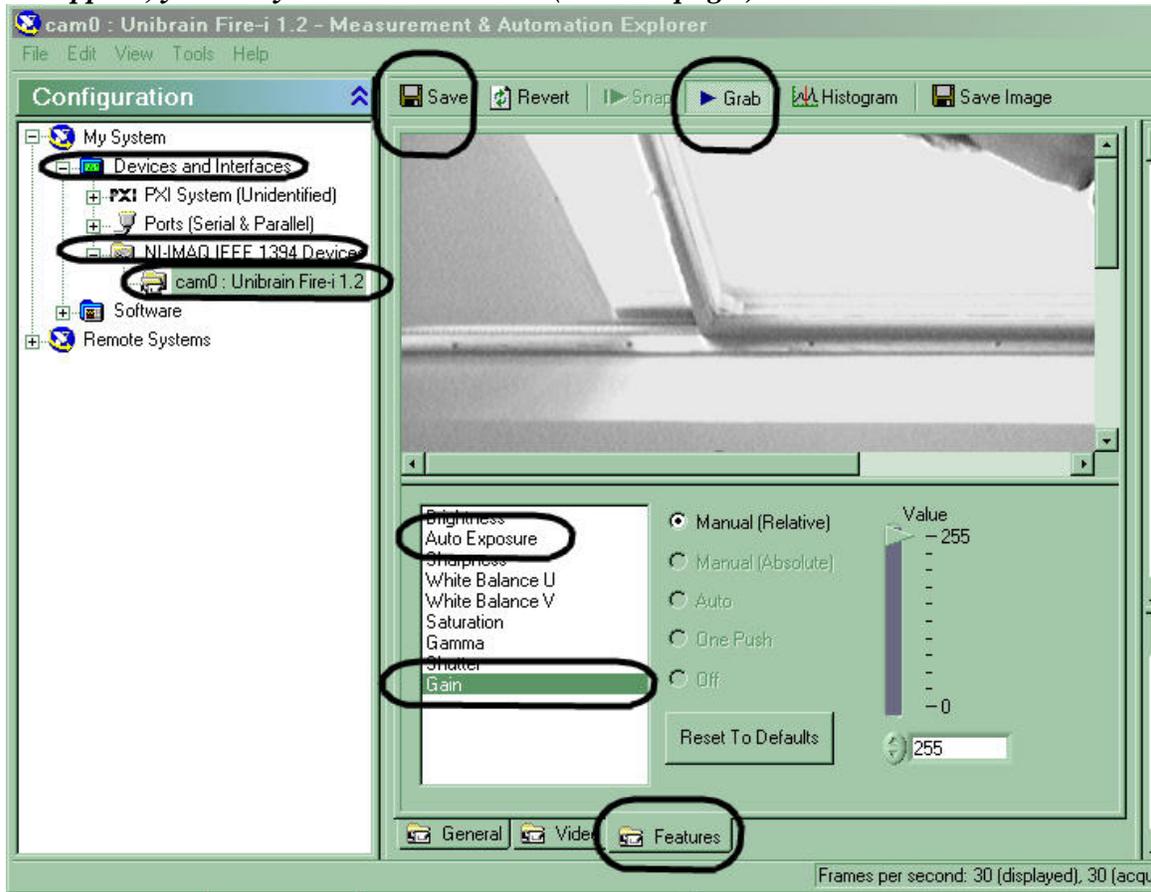
5. On the same panel, click the icon for the camera ("Unibrain cam0:…")
6. Click GRAB *(along the top, shown above)* to see what the camera sees
7. Click the Video tab *(along the bottom, next to the circled features tab)*
8. Change Video Mode by selecting the last option in the pull down menu (640x480 Y (Mono8)(30fps))

To help your students get useful data from the video camera, it may be necessary for you to adjust additional camera settings. (These settings should be stable, but may change when a camera is unplugged from its computer.)

9. Click the FEATURES tab *(along the bottom, shown above)*

In the picture below, "gain" is selected, and is set to its maximum value of 255.

