Instructor's Handbook

TA Orientation
School of Physics and Astronomy
Fall, 2004

Table of Contents

This work was supported, in part, by the U.S. Department of Education, Fund for the Improvement of Postsecondary Education (FIPSE), and by the University of Minnesota.

By: Patricia Heller, Kenneth Heller, Tom Foster, Jennifer Blue, Andrew Ferstl, Andrew Kunz, Vince Kuo, Laura McCullough, Kevin Parendo, and Masaya Nishioka, Alexander Scott

TA 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 since that serves the most undergraduates. A teaching team typically consists of one faculty member and four to five TAs. This team is responsible for all aspects of the course for about 140 undergraduates.

If you have a 25% appointment, you will be teaching one discussion session and one lab, with the same students (less than 20) in your discussion session and your lab. 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 on Thursdays, and labs meet throughout the week for 2 hours at a time.

Team Organization Meetings

Each week, the TAs and professor will meet as a team to discuss their course. This is the opportunity to discuss the mechanics of the course (e.g., who will grade what, who will proctor, etc.). However, the most important reason for the meetings is the communication between the different members of the teaching team. Important issues for this feedback 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 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.

It is important that you take an active role in these team meetings.

TA Seminar

All new TAs are required to take a course "Teaching Introductory College Physics (CI5540)" in the both Fall and Spring semesters. In the course, instructors will help you to become more comfortable with the decisions you need to make before and during your teaching. The fall semester course has one credit; the spring semester course has two credits because it includes the scores of TA summer orientation.

Preparation for Laboratory

You will only have a new laboratory to teach every 2 - 3e weeks. You should become very familiar with the equipment, and consult the Instructor's 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 which lab problems your students will do that week.

- You need to solve all the methods questions for the problems that your team assigned to your students. In the team meetings (and some All-TA meetings), you will discuss difficulties that students have had with the physics principles they need to do solve the lab problem.
- Students will solve computer laboratory preparation quizzes before each new lab. You will be shown how to use a program to check whether your students have completed their assigned programs before they get to lab (see page //). You should go through these questions before your students do, because some of your students might ask questions about them.
- Have a goal for each lab, something you want your students to learn. This should be decided in your team meetings after discussion with the professor and other TAs.

Teaching Laboratory Sections

Make sure you get to your laboratory room at least 5 minutes before class starts, and do not let the students enter until you are ready. Use this time alone to check the apparatus to make sure that it is all there, it is neatly arranged, and it is 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.

Preparation for Discussion Sections

- Solve the group problem students will solve in discussion section. Discuss with your team what aspect of the problem you expect will be difficult for the students.
- 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. 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.

Teaching Discussion Sections

Try to get to your assigned classroom several minutes early. If possible, you should be there before most of your students. You may need to tidy the classroom, clean the blackboard, rearrange the chairs (see Fig.1 and 2 on Page //), and/or write on the blackboard (i.e., the agenda for class, groups students should work with, or other announcements). 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 we will try to get it changed.

Office Hours

Office hours will be held in Physics 230. This is your chance to interact one-on-one with your 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.

Meeting with Your Mentor TA

You will each have a half hour appointment with your mentor TA once or twice in the semester. These meetings are to provide you with coaching to become better teachers. You might ask about problem students, difficulties grading, classroom management, course organization, and other questions you may have; you will also discuss other things that the mentor may have noticed in your section. Feel free to bring up anything else that relates to being a TA.

Attending the All-TA Meeting

//Every other week the mentor TAs will convene a lunchtime All-TA Meeting for the TAs of the introductory physics courses. These meetings will include an informal time to talk about teaching plus some time for a more formal discussion on how to handle difficult situations such as cheating and how to explain physics that has been difficult for students in the past. Since this meeting is optional, lunch will be provided by the Physics Department.

Grading Labs

You will be grading written lab reports every two or three weeks. 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 group must have the same policy.

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.

Grading Tests

- At this time, the estimate for how much time it takes to grade one of the most difficult problems is as follows:

$$(0.5\text{ hr classifying}) + \left(\frac{140\text{ probs}}{\text{quiz}}\right)\left(\frac{3\text{ min}}{\text{prob}}\right)\left(\frac{1\text{ hr}}{60\text{ min}}\right) + (0.5\text{ hr recording}) = 8\text{ hrs}$$

  On average, each TA will grade 3 such questions each term, plus one group problem (about 50 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 118).
- After you have completed the grading, you will enter the grades into the computer (see Ch. V, Entering Course Grades in this Handbook).
- 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 your team meetings.

Miscellaneous

If you get a chance, it is highly recommended that you go to lectures. It is a good opportunity to see exactly what is happening, and it also shows the students that you think lectures are important.

Final Exams and Lab Grades

Each TA will probably grade one or two final exam problems that will take about 8 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 term. In addition, you must be sure to have integrated your lab and homework grading into the course grading spreadsheet before the semester ends.

Average Time/Week During the 14-week Semester

Often, TAs want to know about how much time they should be spending on different duties. Your average weekly load during the 14 weeks of class for a 50% appointment should be approximately that listed below.

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	
Grading and Entering Grades:		
Labs	2.0 hrs	(average)
Tests and Homework	3.0 hrs	(average)
	5.0 hrs	
Feedback and Support:		
Meet with Mentor TA	0.5 hrs	
All - TA meeting	0.5 hrs	(optional)
	0.5 hrs	
Proctoring Tests:	1.0 hrs	
Miscellaneous:		1.5 hrs
(dealing with the front office, helping students outside of office hours, etc.)		
TOTAL	20.0 hrs/week*	

* The University does not recognize the time between terms as holidays. Although the Physics Department typically does not assign TA duties after final exam grades are recorded, this time must be counted to compute your actual average hours worked per week.

II. Using Your Mentor TAs

Your mentor TAs each work 10 to 20 hours a week to help you improve the skills you need to become a better TA which will ultimately improve the undergraduate education in the physics department.

Specifically, the duties of the mentor TAs are to:

- be active instructors in the TA orientation in August.
- organize and moderate the all-TA meetings in which we discuss:
  - teaching concepts relevant to the week's materials
  - problems with the previous lab
  - difficult students
  - your issues and ideas about teaching
- co-teach the TA Seminar in the Fall and Spring in which we discuss topics similar to those in the all-TA meeting, and other topics including:
  - lab preparation
  - assigned readings
  - grading exams and homework
  - alternative conceptions your students may have
  - problem-solving strategies
- visit several of your labs and discussion sessions to:
  - observe your teaching techniques,
  - help you with intervening in groups,
  - give you feedback and answer questions about your teaching.
- report any unrescinded inappropriate behavior (i.e. behavior that is harmful to students) to the director of undergraduate studies.
- 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 teaching letters of recommendation.
- be willing to discuss the graduate school experience (both good and bad.)

Remember, like any instructional relationship, the mentor TA can provide you with ideas and suggestions, but the only impetus to improve your teaching lies within you.

Cooperative Problem Solving

Page

I. How Do I Form Cooperative Groups?

The 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. Our recommended structures and their rationale are described in this section. The Figures contain a brief description of the research that supports each structure (taken from our published papers[1,2]), so they can be skipped or read, as you like.

Group Size and Assignment

We found that the optimal group size 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.

We recommend assigning 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 25 years of past research in cooperative group learning (including our own) indicates that students learn more when they work in ***mixed-achievement groups*** (i.e., based on past test performance) than when they work in homogeneous-performance groups. We do not, however, want students to wonder whom the high, medium and lower-performance students are in their groups, and so we 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 we called it 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. If you assign groups at the beginning, you will have fewer disgruntled students.

Figure 1. 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 precollege students.[3]

`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 of 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 learning gains.

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 term 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 a better group. Strategies for dealing with difficult group members are discussed in Section III.

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.

So 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, we change groups about 3 - 4 times in the first semester, but fewer times in the second semester. Since students are very sensitive to grades, we change groups only after a class test.

Figure 2. 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 precollege students.[3]

II. What criteria do I use to assign students to groups?

There are three criteria we use to assign 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.

> 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.

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 ESL students to same-gender groups of three.

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 use the criteria 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). We found it most convenient to use a spreadsheet.

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 in groups. 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 in groups assign them to groups.

Step ⑤. Resort 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 II 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 class, or make an overhead to take to class. 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.** This is particularly important for the computer labs. 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

Footnotes

1 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.

[2] 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.

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

III. How Can I Structure Group Work to Maintain Well-functioning Groups?

With structure and guidance, most students learn to function relatively well in groups. Occasionally, a group may exhibit one of the following dysfunctional 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).

This section gives several suggestions to help you maintain 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 3 and 4 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, 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.

Group Role Assignment and Rotation

Many different roles can be assigned for different types of tasks. For problem solving, we assign planning and monitoring roles that students have to assume when they solve challenging problems *individually* --Manager, Checker/Recorder, and Skeptic/Summarizer. When students solve problems, they have to be an executive *manager*, organizing a plan of action to solve the problem, and making sure they don't loose track of where they are and what they need to do next. At the same time, they have be a *recorder* of the solution. During this process, they must *check* their solution and make sure it *explains* what they did (to a knowledgeable reader) in a logical and organized fashion.

Figure 1. Bad Example of Seating Arrangement

Figure 2. Good Example of Seating Arrangement

Figure 3. Research on Assigning and Rotating Group Roles.

Our[1] observations of group interactions after we assigned roles indicated that the number of dysfunctional (e.g., one student dominates; students cannot resolve a difference of opinion) at any given time decreased from about 40% (2 in 5 groups) to about 10 - 20% (less than 1 out of every 5 groups). With fewer dysfunctional groups, an instructor has more time for appropriate and timely intervention to coach physics. This optimizes the learning of *all* students. Our interviews confirmed that students in groups with assigned and rotated roles were more comfortable with their group interactions, particularly at the beginning of the course. Our results are consistent with the research on precollege students.[2]

Finally, they have to continually be *skeptical*, asking themselves questions about each step -- "Am I sure that this is the right physics?" "This doesn't seem right. What have I forgotten to take into account?" A description of the group roles you will use is shown on the next page.

In *well functioning groups*, members share the roles of manager, checker, explainer, skeptic and conciliator (who solves conflicts and strives to minimize interpersonal conflict), and role assumption usually fluctuates over time. Students in these groups do not need to be reminded to "stick to their roles." But students in Students in dysfunctional groups *cannot* learn, and the result is very disgruntled students.

The purpose of the roles is to give you a structure to help you intervene with groups that are not functioning well or that are having difficulty with physics (see Section III, pages // to //). The roles help reduce the number of dysfunctional groups in several ways.

`Individual Responsibility.` At the beginning of an introductory class, some students have never participated in cooperative problem solving and do not know what they are supposed to do. The roles remind them of appropriate individual actions in a group.

`Optimal Learning.` Assigning and rotating roles helps to avoid both dominance by one student (the person with the pencil or keyboard has the real "power" in the group) and the free-rider effect. Assigning roles allows students to practice behavior that may not be natural or even socially acceptable. For example, "I don't want to be bossy, but I am the manager. Let's move on to . . ." In addition, we initially had some students who were too polite to disagree openly with the ideas of other group members (conflict avoidance). The role of "Skeptic" allowed these students a socially acceptable way to disagree. The roles also help groups that tend towards destructive conflict.

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 assign roles when you finally discover that you need them. As students become more comfortable and competent with CPS, the group roles slowly and naturally "fade" away from students' minds, except when you intervene with an occasional dysfunctional group.

Group Roles

In your discussion section 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 STEPS. KEEP YOUR GROUP "ON-TRACK." MAKE SURE EVERYONE IN YOUR GROUP PARTICIPATES. WATCH THE TIME SPENT ON EACH STEP.	*"First, we need to draw a picture of the situation."* *"Let's come back to this later if we have time."* *"Chris, what do you think about this idea?"* *"We only have 5 minutes left. Let's finish the algebra solution.*
RECORDER/CHECKER ACT AS A SCRIBE FOR YOUR GROUP. CHECK FOR UNDERSTANDING OF ALL MEMBERS. MAKE SURE ALL MEMBERS OF YOUR GROUP AGREE WITH EACH THINK YOU WRITE. MAKE SURE NAMES ARE ON SOLUTION.	*"Do we all understand this diagram I just finished?"* *"Explain why you think that . . . ."* *"Are we in agreement on this?"* *"Here, sign the problem we just finished!"*

SKEPTIC/SUMMARIZER	
HELP YOUR GROUP AVOID COMING TO AGREEMENT TOO QUICKLY. MAKE SURE ALL POSSIBILITIES ARE EXPLORED. SUGGEST ALTERNATIVE IDEAS. SUMMARIZE (RESTATE) YOUR GROUP'S DISCUSSION AND CONCLUSIONS. KEEP TRACK OF DIFFERENT POSITIONS OF GROUP MEMBERS AND SUMMARIZE BEFORE DECIDING.	"*What other possibilities are there for …?*" "*I'm not sure we're on the right track here. Let's try to look at this another way. . . .*" "*Why?*" "*What about using . . . . instead of . . . . ?*" "*So here's what we've decided so far. .*" "*Chris thinks we should . . . . , while Pat thinks we should . . . .*"

Figure 4. Research on Assigning and Rotating Group Roles.

When students were given a chance to discuss their group's functioning, their attitude about group problem solving improved. There was also a sharp decrease in the number of students who visited instructors during office hours to complain about their group assignment. In addition, groups that were not functioning well improved their subsequent effectiveness following these discussions. For example, in groups with a dominant student, the other group members were more willing to say things like: Hey, remember what we said last week. Listen to Kerry. She's trying to explain why we don't need all this information about the lunar lander's descent." In groups that suffered from conflict avoidance, there were comments like: "Oops! I forgot to be the skeptic. Let's see. Are we sure friction is in this direction. I mean, how do we know it's not in the opposite direction?" As usual, this result was consistent with the research on precollege students.[3]

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 group work, 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.

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 how well they are maintaining effective working relationships among members. For this purpose, you could use the *Group Functioning Evaluation* form shown on the next page. After the group has discussed and completed the evaluation, the instructor spends 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, we recommend doing group processing *every* class session. After two to three 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?	**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. How did each of us contribute to the group's success?

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

Group Signatures:

Manager: ________________________________.
Skeptic: ________________________________.
Recorder/Checker: ________________________________.
Summarizer: ________________________________.

Grading

The Zeroth Law of Education is:

0th Law

If you don't grade for 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 want 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 problem reports.

Footnotes

[1] 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

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

IV. How Do I Coach Students During Group Work?

There are two important instructor actions involved in efficient and timely coaching of groups 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.

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). 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.

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 with the physics or with group functioning.

This section contains recommendations of how to monitor and coach groups

Monitor and Diagnose

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 easily 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 applying physics principles to the problem solution, so you know which group to return to first.

Step 3. If several groups are having the **same** difficulty, you may 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 principles are introduced. If about half of your groups are doing this, stop the whole class. Remind your students that the first step in problem solving is a thorough analysis of the problem *before* the generation of mathematical equations.

If you begin intervening too soon (without first diagnosing all groups), it is not fair to the last groups. By the time you recognize that all groups may have the same difficulty, the last groups will have wasted considerable time.

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, but 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.

In *well functioning groups*, members share the 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." For dysfunctional groups, however, group roles are an important part of *all* intervention strategies. For example, one way to intervene with a dysfunctional group (e.g., a dominant student, one person working alone) is to ask: "Who is the manager (or skeptic/summarizer, or recorder/checker, depending on the dysfunctional group behavior)? What should you be doing to help resolve this problem?" If the student does not have any suggestions, then model several possibilities.

Coaching Dysfunctional Groups

First Few CPS Sessions.

In the first CPS sessions, students with no prior experience with cooperative learning do not understand their role in a group co-construction of a problem solution. There is a tendency to solve problems individually, especially if there is a disagreement within the group. The three examples below illustrate some common difficulties and possible interventions for the first CPS sessions.

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.

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. Manager and Skeptic/Summarizer put your pencils away and work with the Recorder/Checker to solve the problem."

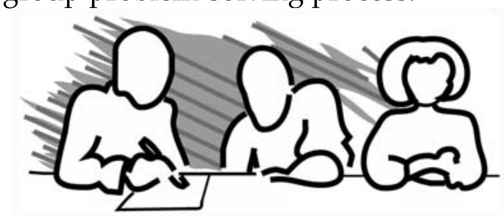
If necessary, make the students rearrange their chairs so they can all see what the Recorder/Checker is writing. If the students persist in solving the problem individually and only then return to the group to compare answers, explain again that they should be solving the problem together. Take the pencils from the Manager and Skeptic (return them at the end of class), and have the group read the Group Role sheet again. 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.

Occasionally, 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 procedures 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 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 do 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 role description from the Group Role sheet.] 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.

Later CPS Sessions.

With appropriate structure (see Section II) and coaching, most students learn to function in groups relatively well. Occasionally, however, a group may exhibit one of the following dysfunctional behaviors.

- Lower-achievement members sometimes "leave it to John" to solve the group problem, creating a *free-rider* effect. At the same time, higher achieving group members may expend decreasing amounts of effort to avoid the *sucker* effect. This sucker effect is unusual when group problems are graded occasionally.

- Higher-performance 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 *dominant student* or *the rich-get-richer* effect).
- Groups with no natural leaders may avoid conflict by "voting" or not making any decision 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*).

The last section included an example of how to intervene in a group with a “free-rider.” The two examples below suggest how to coach groups with a dominant students or a conflict.

`Example 1: 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.

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 either have the group read their *Group Role* sheet (early in course) or make a suggestion, such as: “For each step in your problem solving process, ask each member of your group what they think.” Point to a specific part of the group’s solution and model some specific questions the Manager could ask.

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 part of the group’s solution and model some specific questions.] 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 specific parts of the group’s solution and model specific questions the skeptic could ask.]

`Example 2: Conflict Avoidance or Destructive Conflict.`

You observe a group that is struggling to come to a decision, but does not appear to have any strategy to reach a decision (conflict avoidance) or a group that is arguing loudly, but does not appear to be resolving their conflict (destructive conflict). Ask the group: "Who is the Skeptic/Summarizer (or Summarizer in a four-member group)? I noticed that you are having difficulty deciding . . . . . Summarizer, what could you be doing to help the group come to a decision that is agreeable to all of you? If the Summarizer has no idea, then either have the group read the *Group 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.

Coaching Groups with Physics Difficulties

As the number of dysfunctional groups decreases, you will spend more of your time coaching groups that are having difficulty applying physics concepts and principles to solve the problem. The general approach to coaching is 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 with physics difficulties.

`Step 1.` Before you intervene, listen to the discussion in a group for a few minutes and look at what the checker/recorder is drawing and writing. Diagnose the group's specific difficulty. A checklist of common student difficulties is shown in Figure 6 on the next page

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

- Use Group Roles. Point to something on the answer sheet and state the general nature of the difficulty or error. Then ask: "Then ask: "Who is the manager (or skeptic/summarizer, or recorder/checker)? What could you be doing to help resolve this problem?" If the student/group does not have any suggestions, then model several possibilities.
- General Questions. If you can not point to something specific written on the group's answer sheet, begin by asking the group some general questions to find out what they are thinking, such as: (a) What are you doing? (b) Why are you doing it? and (c) How will that help you?

`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.

Figure /./

Analyze the Problem

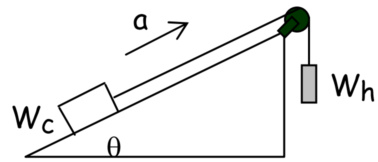
1. **Picture or Diagram is missing, misleading, or inaccurate**
    a. picture/diagram missing
    b. picture/diagram missing important objects or interactions
    c. picture/diagram includes spurious (irrelevant) objects or interactions
    d. other incorrect diagrammatic translations of problem information
2. **Relevant variables not assigned and clearly labeled**
    a. many important variables are not defined
    b. defined variables are not clearly distinguished from each other
3. **Approach invalid, too vague, or missing**
    a. application of principles is inappropriate
    b. misunderstanding of fundamental principle
    c. simplifying approximations not stated or inappropriate
4. **Necessary fundamental principles missing**
5. **Incorrect or invalid statement of known values or assumptions**
6. **Incorrect assertion of general 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, such as $a_1=a_2$.
    d. misunderstanding of a physics concept
7. **Incorrect statement of target variable or no target stated**
    a. target variable doesn't correspond to question in Approach
    b. does not explicitly state target variable
    c. wrong target
8. **Major misconception**

Plan the Solution

9. **Poor use of the physics description to generate a plan**
    a. physics description was not used to generate a plan
    b. inappropriate equation(s) was introduced
    c. undefined variables used in equations
10. **Improper construction of specific equations**
    a. inappropriate substitution of variables into general equations
    b. numerical values were substituted too soon
11. **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
12. **Plan cannot be executed**
    a. there are not enough equations (usually an equation is needed from analysis of problem situation)
    b. a relationship was counted more than once

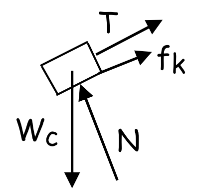
Examples of Coaching Using Group Roles

Suppose your students are solving a modified Atwood machine problem, as shown in the diagram at right. As part of the solution, students must find the tension of the rope. Below are some examples of a coaching technique that uses group roles.



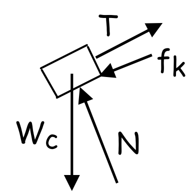
Example 1: Misunderstanding of Physics Concept

You observe that a group has drawn the frictional force in the wrong direction on their diagram. 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?" When the skeptic has responded (e.g., Does each interaction result in a push or a pull on the carton? In what direction?), then leave the group.



Example 2: Improper Construction of Specific Equation

You observe that a group has drawn a correct force diagram, but there is a sign wrong for the frictional force in their Newton's 2nd Law component equation:



$$\sum F_x = ma_x$$

$$T - W_c \sin\theta - \mu W_c \cos\theta = \frac{W_c}{g} a$$

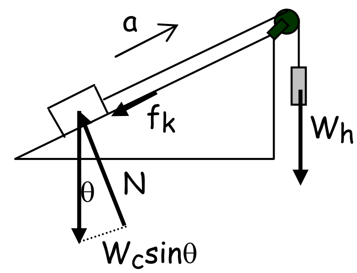
Point to the force diagram *and* the equation: "You have made a mistake in translating from your diagram to this equation. Skeptic, what questions could you ask about each translation?" When the group has responded (i.e.,?), then leave the group.

Example 3: Diagram Missing

You observe that a group has not drawn a separate force diagram. But their 2nd Law equation is correct except for the wrong sign for the frictional force. Point to the equation: "There is a simple mistake in this equation. Manager, what do you think is an important part of analyzing a problem that could have led to a mistake in this equation?" When the group has responded with "a force diagram," leave the group.

Example 4: Major Misconception

You observe a group that has not drawn separate force diagrams for both the carton and the hanging weight. Instead, they sketched some forces on the picture, as shown at right. In addition, they did not start their equations with Newton's Second Law in it's general form, $\Sigma F_x = ma_x$. Instead, the first equation is:



$$T = W_h - f_k - W_c \sin\theta$$
$$= W_h - \mu W_c \cos\theta - W_c \sin\theta$$

Equations of this type often indicate a misconception about Newton's 2nd Law. We have found that about 20% of students in the calculus-based course solve Newton's Law problems by setting the unknown force (tension in this problem) equal to the sum of the known forces (in this case all the other forces acting on the carton and the hanging weight). [In addition, about 20% solve Newton's Law problems by setting the unknown force (e.g., tension) equal to "ma," or by setting the sum of the forces equal to zero even when there is an acceleration.]

Point to the equation: "This equation is wrong. Checker/recorder (or Summarizer), could you describe how your group arrived at this equation?" Specific follow-up questions will depend on the response of the group. If you have Newton's Second Law ($\Sigma F_x = ma_x$) on the Problem & Information sheet, then you could point to this equation and ask the group what this equation means. Finally, you may need to coach the group through drawing free-body force diagrams for each object (carton and hanging weight).

General-Questions Coaching Technique

Sometimes, by the time you get to a group, students are having several interrelated problems. Sometimes it is impossible to identify a specific error. Your intervention with this group will take longer. You can start coaching by asking the group: (a) What are you doing? (b) Why are you doing it? and (c) How will that help you? This often provides you with enough information to diagnose the problems and deal with them one at a time. Always try to ask questions, rather than give answers.

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. An example of an opening move is shown in Figure1 on the next page.

Middle Game (~ 35 minutes). This is the learning activity -- students work collaboratively to solve the problem. During this time, your role is one of listener and facilitator. You circulate around the room, listening to what students in each group are saying and observing what the Checker/ Recorder is writing. You intervene when a group needs to be coached on an aspect of physics or is not functioning well. 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.

End Game (~ 10 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?

Figure 1. Example of Group Practice Problem,, Opening Moves, and End-game Questions

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.

Example of Opening Moves

We have been studying the 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 *when and how to apply these principles.*

You will have 35 minutes to work on the problem. At the end of that time, you will be asked to draw your diagrams and list the equations you used to solve the problem on the board.

Example End-game Questions

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 diagrams, or the same physics?

Look at the 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?

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. Examples of some end-game questions are shown in Figure 1 above.

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, on overhead or written on board)
- ❑ Photocopies of Problem & Useful Information *(one per person)* OR □□□□ of useful information to put on board
- ❑ Photocopies of Answer Sheet (optional) or 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 Group Roles Sheet

	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; 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 (optional)	• Solve the problem: - participate in group discussion, - work cooperatively, - check each other's ideas. • Finish work on problem • 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 (optional) ⑦ Pass out the problem solution as students walk out the door.	• Participate in class discussion

III. Detailed Advice for TAs about
General Discussion Section Lesson Plan

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.]

Check out the equipment you will need to use. If you are using the blackboard, you need time to 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 (optional, see below)

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 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 specific 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. Provide 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.

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 (~ 25-30 minutes)

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

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

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

After group pictures and equation list 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 such as:

- ♦ 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, instructors will answer their own questions and we won’t have to think. We recommend 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: “Group 3, 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:

- Which representations on the board include all the assumptions and information necessary to solve the problem? Why is this important?
- Do you think the assumptions you needed to make to solve this problem (no transfer of energy or momentum) made a big difference in your answer? Why or why 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 (optional, ~ 5 minutes)

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

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

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

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

Good group problems encourage students to use an organized, logical problem-solving framework instead of their novice, formula-driven, "plug-and-chug" 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” on all solution paths that do not involve using a logical and organized problem-solving framework.

- ✓ It is difficult to use a formula to plug numbers to get an answer.
- ✓ 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.]
- ✓ It is difficult to solve the problem without first analyzing the problem situation.
- ✓ Physics words such as “inclined plane,” “starting from rest,” or “inelastic collision” are avoided as much as possible.

In addition, group problems should have an appropriate *level of difficulty* for its intended use (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. **Difficult mathematics is best accomplished by individuals, not by groups.** So problems that involve long, tedious mathematics but little physics, or problems that require the use of a shortcut or "trick" that 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., $v_f^2 - v_o^2 = 2ad$).

The application of some of these criteria to the Skateboard Problem (page 36) is shown on the next page.

Table 1. Criteria for A Good Group Problem

Criteria for Group Problem	Skateboard Problem
❶ **A group problem must be designed so that:**	
✓ There is something to discuss *initially* so that *everyone* (even the weakest member) can contribute to the discussion.	Students need to spend time initially drawing a picture of the situation.
✓ There are several decisions to make in solving the problem.	Students must decide what assumptions to make and what their target variable will be.
❷ **A group problem must be *challenging* enough so that**:	
✓ Even the best student in the group cannot immediately see how to solve the problem, and all students feel good about their role in arriving at a solution.	The problem cannot be solved by substitution of known values into momentum or energy equations.
✓ Knowledge of basic physics concepts is necessary to interpret the problem.	Students must apply the conservation of momentum and the conservation of energy.
✓ Students' alternative conceptions about the physics naturally arise and must be discussed.	Students must understand the *difference* between conservation of energy and momentum, and when it is appropriate to use these principles.
❸ **At the same time, the problem must be *simple* enough so that:**	
✓ The mathematics is not excessive or complex.	The problem requires only simple algebra.
✓ The solution path, once arrived at, can be understood, appreciated, and easily explained to all members of the group.	Once students have decided when and how to apply the conservation of momentum and energy, the solution is straightforward.
✓ A majority of groups can reach a solution in the time allotted.	Figuring out *how* to solve the problem, which takes the most time, can be done in the time allotted (about 35 minutes).

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://www.spa.umn.edu/groups/physed/

V. Decision Strategy for Judging Problems

Outlined below is a decision strategy to help you decide whether a problem is a good individual test problem, group practice problem, or group graded/test problem.

1. *Read* the problem statement. *Draw* the diagrams and *determine* the equations needed to solve the problem.

2. *Reject* if:
   ____ the problem can be solved in one step,
   ____ the problem involves long, tedious mathematics, but little physics; or
   ____ the problem can only be solved easily using a "trick" or shortcut that only experts would be likely to know. (In other words, the problem should be a straight-forward application of fundamental concepts and principles.)

3. *Check* for the twenty-one characteristics (see page 47-53) that make a problem more difficult:

Approach	Analysis	Mathematical Solution
1. Cues Lacking ___ A. No target variable ___ B. Unfamiliar context 2. Agility with Principles ___ A. Choice of principle ___ B. Two principles ___ C. Abstract principle 3. Non-Standard Application ___ A. Atypical situation ___ B. Unusual target	4. Excess or Missing Info. ___ A. Excess data ___ B. Numbers required ___ C. Assumptions 5. Seemingly Missing Info. ___ A. Vague statement ___ B. Special constraints ___ C. Diagrams 6. Additional Complexity ___ A. >2 subparts ___ B. 5+ terms ___ C. Vectors	7. Algebra required ___ A. No numbers ___ B. Unknown(s) cancel ___ C. Simultaneous eqns. 8. Targets Math Difficulty ___ A. Calc/vector algebra ___ B. Lengthy algebra

4. *Decide* if the problem would be a good group practice problem (20 - 25 minutes), a good group test problem (45 - 50 minutes), or a good (easy, medium, difficult) individual test problem, depending on three factors:
   (a) the complexity of mathematics,
   (b) the timing (when problem is to be given to students), and
   (c) the number of difficulty characteristics of the problem.

   Use the tables on the following page

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

Type of Problem	Timing	Diff. Ch.
Individual Problems can be easy, medium-difficult, or difficult: Easy	 • just introduced to concept(s) • just finished study of concept(s)	 0 -1 1 - 2
Medium-difficult	• just introduced to concept(s) • just finished study of concept(s)	1 - 2 2 - 3
Difficult	• just introduced to concept(s) • just finished study of concept(s)	2 - 3 3 - 4

There is considerable overlap in the criteria, so many problems can be judged both a good group practice or graded/test problem *and* a good easy, medium-difficult, or difficult individual problem.

VI. Difficulty Characteristics of Problems

There are twenty-one characteristics of a problem that can make it more difficult to solve than a standard textbook exercise. These difficulty characteristics are described below. Two problems are used to illustrate some of these difficulty characteristics. These problems and their partial solutions are shown in Figures 1 and 2.

Approach

The traits in the Approach category are grouped together because they all affect how a student decides which concepts, principles and laws to apply to a problem. In traditional textbook problem this is often given to the students either by a direct statement, such as "the carts have an inelastic collision" or merely by placing the problem at the end of the chapter under a subheading such as “Inelastic Collisions.” Without such cues, the following 7 problem traits can make it more difficult for students to decide how to approach a problem.

1. Problem statement lacks standard cues

Novice problem solvers often decide on an approach from the "cues" in a problem statement. The two difficulty traits in this subcategory thwart this tendency.

A. `No explicit target variable.` The unknown variable of the problem is not explicitly stated. Problems with this difficulty trait typically include statements such as: “Will this plan (design) work?” or “Should you fight this traffic ticket in court.”

B. `Unfamiliar context.` The context of the problem is *very* unfamiliar to the students (e.g., cosmology, molecules). The CO_2-ion problem (Figure 2, page 49) is an example of a classic Coulomb’s Law problem that is more difficult to solve because of students’ lack of familiarity with an abstract molecular context.

2. Solution Requires Agility in Using Principles

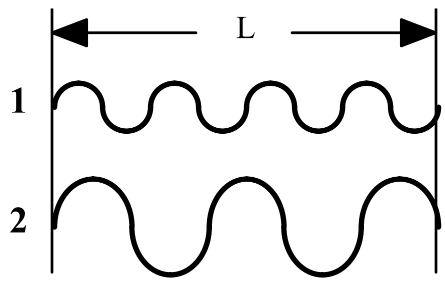
As novices in physics, most students are not initially very adept at using fundamental principles they just learned, or in making connections between principles. Problem statements that require the students to appreciate a concept’s complexity will be more difficult for them. The next three difficulty traits are examples of how problem statements can force students into be fluent with principles.

A. `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.

Figure 1: Engine Vibration Problem and Partial Solution

You are working for an aerospace company on a team assigned to fix a design error in a new jet engine. It is important for the design that none of the engine parts vibrate too much during normal engine operation. This engine contains a control wire that is held at both ends. The wire develops a standing wave with 7 nodes (not counting the ends) at the engine turbine's maximum rotational speed of 45,000 revolutions per minute. The amplitude of this standing wave is not large enough to be a problem. A problem occurs, however, at a lower engine speed, where a larger amplitude standing wave with 4 nodes (not counting the ends) develops. You have been assigned to calculate the engine turbine's rotational speed when the 4-node standing wave occurs. The lead engineer tells you that the frequency of the standing wave on the wire is directly proportional to the turbine rotational speed. You also know that for any wave, its wavelength is related to its frequency and the speed of a wave on the wire.

<u>Problem Description and Approach</u>



when engine speed = 45,000 rpm

when engine speed = ???? rpm

Approach: Use the definition of the velocity of a wave.

<u>Mathematical Expressions Needed for Solution:</u>

From General Principle(s):	$v_1 = \lambda_1 f_1$	$v_2 = \lambda_2 f_2$	
From Problem Analysis:	$s_1 = \alpha f_1$	$s_2 = \alpha f_2$	(vague statement in problem)
	$4\lambda_1 = L$	$2.5\lambda_2 = L$	(from diagram)
	$v_1 = v_2$		(constraint)

7 equations and 8 unknowns: unknown L factors out of final solution

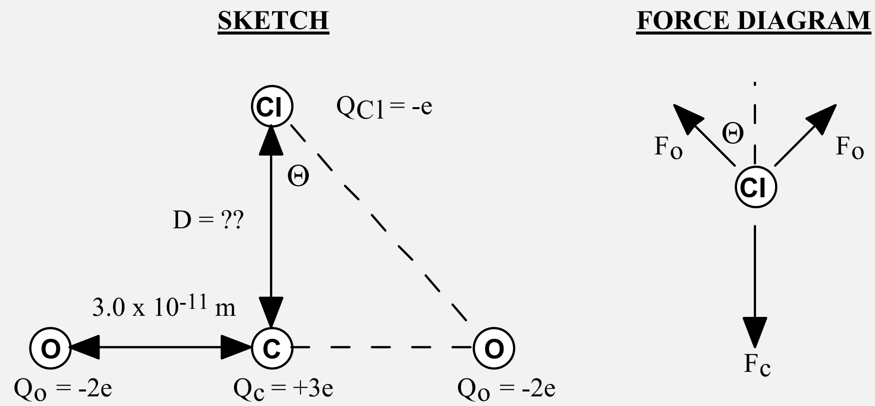
B. `Two general principles.` The correct solution requires students to use two or more major principles. Examples include pairings such as Newton's Laws and kinematics, conservation of energy and momentum, conservation of energy and kinematics, or linear kinematics and torque.

C. `Very abstract principles.` The central concept in the problem is an abstraction of another abstract concept. While concepts like angular momentum and electric fields are abstract, their presence alone does not warrant a difficulty trait. Rather, when the problem requires the students to use an abstract concept that is based upon another abstract concept, then this difficulty trait is present. Examples of very abstract principles include electric potential and magnetic flux.

Figure 2. $C0_2$-ion Problem and Partial Solution

You are spending the summer working for a chemical company. Your boss has asked you to determine where a chlorine ion of effective charge -e would situate itself near carbon-dioxide ion. The carbon dioxide ion is composed of 2 oxygen ions each with an effective charge -2e and a carbon ion with an effective charge +3e. These ions are arranged in a line with the carbon ion sandwiched between the two oxygen ions. The distance between each oxygen ion and the carbon ion is 3.0×10^{-11} m. What is the equilibrium distance for the chlorine ion relative to the carbon ion? Assume that the chlorine ion is on a line which is perpendicular to the axis of the carbon dioxide ion, and that the line goes through the carbon ion. For simplicity, also assume that the carbon-dioxide ion does not deform in the presence of the chlorine ion.

Problem Analysis



Approach: Use Newton's Law of Motion and Coulomb's Law..

Mathematical Expressions Needed for Solution:

From General Principle(s): $\sum \vec{F} = 0$ so $2F_O \cos\theta = F_c$ (vector analysis)

$$F_O = \frac{kq_O q_{Cl}}{D^2 + a^2} \qquad F_C = \frac{kq_C q_{Cl}}{D^2}$$ (from diagram, Coulomb's Law)

From Problem Analysis: $\cos\theta = \dfrac{D}{\sqrt{D^2 + a^2}}$ (from diagram)

Mathematical Expressions Needed for Solution:

$$2F_{O,Y} = F_C$$

$$2\frac{kq_O q_{Cl}}{D^2 + a^2}\cos\theta = \frac{kq_C q_{Cl}}{D^2}$$

Solution requires detailed algebra:

3. Non-standard Application of Concepts and Principles

Students typically learn new concepts or principles by solving problems that require only a simple, straightforward application of the concept or principle. For example, students initially learn Coulomb's Law by solving problems that require students to find the total force on a charge located at known distances from other charges. The two difficulty traits in this subcategory require students to generalize their problem-solving knowledge to atypical situations or combinations beyond the standard situations.

A. Atypical situation. The setting, constraints, or complexity is unusual compared with textbook problems. That is, the problem combines objects or interactions that are not normally put together. The CO_2-ion problem (Figure 2, page 49) has this trait since the electric field the chloride ion encounters is from three charges in a line instead of the usual dipole. Another atypical situation might include an energy conservation problem involving multiple potential energy terms in the total energy.

B. Unusual target variable. The problem involves an atypical target variable when compared with homework problems. The CO_2-ion problem (Figure 2, page 49) has this trait since the students must solve for the equilibrium distance, a distance that is usually supplied in standard problems.

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 9 traits are all examples of how problems that require a careful and complete qualitative analysis are more difficult for students to solve.

4. Excess or Missing Information

Typical textbook problems give exactly the information necessary to solve the problem. Consequently, some students use these values in helping them decide which "formulas" they need to solve the problem. Excess or missing information in a problem thwarts this naive strategy and requires students to analyze the problem situation to decide how to proceed

A. 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.

B. `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.

C. `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.

5. Seemingly Missing Information

The problem requires students to generate a mathematical expression from their analysis of the problem. This expression might be derived from their understanding of how real system work or from a careful diagram. The creativity involved in overcoming this class of obstacles is not normally encountered in textbook problems nor is it usually taught. There are three difficulty traits in this subcategory.

A. `Vague statement.` The problem statement introduces a vague, new mathematical statement. For example, if the problem statement tells the students that "A is proportional to B," then the students must not only translate the written statement into a mathematical expression, but then know where and how to use it. The engine-vibration problem has this difficulty trait (see Figure 1, page 48). Additional examples of statements that require a translation into a mathematical expression are: "The car has a weight of 1400 pounds, and 75% of that weight is carried by the front tires," and "The counterweight is always twice the mass of the package on the ramp."

B. `Special conditions or constraints.` The problem requires students to generate information from their analysis of the conditions or constraints. The engine-vibration problem (Figure 1, page 48) has this difficulty trait. Students must recognize from their analysis of this problem that the traveling wave velocities in the two resonance situations are equal: $v_1 = v_2$. Another example is the generation of the

relationship
$a_1 = a_2$ for the two masses in an ideal Atwood machine.

C. `Diagrams.` The problem requires students to extract information from a spatial diagram. The engine-vibration problem (Figure 1, page 48) has this difficulty trait. Students must use a diagram to relate the wavelength of a standing wave to the overall length of the wire by counting nodes. The CO_2-ion problem (Figure 2, page 49) also has this difficulty trait. Students must express the cosine of an angle between forces in terms of known and unknown distances.

6. Additional Complexity

The problems in this subcategory require students to be especially careful in their analysis and variable definitions. The more "pieces" students have to keep track of, the more difficult the problem.

A. `More than two subparts.` The problem solution requires students decompose the problem into more than two subparts. Two or more sub-parts can arise because there are more than two interacting objects or more than two important time intervals. Changing systems of interest for students can be hard. Also, novice problem-solvers will often lose sight of the problem goal through numerous subparts. Examples of this trait include such classic problems as the ballistic pendulum (which requires conserving energy before and after the impact, but not during the impact) or the massive-pulley Atwood machine (which requires analyzing the suspended masses and the pulley).

B. `Five or more terms per equation.` The problem involves five or more terms in a principle equation. Typical examples are problems in which 5 or more forces are acting on a single object along one axis, or there are 5 or more energy terms in the conservation of energy equation or finding the potential from 5 individual charges. Problem statements with this trait require special care in specifying variables and signs for each term

C. `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. For example, decomposing electric field vectors into components is one of the stumbling blocks in integrating the field of continuous charge distributions. The CO_2-ion problem (Figure 2, page 49) also demonstrates this difficulty trait. The solution requires the students to decompose the contribution to the net force from the oxygen atoms.

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.

7. Algebra Required

A strictly algebraic solution is challenging for many novice problem-solvers. Three problem types can require algebraic solutions.

A. `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.

B. `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. The engine-vibration problem (Figure 1, page 48) has this trait: there are 7 equations and 9 unknowns, but the length of the wire and the proportionality constant factor out of the solution.

C. `Simultaneous equations.` The solution requires solving simultaneous equations. Simultaneous equations are hard 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.

8. Targets Math Difficulties

The problems in this subcategory require students to use mathematics that is known to be problematic.

A. `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.

B. `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. The CO_2-ion problem (Figure 2, page 48) has this difficulty trait. This problem requires the students to correctly solve for the unknown that is part of a summation under a square root that is in the denominator.

VII. Examples of How to Judge Problems

Example 1. Engine Vibration Problem

1. *Read* the problem statement. *Draw* the diagrams and *determine* the equations needed to solve the problem.

   see Figure 1, page 48

2. *Reject* if:

   No the problem can be solved in one step,

   No the problem involves long, tedious mathematics, but little physics; or

   No the problem can only be solved easily using a "trick" or shortcut that only experts would be likely to know. (In other words, the problem should be a straight-forward application of fundamental concepts and principles.)

3. *Check* for the twenty-one characteristics (see page 47-53) that make a problem difficult:

Approach	Analysis	Mathematical Solution
1. Cues Lacking ___ A. No target variable ___ B. Unfamiliar context 2. Agility with Principles ___ A. Choice of principle ___ B. Two principles ___ C. Abstract principle 3. Non-Standard Application ✓ A. Atypical situation ___ B. Unusual target	4. Excess or Missing Info. ✓? A. Excess data ___ B. Numbers required ___ C. Assumptions 5. Seemingly Missing Info. ✓ A. Vague statement ✓ B. Special constraints ✓ C. Diagrams 6. Additional Complexity ___ A. >2 subparts ___ B. 5+ terms ___ C. Vectors	7. Algebra required ___ A. No numbers ✓ B. Unknown(s) cancel ___ C. Simultaneous eqns. 8. Targets Math Difficulty ___ A. Calc/vector algebra ___ B. Lengthy algebra **Total = 5.5**

4. *Decide* using Tables on page 46. This problem has a difficulty rating of 5 - 6, one in the approach, 4 in the analysis, and one in the mathematical solution. The mathematics involved is easy. This makes the problem too difficult for even a graded/test group problem! The problem should be rewritten to eliminate at least 1 of the difficulty characteristics in the analysis.

Example 2. CO_2-ion Problem

1. *Read* the problem statement. *Draw* the diagrams and *determine* the equations needed to solve the problem.

   See Figure 2 on page 49.

2. *Reject* if:

   _No_ the problem can be solved in one step,

   _No_ the problem involves long, tedious mathematics, but little physics; or

   _No_ the problem can only be solved easily using a "trick" or shortcut that only experts would be likely to know. (In other words, the problem should be a straight-forward application of fundamental concepts and principles.)

3. *Check* for the twenty-one characteristics (see page 47-53) that make a problem difficult:

Approach	Analysis	Mathematical Solution
1. Cues Lacking ___ A. No target variable ✓ B. Unfamiliar context 2. Agility with Principles ___ A. Choice of principle ___ B. Two principles ___ C. Abstract principle 3. Non-Standard Application ✓ A. Atypical situation ✓ B. Unusual target	4. Excess or Missing Info. ___ A. Excess data ✓? B. Numbers required ___ C. Assumptions 5. Seemingly Missing Info. ___ A. Vague statement ___ B. Special constraints ✓ C. Diagrams 6. Additional Complexity ___ A. >2 subparts ___ B. 5+ terms ✓ C. Vectors	7. Algebra required ___ A. No numbers ___ B. Unknown(s) cancel ___ C. Simultaneous eqns. 8. Targets Math Difficulty ___ A. Calc/vector algebra ✓ B. Lengthy math **Total = 6.5**

4. *Decide* using Tables on page 46. This problem has a difficulty rating of 6 - 7, three in the approach, 3 in the analysis, and one in the mathematical solution. The mathematics involved is easy, but long. This makes the problem too difficult for even a graded/test group problem! The problem should be rewritten to eliminate at least 2 of the difficulty characteristics.

Example 3. Skateboard Problem

You are helping your friend prepare for her next skate board exhibition. For her program, she plans to take a running start and then jump onto her heavy-duty 15-lb stationary skateboard. She and the skateboard will glide in a straight line along a short, level section of track, then up a sloped concrete wall. She wants to reach a height of at least 10 feet above where she started before she turns to come back down the slope. She has measured her maximum running speed to safely jump on the skateboard at 7 feet/second. She knows you have taken physics, so she wants you to determine if she can carry out her program as planned. She tells you that she weighs 100 lbs.

Assume that students have just started to study the conservation of energy and momentum.

1. *Read* the problem statement. *Draw* the diagrams and *determine* the equations needed to solve the problem.

2. *Reject* if:

   _No_ the problem can be solved in one step,

   _No_ the problem involves long, tedious mathematics, but little physics; or

   _No_ the problem can only be solved easily using a "trick" or shortcut that only experts would be likely to know. (In other words, the problem should be a straight-forward application of fundamental concepts and principles.)

3. *Check* for the twenty-one characteristics see page 47-53) that make a problem difficult:

Approach	Analysis	Mathematical Solution
1. Cues Lacking _√_ A. No target variable ___ B. Unfamiliar context 2. Agility with Principles ___ A. Choice of principle _√_ B. Two principles ___ C. Abstract principle 3. Non-Standard Application ___ A. Atypical situation ___ B. Unusual target	4. Excess or Missing Info. ___ A. Excess data ___ B. Numbers required _√_ C. Assumptions 5. Seemingly Missing Info. ___ A. Vague statement ___ B. Special constraints ___ C. Diagrams 6. Additional Complexity ___ A. >2 subparts ___ B. 5+ terms ___ C. Vectors	7. Algebra required ___ A. No numbers ___ B. Unknown(s) cancel ___ C. Simultaneous eqns. 8. Targets Math Difficulty ___ A. Calc/vector algebra ___ B. Lengthy algebra **Total = 3**

4. *Decide* using Tables on page 46. This problem has a difficulty rating of 3, two of which are in the approach. The mathematics involved is easy. This would make a decent group practice problem or a medium-difficult individual test problem. It is too easy for a graded/test group problem. If you were teaching this as a group practice problem, you could expect students to spend more time on the setup of the problem, and less time on the math.

Example 4. Electric and Gravitational Force

Electric and Gravitational Force: You and a friend are reading a newspaper article about nuclear fusion energy generation in stars. The article describes the helium nucleus, made up of two protons and two neutrons, as very stable so it doesn't decay. You immediately realize that you don't understand why the helium nucleus is stable. You know that the proton has the same charge as the electron except that the proton charge is positive. Neutrons you know are neutral. Why, you ask your friend, don't the protons simply repel each other causing the helium nucleus to fly apart? Your friend says she knows why the helium nucleus does not just fly apart. The gravitational force keeps it together, she says. Her model is that the two neutrons sit in the center of the nucleus and gravitationally attract the two protons. Since the protons have the same charge, they are always as far apart as possible on opposite sides of the neutrons. What mass would the neutron have if this model of the helium nucleus works? Is that a reasonable mass? Looking in your physics book, you find that the mass of a neutron is about the same as the mass of a proton and that the diameter of a helium nucleus is 3.0×10^{-13} cm.

Assume that students have just finished studying electric forces.

1. *Read* the problem statement. *Draw* the diagrams and *determine* the equations needed to solve the problem.

2. *Reject* if:

   _No_ the problem can be solved in one step,

   _No_ the problem involves long, tedious mathematics, but little physics; or

   _No_ the problem can only be solved easily using a "trick" or shortcut that only experts would be likely to know. (In other words, the problem should be a straight-forward application of fundamental concepts and principles.)

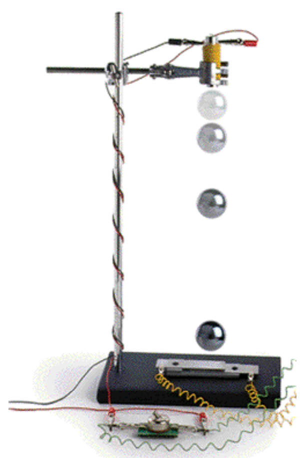
3. *Check* for the twenty-one characteristics (see page 47-53) that make a problem difficult:

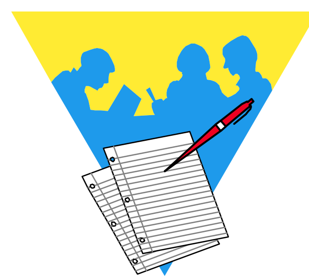
Approach	Analysis	Mathematical Solution
1. Cues Lacking _√_ A. No target variable _√_ B. Unfamiliar context 2. Agility with Principles ___ A. Choice of principle _√_ B. Two principles ___ C. Abstract principle 3. Non-Standard Application _√_ A. Atypical situation ___ B. Unusual target	4. Excess or Missing Info. ___ A. Excess data ___ B. Numbers required ___ C. Assumptions 5. Seemingly Missing Info. ___ A. Vague statement ___ B. Special constraints _√_ C. Diagrams 6. Additional Complexity ___ A. >2 subparts ___ B. 5+ terms ___ C. Vectors	7. Algebra required ___ A. No numbers ___ B. Unknown(s) cancel ___ C. Simultaneous eqns. 8. Targets Math Difficulty ___ A. Calc/vector algebra ___ B. Lengthy algebra

4. *Decide* using Tables on page 46. This has a difficulty rating of 5, four of which are in the approach. The mathematics involved is easy, but the difficulty is all in the setup. Students probably have not studied gravitational force lately, which makes the problem more difficult. This would be a difficult group test problem.

   If you were teaching this as a graded/test group problem, you could expect groups to spend most of their time on the setup of the problem, so don't worry if they haven't gotten to the math by the middle of the hour.

Teaching a Laboratory Section





I. Problem-Solving Labs in Operation

Introduction

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

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

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

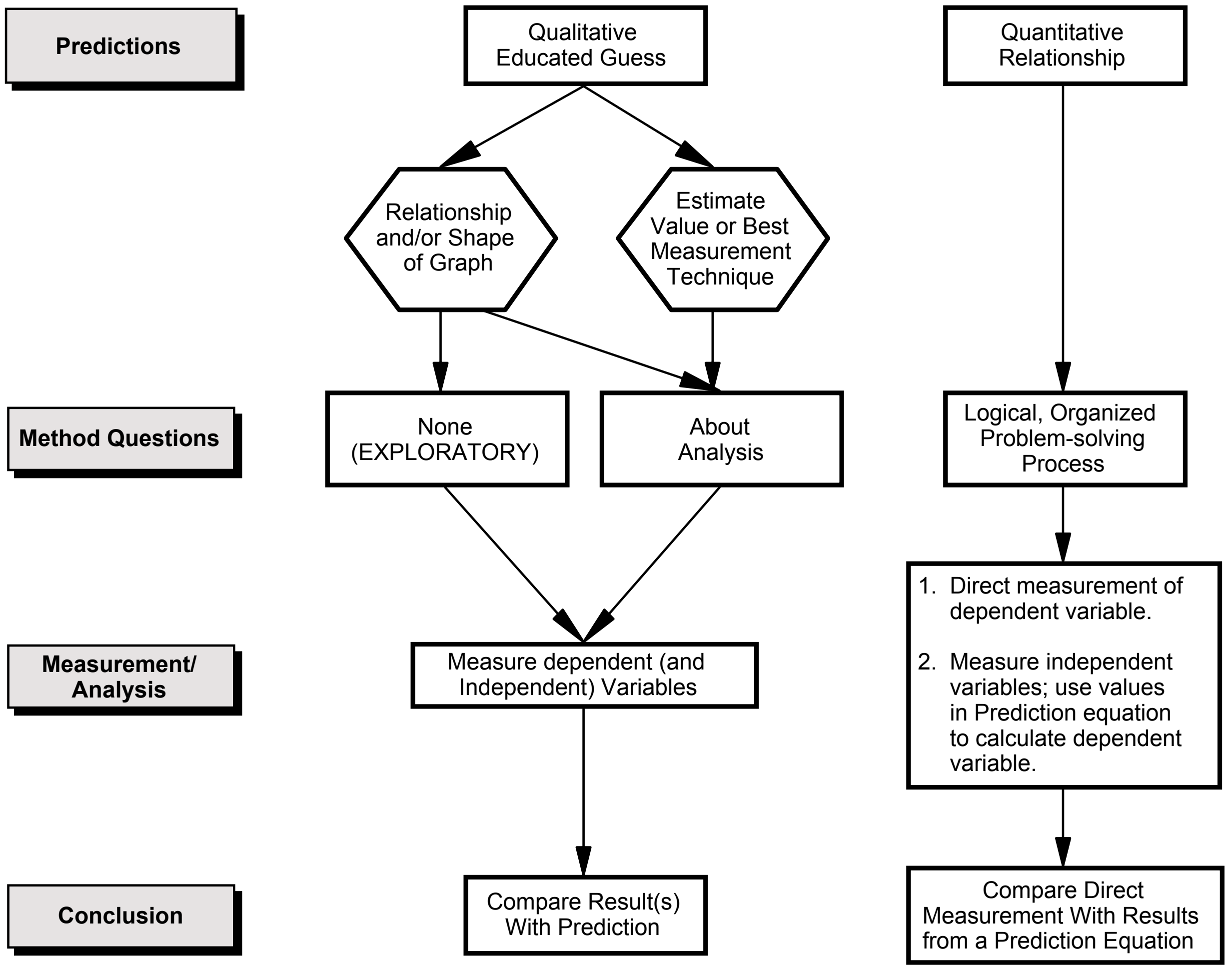
Each problem is broken down into sections that represent the processes expert researchers use in a laboratory. The sections are: introduction to the problem, description of the equipment, a prediction of the outcome, method questions, exploration, measurement, analysis and conclusion. Each lab problem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

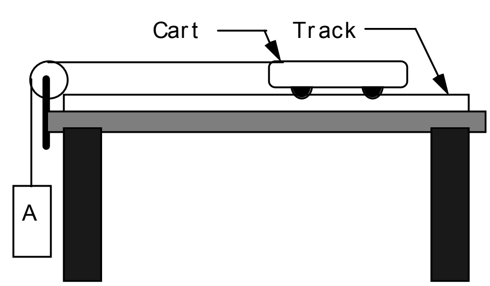
There are two different types of lab problems, as shown in Figure 1 (page 63). That is, the Prediction can be either a qualitative (educated guess) or a quantitative solution to the problem. There are two types of qualitative predictions. Students may be asked to predict a *relationship and/or the shape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

COMPARISON OF DIFFERENT TYPES OF LABS

TRADITIONAL VERIFICATION LABS	**U OF MN PROBLEM-SOLVING LABS**	**INDUCTIVE OR "INQUIRY LABS**
MAJOR PURPOSE: To illustrate, support what is being learned in the course and teach experimental techniques	**MAJOR PURPOSE:** To illustrate, support a logical, organized problem-solving process	**MAJOR PURPOSE:** To learn the process of doing science
INTRODUCTION: • Students are given quantity to compare with measurement. • Students are given theory and how to apply it to the lab. • Students are given the prediction (value measurement should yield).	**INTRODUCTION:** • Students are given a problem to solve. • Students must apply theory from text/lecture. • Students predict what their measurements should yield.	**INTRODUCTION:** • Students are given a question to answer. • Sometimes students are given related theory. • Sometimes students are asked for a prediction.
METHODS: • Students are told *what* to measure. • Students are told *how* to make the measurements.	**METHODS:** • Students are told *what* to measure. • Students decide in groups *how* to make the measurements (guided qualitative exploration).	**METHODS:** • Students decide *what* to measure. • Students decide *how* to make the measurements (open-ended qualitative exploration).
ANALYSIS: • Students usually given analysis technique(s). • Emphasis is on precision and experimental errors.	**ANALYSIS:** • Students decide in groups details of analysis. • Emphasis is on concepts (quantitatively).	**ANALYSIS:** • Students must determine analysis techniques. • Emphasis is on concepts (qualitatively).
CONCLUSION: Students determine how well their measurement matches the accepted value.	**CONCLUSION:** Students determine if their own ideas (prediction) match their measurement.	**CONCLUSION:** Students construct an hypothesis to explain their results.

Figure 1. Types of Laboratory Problems





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

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

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

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

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

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

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

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

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

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

NOTES:

II. Rationale for Problem Solving Labs

What goals do these labs address?

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

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

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

Why this style of lab?

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

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

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

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

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

Why have students work in groups?

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

Why are there so many problems in each lab?

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

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

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

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

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

Why have students answer the Methods Questions?

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

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

What is the reason for minimal laboratory instructions?

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

Why should the students write up lab problems?

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

Why have team meetings?

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

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

III. Grading the Labs

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

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

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

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

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

Each of the three grading procedures is described below.

Grading Predictions.

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

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

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

So what does reasonable effort mean? Students receive the maximum number of points if they:

- answer all the questions correctly;
- answer all the questions, *even if some of answers are incorrect*;
- answer some of the methods questions, and clearly indicate where they got stuck and why.

Students receive no points (0) if they

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

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

Grading Lab Procedures

Grade each students' lab procedure and journal at least once during the 2 – 3 sessions of a lab. Observe whether

- a measurement plan recorded in journal **before** students begin making measurements;
- tables and graphs made in journal **as data is collected**;
- observations are written in the journal;
- analysis is completed before students discuss conclusions.

Written Laboratory Report.

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

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

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

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

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

IV. Outline for Teaching a CPS Lab Session

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

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

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

NOTES:

V. Detailed Advice About Laboratory Lesson Plan

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

Opening Moves

Step ⓪. Be at the Classroom Early

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

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

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

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

Pass out the students' solutions to the lab problem.

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

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

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

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

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

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

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

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

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

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

Middle Game

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

Step ③. Coach Groups in Problem Solving

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

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

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

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

Step ④. Grade Lab Procedure

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

In <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 are done grading journals. Also, pass out group-functioning forms at this time (if necessary, about every 2 - 3 weeks).

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

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

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

End Game (~ 10 - 15 minutes)

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

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

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

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

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

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

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

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

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

Step ⑧. Start Next Lab Problem

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

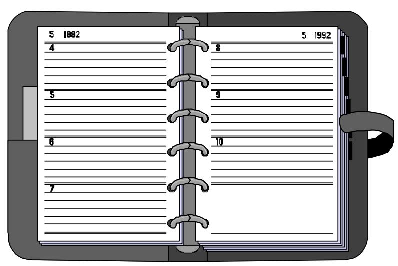
Step ⑨. End of Lab Session

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

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

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

Other Teaching Resources



Page

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 method 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 All-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*

<u>Cheating</u>

- 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.

<u>Syllabus - Grading scheme</u>

- <u>Zeroth Law</u> - 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.
- <u>Special grading policies</u>: What to do:
  - about regrades?
  - about late assignments?
  - when a student misses a discussion section during non-quiz weeks?
  - about lab computer prep quiz?

<u>Lab Grading</u>

- 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

<u>Lecture</u>

- ❑ 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?

<u>Lab</u>

- ❑ 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?

<u>Discussion section</u>

- ❑ 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?

<u>General</u>

- ❑ 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. <u>Make sure that students know where they are having difficulties</u>

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 <u>problems for another classes</u>. 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. <u>Give some hints to their questions</u>

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 <u>you do not write anything down</u>. 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.

<u>Before the exam starts</u>:

- TAs given the assignment of proctoring will pick up exams from Room 148, the Undergraduate Offices.
- 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.

<u>At the start of the exam</u>:

- 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.

<u>During the exam:</u>

- **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 121 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.

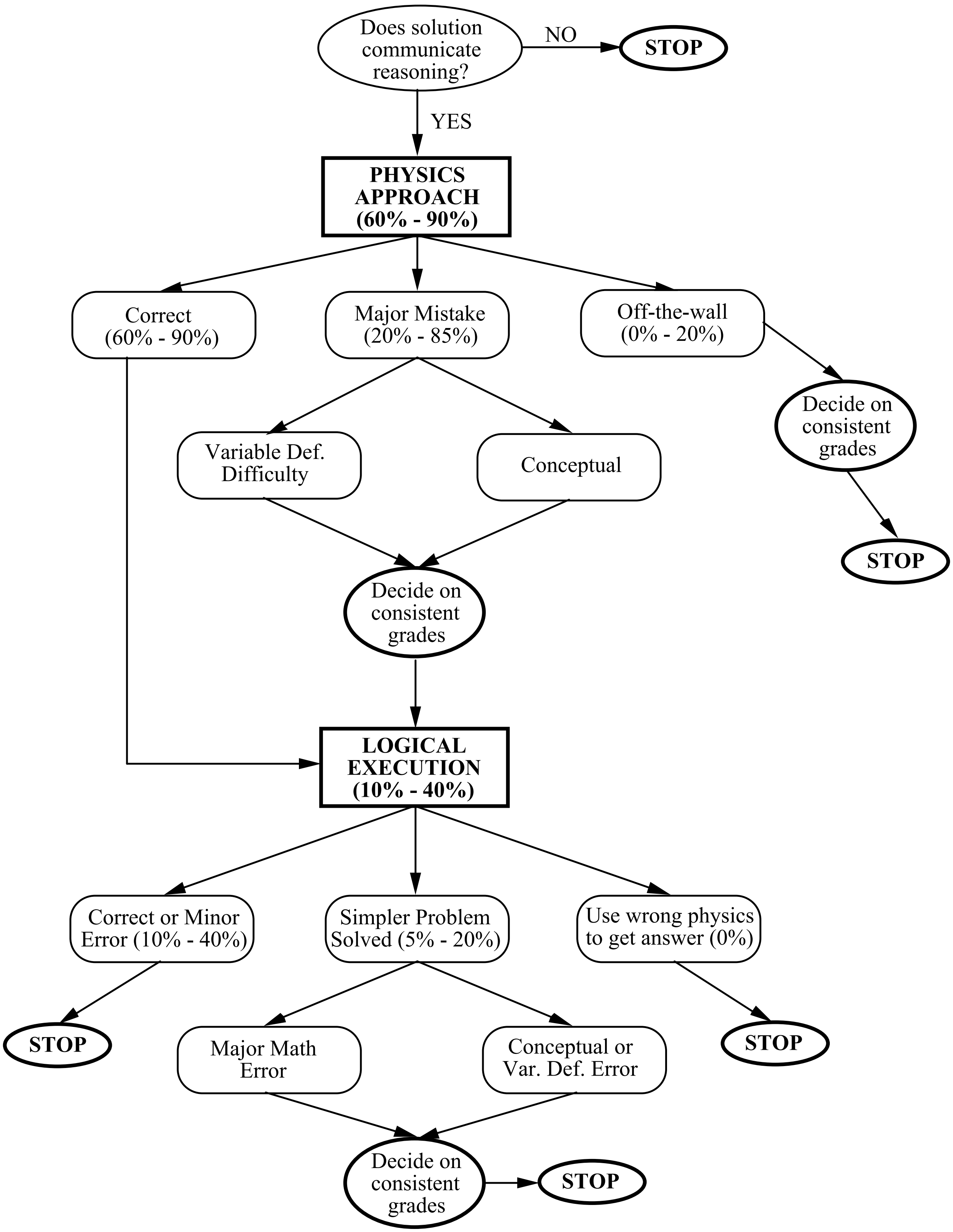
   B. Physics Approach (60% - 90%): Look at the combination of student's diagrams, general equation(s), and specific equation(s). Do **not** look at execution or numerical answers. Keep a list of the types of approaches you find, and how many points you assign each approach.

      i. Correct Approach: 60% - 90%

      ii. Major mistake of some kind: There are two kinds of mistakes, quantity definition and conceptual mistakes.

         Quantity definition 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



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/handbooks/gradepost.html .
- This system is accessible only from registered hosts of the University of Minnesota.
- You must use a Netscape web browser (Microsoft Internet Explorer will not work!)

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

- **NEVER** 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.
1. 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.)

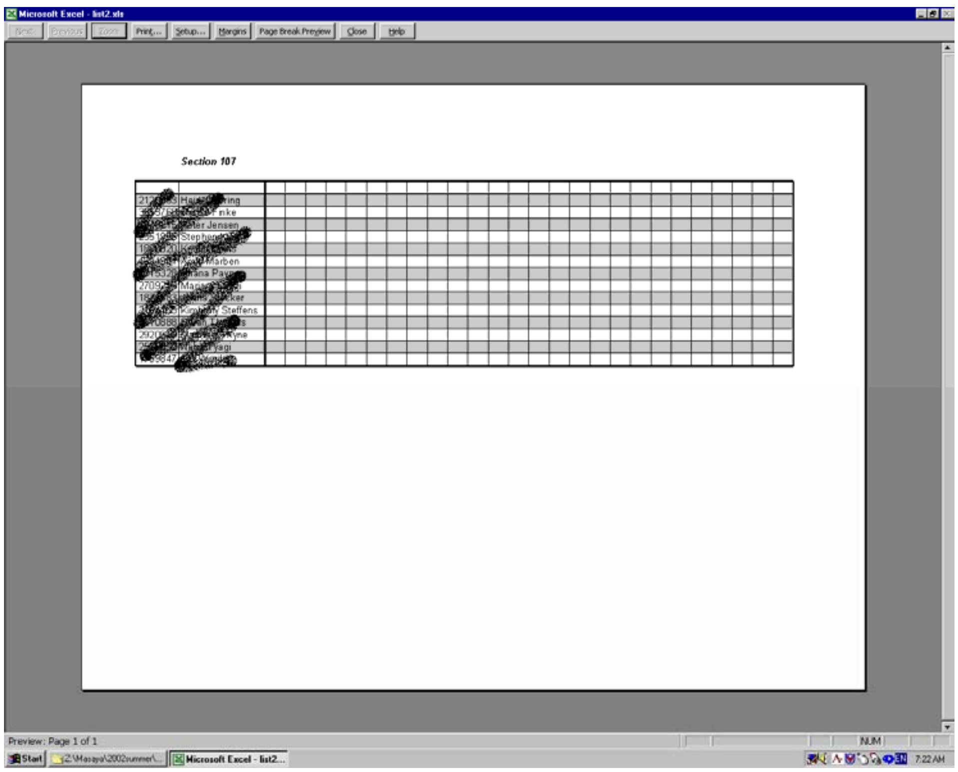
C1 - To Download Class Roster as a csv file (Comma delimited text):

2. In the upper right corner, there are maroon buttons. Click on **Save to CSV.**
3. Click the link "**Click here to get the CSV file**".
4. 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.)
5. You can open the file you have downloaded using the Notepad or any text file editor. (It is better to change the file name.)
6. 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**.
7. 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

MAKING CLASS LISTS WITH STUDENTS' PICTURES

It is recommended that you should make a class list with students' pictures, so that you will remember your students' names as soon as possible. Before making the rosters with pictures, you have to have the name lists of your students. To get the name lists, see "Downloading Class Lists" on page 124 of this handbook.

A - To Download Your Students' Pictures:

You can get the students' pictures from University of Minnesota web pages. (The pictures will be available at beginning of the semester)

5. Access Netscape or Microsoft Internet Explorer.
6. Enter the URL- http://www.umreports.umn.edu
7. Click on **User Login**. If you receive a warning text box, click on **continue**.
8. 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**.
9. The next screen should be "home page" with your name at the top. Click on **Class List**.
10. Choose "my classes"**.**
11. Select the class you would like to see.
12. The class roster should appear.
13. Click the **camera** icon on the left of the name of the student you would like to see.
14. Then, the picture will appear.
15. Right click on the picture and select **Save Picture As…** or **Save Image As….**
16. Choose the folder where you want to save the file and write the filename of the picture. Click on the **Save** button.
17. Save all pictures in the same way.
18. Once you have all pictures, click **exit** on the top of the page and use the logoff screen to exit Management Reporting. Do not forget to click on **Logout** button in the small login window appeared in A-4.

B – To Make Class Lists With Students' Pictures:

There are many ways to make the class lists. The procedure mentioned below is just one way to do that, but it might be the easiest way.

5. Open Microsoft Word.
6. On the **Insert** menu, click **Picture**, then **From File…**.
7. Select the picture file you would like to insert, and then click on **Insert**.
8. Right click on the picture. Then, click **Format Picture…**.
9. Choose **Size** Tab.
10. Change both **Height** and **Width** of **Scale** (38% is good). Click **OK**.
11. Push Tab key on your keyboard twice.
12. Again, insert another picture, change the scale and push Tab key twice in the same way.
13. Once again, do the same thing. This will make three pictures on the 1st row.
14. Push Enter key on the right of the last picture.
15. Enter the names below the pictures. It is better to use Tab key instead of Space key between the names.
16. Push Enter key twice on the right of the last name.
17. Do the same procedure (2-12) for the 2nd, 3rd, 4th and 5th row.
18. To print the file, click **Print…** on **File** menu. Select the printer's name: \\spartha\137 or 216. Then, click **OK**.
19. To save the file, click **Save** on **File** menu. Select the folder where you would like to save and write the file name. Then, click **Save**.

The following statement is from the UMN web page. *"Student pictures should under no circumstances be given to anyone. Instructors must not post, circulate, or otherwise distribute these pictures."*

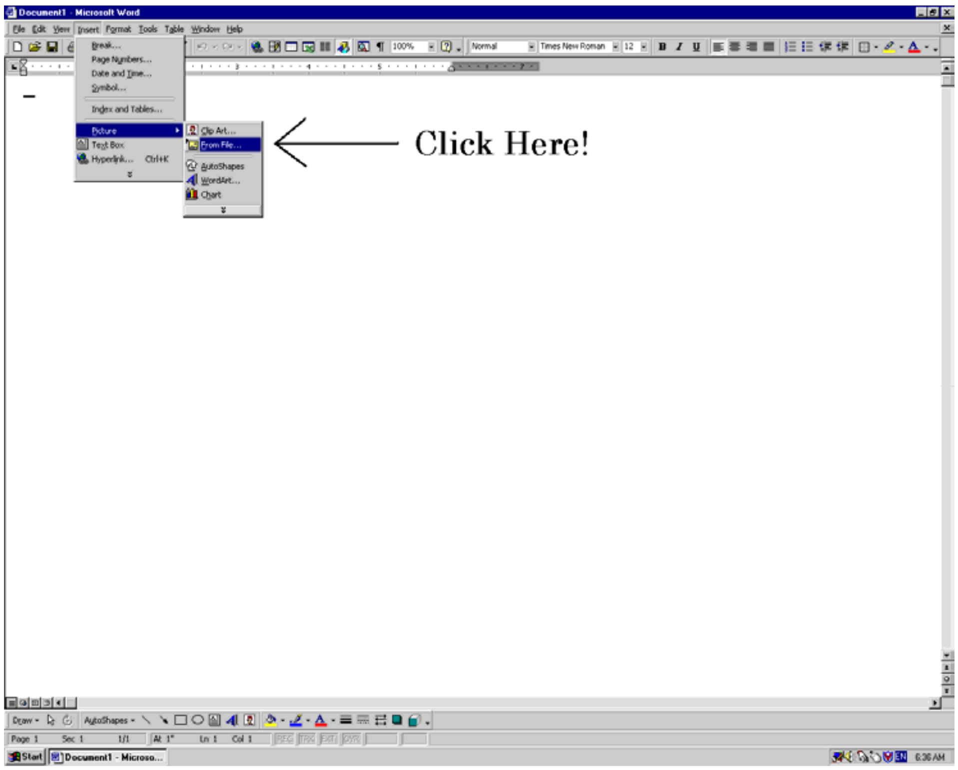


Illustration of Step B-2

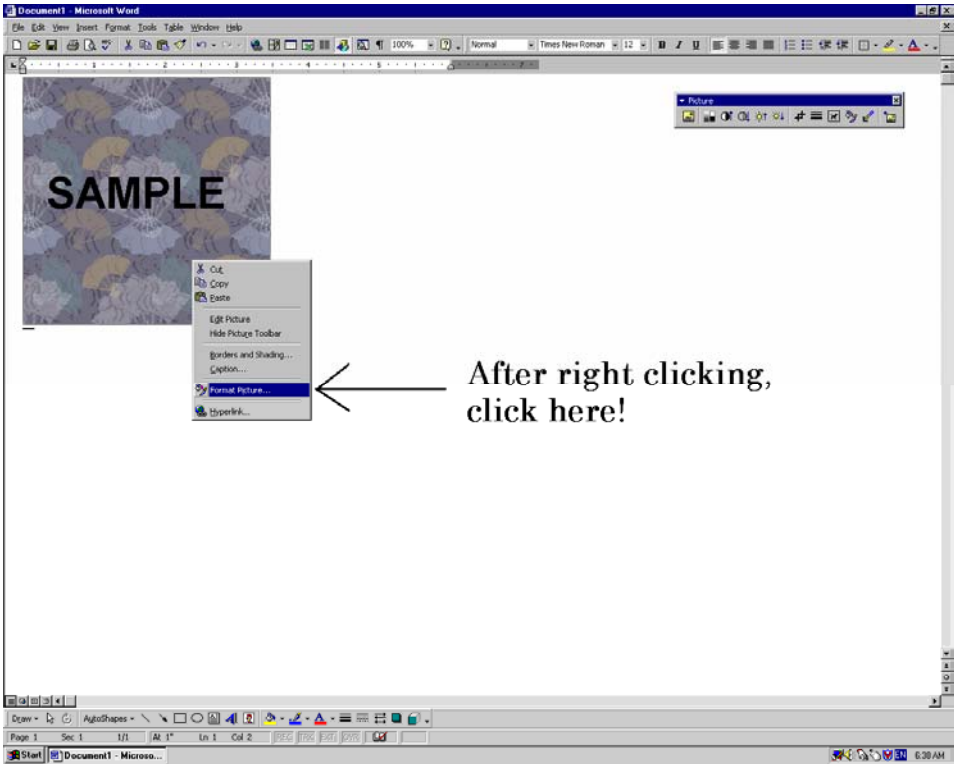


Illustration of Step B-4

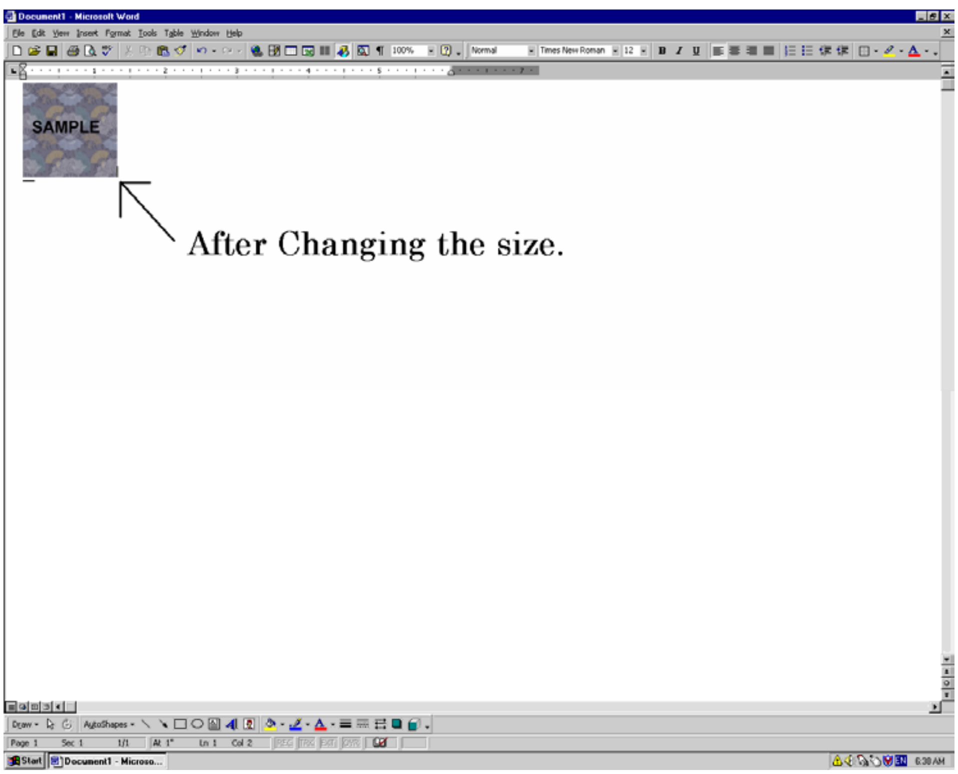


Illustration of Step B-6

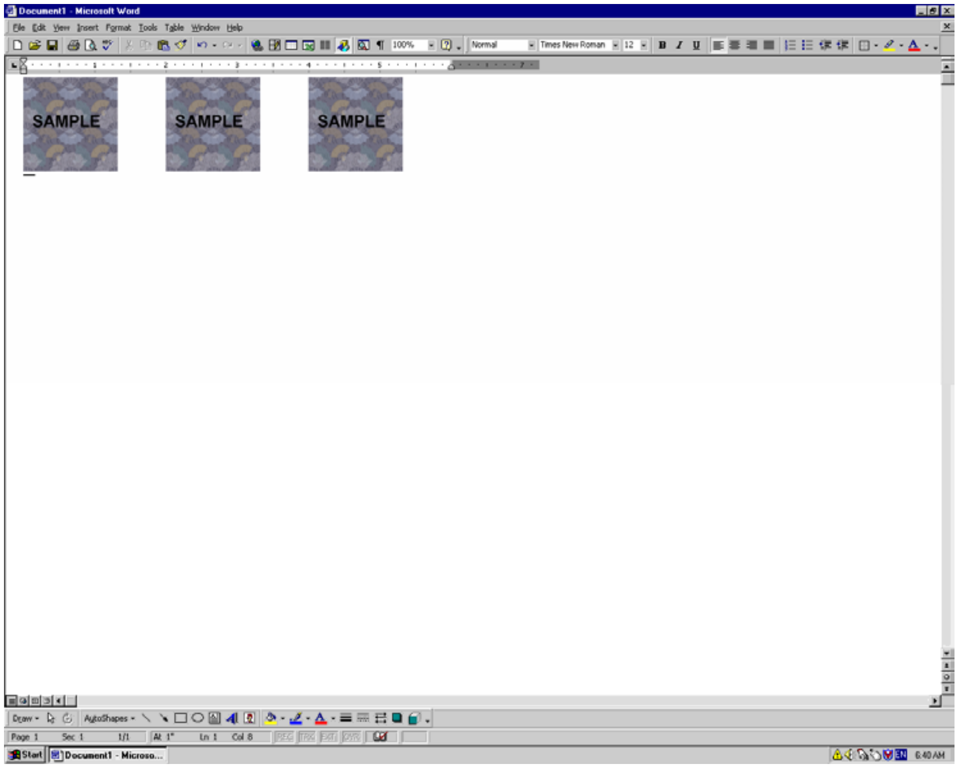


Illustration of Step B-9

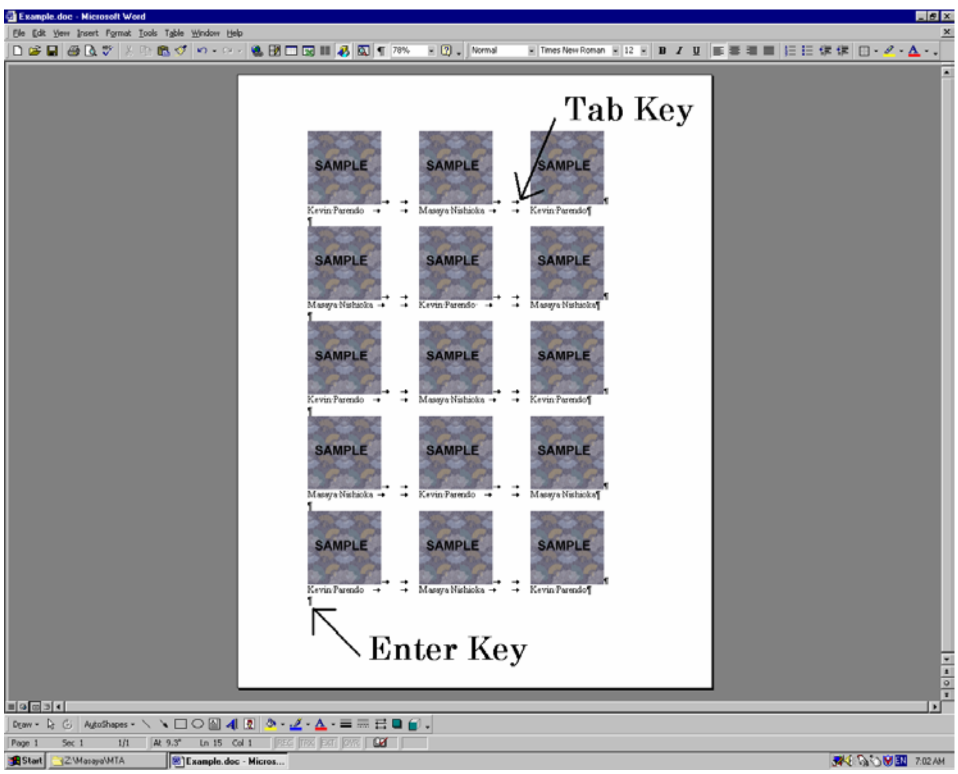


Illustration of Step B-13

VIII. Checking Students' Pre-lab Quiz Scores

For many classes, students have to take and pass a pre-lab quiz before every laboratory session (your professor will decide whether or not to require this). The webpage where your students will take the quizzes is http://labquiz.physics.umn.edu/.

- You should attempt to take each lab quiz yourself, in order to know that the system is working and that the correct material is covered.

You must check that all of your students pass the pre-lab quiz BEFORE the lab class.

1. Access http://labquiz.physics.umn.edu/report/

2. Click the link "How Do I Find Out Who Passed?"

3. Enter the account and the password. As of July 25, 2003, the account is 1101_TA or 1301_TA, and the password is de5tpUs4Z. Push "Enter" button.

4. Enter the course, section and quiz number you want to check. Press "GO!" button.

    - Sometimes the names of some students who pass the quiz are missing on the list due to the breakdown of the database. In that case, ask them to tell you their confirmation number in class (Each student gets his/her confirmation number at the end of the pre-lab quiz). You can check whether they passed or not using those numbers and the algorithm given by Pete Border.

    - **For all problems involving the labquiz system or grades, contact Pete Border at 624-1020 or border@physics.umn.edu**

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)
- Pre-lab Quiz
  http://labquiz.physics.umn.edu/ (for your students)
  http://labquiz.physics.umn.edu/report/ (database for TAs)
- Electronic Grading
  http://www.physics.umn.edu/resources/handbooks/gradepost.html (general)
  http://www.physics.umn.edu/resources/classes/gradebooks/ (for download)
- 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 (Kimia Ghanbeigi)	624-7008	(Room 56)
(Alexander Scott)	624-7861	(Room 253)