10. **Set GAIN to its MAXimum value (this may cause a "washed-out" image).**
11. **Set AUTO EXPOSURE to the MINimum value that shows a useful image (depending on camera and lighting, 180 or below may be possible).**

12. Click <u>SAVE</u> (*top left*) to save the settings.
13. <u>Exit</u> the "Measurement & Automation" application.

"Good" camera settings	"Bad" camera settings (factory default)
- short Exposure time - high amplification (Gain) Motionless objects may look grainy; objects in motion have well-defined edges (The ball below has fallen through the entire frame).	- long Exposure time - low amplification (Gain) Motionless objects look nice; motion causes blur (The blurred ball below has fallen only a short distance).
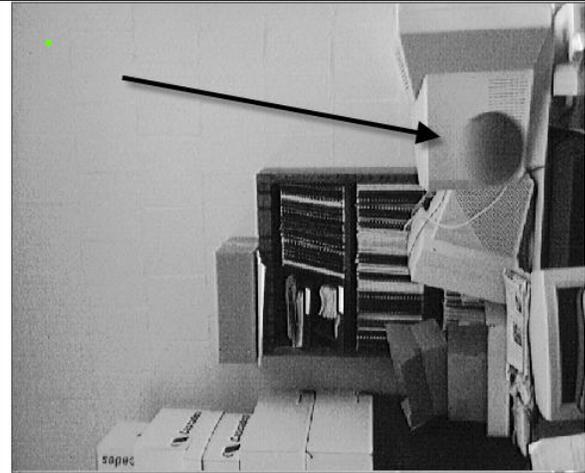
To check to see if a camera is bad:

1. Hook up camera to firewire cable.
2. Launch the <u>"Measurement & Automation"</u> application (icon on desktop)
3. On the left-hand panel, expand <u>"Devices and Interfaces"</u>
4. On the same panel, expand <u>"NI-IMAQ IEEE 1394 Devices"</u>

If a device (camera) does not appear, you have a bad camera, cable or firewire card. Check the cable, making sure the connectors are intact and not plugged by debris. Look at the firewire card in the back of the computer - try to use the port that looks best. If the camera still does not work, get a new camera and start over. If the new camera doesn't work, reboot the computer and try again, possibly with a third camera. You can also use the TA computer and see if the camera will work on that machine. Remember to submit an electronic lab problem report form about any unresolved problems and bad cameras.

X.Accessing Pre-Lab Computer Quiz

The pre-lab computer quiz can be accessed from web site ***http://webct.umn.edu*** .

1. Select **Site Log In** link.
2. Click on **myU Login** under **Access WebCT sites**.
3. A small screen will appear, click **Click here to sign in**. Then sign in using you X.500 ID.
4. You will see the list of the courses you teach under **Courses** menu. Clicking a course will bring the list of available quizzes.
5. To see the grades, choose the **Gradebook** tab. To see the students in a specific section, choose **Find Members**. Search for the section ID in column **Section**.

XI. Useful Information for TAs

Websites

General

http://www.tc.umn.edu/ (University of Minnesota, Twin Cities Campus)
http://www.physics.umn.edu/ (U of M, School of Physics and Astronomy)
http://www.onestop.umn.edu/ (Information and services for students and staff)
http://webct.umn.edu/ (Pre-Lab Computer Quiz)

Electronic Grading

http://www.physics.umn.edu/resources/classes/gradebooks/

Class Rosters

http://www.umreports.umn.edu/ (follow the link 'class lists')

Physics Education

http://groups.physics.umn.edu/physed/ (U of M, Physics Education Home)
http://groups.physics.umn.edu/physed/Research/CRP/on-lineArchive/ola.html
(Context rich problems On-line Archive)

Phones

Front Office (MetteMarie Stewart)	624-7375	(Room 148)
Lab Services Coord. (Sean Albiston)	625-3598	(Room 135)
Mentor TAs (Emir Gumrukcuoglu)	625-7330	(Room 312)
(Brita Nellermoe)	625-9323	(Room 161B)
(Matthew Parker)	626-7764	(Room 79)

Useful things to know:

1. In case of emergency if you can't fulfill your TA duties, the phone number to contact with is Mette Marie Stewart, Rm 148, 612-624-7375. (mette@physics.umn.edu)

2. If you encounter problems about the equipment in your lab Sean Albiston, RM 137 of demonstration room, is the right person to contact with, or Click on the LabHelp icon on any computer in your lab and place your request. If you can't find Sean, contact Brian Anderson (Lecture Demonstration Facility off room 170, 625-3598)

3. For the few weeks, you can get name tags and pencils from room 148.

4. Copy codes are the first 4 digits of the course number you are teaching.

5. The code for the computer lab (room 137) can be found at
   http://www.physics.umn.edu/resources/computing/labcode.html

6. Teaching supplies could be asked from room 80 (the budget number is 533-1005).

7. If you want to have a review session for your students, you could do a room reservation from room 148 (do this a couple of days in advance).

8. Talk to Graham Allan (S43, 624-5049, allan@physics.umn.edu) about your network issues.

9. Judy Soine and Julie Murphy are the right people to talk to about your tuition or payroll questions.

10. If you have questions regarding to building maintenance Ginny Olson is the person to contact with.

11. Be aware of student fees that you will be paying each semester, it varies depending on being domestic or international student. You can find information about Tuition & Billing from Onestop.umn.edu

NOTES: