1102 IG -- Table of Contents

INTRODUCTION

Traditionally, the second semester of introductory physics is much more difficult than the first for the students. Grades fall, confusion increases, and they will ask you for more help than before. Most of this confusion is because the concepts covered in 1102 are more abstract than previous ones. For example, this is the first time many students encounter the *field* concept. This material builds on the knowledge of physics that students should have learned earlier. Students' weaknesses in their systematic problem solving, or comprehension of vectors, integrals, forces, and energy will become a major stumbling block. Furthermore, much of this material was not taught to students in high school; everything is brand new. The 1102 labs have been written with these concerns in mind. The students will find problems designed to illustrate the necessity of connecting new ideas and techniques with ones learned previously. Examples from the book are actually done in lab so abstract concepts can become more concrete. Students will have opportunities to explore things that are unfamiliar.

THE GOALS OF LAB

The goal of the introductory physics labs at the University of Minnesota is to provide students with practice and coaching in using a logical, organized problem solving process to solve problems. The goal of the labs is the *same* as the goal of the discussion section – to help students slowly abandon their novice problem-solving strategies (e.g., plug-and-chug or pattern matching) and adopt a more logical, organized problem-solving procedure that includes qualitative analysis of the problem.

Since one reason that students cannot solve physics problems is that they have misconceptions about physics, a second goal is to confront some of those misconceptions in the laboratory. The labs include problems that try to illuminate known misconceptions and help students connect their lab experience to reality – all problems begin with a context statement. Now more than ever, the labs give the students a chance to learn physics in the real world. Because your students are so unfamiliar with this material, they may find the labs more frustrating than usual. This lack of familiarity coupled with misconceptions will often lead the students to conclude that the equipment "does not work," since it does not behave the way they think it should. If you are prepared, this is the ideal teaching opportunity. Your students will need you more than ever, and it is crucial that you are familiar with the equipment.

The U of M problem-solving labs do not contain step-by-step instructions; students are generally told *what* to measure, but they must decide in groups *how* to make the measurements (guided qualitative exploration). The students must also decide in their groups the details of the analysis. At the conclusion of the lab session, students must determine if their own ideas (predictions) match their measurements.

LAB SESSION STRUCTURE

OPENING MOVES:

Typically, the first 15-20 minutes of lab are spent preparing students for group work and focusing the lab session on what students should learn. Your "opening moves" as a TA begin when you ask the members of each group to arrive at a consensus about one or two of the warm-up and prediction questions. You should decide which warm-up questions 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; for most lab problems it should take no more than 5-10 minutes (however the discussion for more difficult problems may take longer.)

At the end of the group discussion time, have one representative from ach group put their group's answers to the selected warm-up questions on the board. Ask each group to give their reasons for their answers, and then conduct a class discussion comparing and contrasting their answers and reasons. ***The discussion need not arrive at the correct answers to the questions.*** In fact, more learning occurs in a lab session when there are unresolved disagreements. Wait to resolve the disagreement in the closing discussion, after students have completed checking their solution.

After the opening discussion, *briefly* discuss the measurements students will make to check their solutions. It is often a good idea to ask students, "What are we trying to measure in this lab?" to get their mind focused on the target quantity or quantities. This is also a good time to point out the pieces of equipment they will be using, or give particular instructions about the equipment. This Instructor's Guide also includes suggestions for what to discuss. For the students to get the most out of their lab experience:

DO NOT LECTURE AT THE BEGINNING OF LAB!

Reasons:

1. There is already a lecture component of the course; lab is a time for students to *apply* the theories from their text and lecture. Even though they are unsure of themselves and might *think* they would benefit from explanations of the material, more lecturing will not help - experience and coaching will. Do not reduce the time the students need for hands-on learning activities. If students have not yet attended a lecture on the material, you might need to give them helpful hints to get them started, but keep it short. The lab experiences will serve as a good introduction to the material when it comes up in lecture.

2. If you give the students the answers before they start, you are telling your students that you do not care about their ideas and that they should not care either. Answer their questions only after they have made their best attempt to answer it themselves and within their groups. Let them investigate their own ideas to find which are correct and which are misconceptions. When they are cognitively engaged, they learn.

3. Lecturing often places the listeners in a passive mode, but effective learning takes place in an active mode. Students are in an active mode when they are doing or thinking about a specific problem. Active modes are what the laboratory and discussion sections are designed to evoke.

It is **your responsibility to inform the professor** for the course topics are not synchronized, as well as about any other issues involving the lab and lecture sequence. If you notice this is the case, bring it up at your team meetings and respectfully request a slower pace until the lectures catch up, or discuss alternative methods to approaching the lab topics. You should **resist** if the professor asks you to introduce a new topic in lab by giving students a lecture! Another option would be to hold a problem solving session during lab to allow the lecture to "catch up".

Middle Game:

During the lab session, your role is one of observer, listener, and coach. You should circulate around the room, observing what groups are doing, listening to what students are saying, and observing what the groups are writing in their lab journals. Intervene when a group needs to be coached on an aspect of physics or the Exploration, Measurement, or Analysis procedure.

It is your job as a TA to guide the lab groups and help them focus their questions. Here's where you really earn your money, because it's up to you to decide when and how to help the student groups. It is important that they attempt to work through the problem themselves. However, if they struggle too much they will gain nothing from the lab except frustration and despair.

With 10-20 minutes left of class, have a representative from each group put their group's *corrected* answers to the warm-up questions on the board (if possible, below their original answers.)

END GAME:

A good end game helps students consolidate their ideas and explicitly summarizes the learning focus for the lab session. Give students a few minutes to examine what other groups wrote on the board, and then lead a whole-class discussion of the results (how do their measurements and predictions compare?) and the objectives for the lab session. Depending on time constraints, you may decide to discuss some of the answers to the warm-up and prediction questions.

When you were an undergraduate, your laboratory instructor probably did not stop you to have a class discussion. Doing this is one of the hardest things you will have to do as a TA. You may be tempted to either let students keep working so that they can get as much done as possible, or let them go home early so they will like you better. However, students do not learn from their laboratory experiences unless they are actively engaged in figuring out what they have learned.

TEACHING TIPS

1. Carefully tell the students what you expect of them in the laboratory and why these rules are necessary. Be very strict in enforcing these rules during the first half of the semester. It is easer to establish good habits in your students early in the semester than to try to establish them later. If you are strict and fair, your students will respect you for it. If you do not consistently enforce your rules, some students will never believe anything you say. If you have any questions about this concept, please talk about it to your mentor TAs.

2. Always tell students explicitly that they should hand in answers to both the Predictions and Warm-up questions for the problem(s) that you assign before they come to lab. The deadline for handing them in will be decided in your teaching team – it is usually 1or 2 days before the lab session. *Make sure the students understand that the Warm-up questions are there to help guide them through the analysis*, as well as to help them solve the problem. Even thought the Prediction comes first in the lab manual, they should do the Warm-up questions before the Prediction.

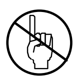
3. It is well known that students do not like to read instructions. They will come to you and ask questions that are answered in the lab manual. If this happens, first ask the student a question to determine if they have read the manual. If not, refer them back to the manual. If they have, give them a straightforward answer.

4. Tell the students what resources are available to them and encourage going to the tutor room 230 if they have any questions. The student lab manual has plenty of information in the Appendices. For example, there are sample lab reports (do not assign these problems for reports!)

SAFETY

Your students' safety is your primary responsibility. For example, if a group blows a 10A fuse they have done something potentially dangerous. You must check what they are doing and inspect the circuits they have built before replacing the fuse.

A first aid kit is available in equipment closet #7 on the second floor. Make sure you are the only person to access the kit unless there is an emergency and an urgent need to do otherwise.



It is important to **verbally warn students about potential dangers.** The lab manual and this guide provide warnings, which are marked with a symbol of a hand with one finger raised in warning, as seen to the left**.**

EQUIPMENT

The batteries run down quickly. Make sure you check the batteries before your students enter the room. Students will grow despondent if they are stuck doing a lab with dead batteries. The fastest way to check a battery is to see if it will light a bulb brightly. Dispose of light bulbs that are burned out.

The DMMs are of high quality and durability. Count them at the beginning and end of each lab, as they may tend to "walk off." Don't "borrow" them from another room without leaving a note in the logbook for that room.

Discharge all capacitors before students enter the room, as they can create a mild shock and spark. To discharge a capacitor, use a wire with banana plugs to briefly connect both terminals of the capacitor (never grasp a wire by its metal end!)

Check all of the DMMs before your students enter the classroom and make sure you get enough spare fuses before class begins. In an emergency check to see if there is an extra fuse tucked inside the DMM itself. You'll have to take its back off to find out. There are both 200 mA and 10 A fuses. If a fuse is blown, replace it. There should be spare fuses in the room, and Sean has screwdrivers. **It is you responsibility to make sure that your students' equipment works.** Nothing is more frustrating for students than trying to start a lab with equipment that does not work.

If there is any bad, broken, or erratic equipment, **use the problem report form** located on any lab computer desktop to **immediately notify the lab coordinator**. This form will send an e-mail directly to the lab coordinator at labhelp@physics.umn.edu Be sure to include a complete description of the problem, and the room number. **Make a note on the clipboard about it** or on the blackboard to inform the next TA of the problem, and that a problem report form has already been submitted.

Remove any broken equipment from the front lab table immediately: students are less respectful towards equipment that they don't see working well.

USING THIS INSTRUCTOR'S GUIDE

This instructor's guide is designed to help you help your students, make sure you:

1. Don't rely on it too much. It is only a guide, not a substitute, for preparation. Make sure you prepare to teach the lab as if you didn't have this manual.
2. **Don't let students have access to it**. It's basically like having a solution manual for textbook problems. It can short circuit the learning process.

We are continually working to improve the instructor's guide. **To add any suggestions, you should write down notes and suggestions on the TA Lab Evaluation found at the end of the Instructor's Guide section for each lab.** Return these forms to Sean Albiston or one of the mentor TAs. You can also e-mail the information to Sean directly at lab@physics.umn.edu

Information from previous laboratory instructors was used to construct this guide as well as modify this year's student lab manuals. Your input is greatly appreciated. Include anything that you feel will be useful. Your notes may include additional comments to be included in the Instructor's Guide, difficulties you or your students had with the problems or the apparatus, and suggestions for changes in the labs.

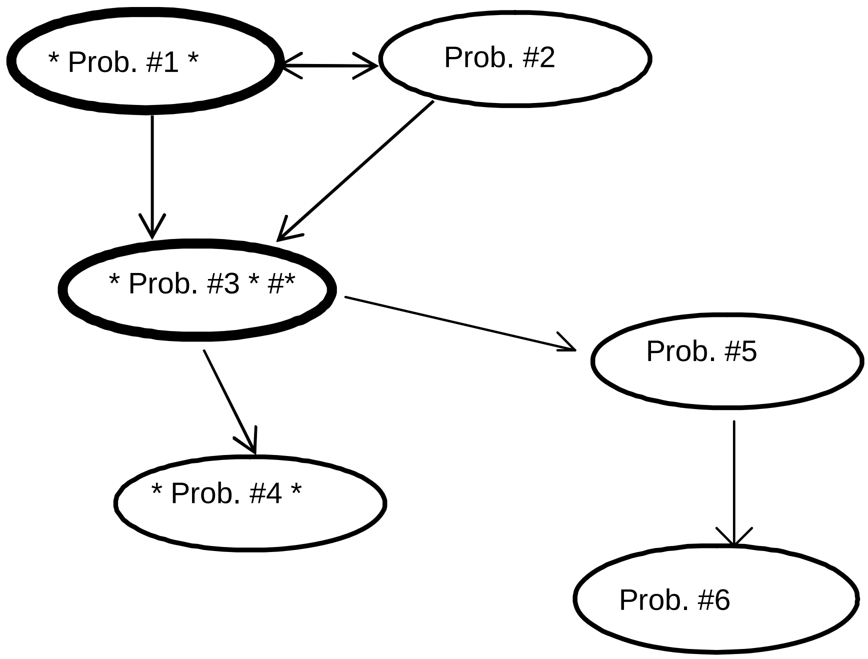
At the start of each chapter in this guide is a **flow chart** that shows the connections between the different problems in that lab. This chart is designed to help you plan your lessons. The elements of the flow charts have the following definitions:

- Bold ovals with stars are the problems that contain knowledge and techniques that are prerequisites to other problems. It is strongly suggested students be required to do these problems.
- The arrows on the connecting lines are directional symbols.
- Dashed lines are optional paths.
- The X across a connecting line implies that if a group has completed one of the problems, that group should skip the other problem.
- Any one group can do any number of problems on the same level.

You can expect your average groups to complete about 2 problems per week.

Laboratory I:
Heat and Conservation of Energy

The problems in Laboratory I deal with the concepts of heat and temperature. Thermodynamics developed alongside the atomic theory, and there are many correlations between the two domains. Help your students make the connection by asking what they think is occurring at the molecular and atomic levels as an object or system of objects undergo a change in temperature.



Equipment:

General Teaching Tips:

- We do not use the word, "calorimetry" to describe these labs. The main idea investigated through these labs is the conservation of energy.
- Be prepared for inaccurate or imprecise results with these labs. There are many factors that contribute to the uncertainty -- the amount of water, the time passing to reach equilibrium, etc.....) Be ready to discuss why the results may be poor, and ways that you could improve the measurement technique.
- Make sure students look at problem 5. This is their only opportunity to study the latent heat, and it is similar to a common exam problem.
- There is a table of specific heats at the end of the lab, page Lab 1 - 25.

By the end of lab students should be able to:

- Use the principle of energy conservation to describe the dynamics of a thermal system.
- Quantitatively determine the transfer of thermal energy from one body to another.
- Understand how an object's specific heat capacity, mass, and change in temperature contribute to describe that object's change in internal energy.
- Recognize that objects of different material will have different heat capacities.

Things to check fifteen minutes before lab:

- Make sure there is enough ice in the ice cooler. Often by the end of the week, much of the ice has melted, so if you have a lab later in the week it is vital to check this! Use the 'Problem Report Form' to report if there is no ice.
- Make sure the thermometers are relatively consistent. They work on batteries and may be run down when your class uses the room. Ask in room 233 for fresh ones.

WARNING: The hot plate and the heated water can both burn you!

Problems 1 and 2: TEMPERATURE AND ENERGY TRANSFER I & II

Purposes: 1) To let the student find the optimal initial temperatures to use for the remainder of the lab.
2) To show students that the rate of energy transfer depends on the difference of temperature in the system.
3) To let students accustom themselves to the equipment and become experts at using it before the following problems.

Equipment:

Teaching Tips

- The first two problems are exploratory. Ask the students if the amount of energy transferred sounds reasonable. (Make a mechanical comparison in Joules, e.g. lifting weights).
- Ask the students what a negative change in internal energy means. A positive change as well.
- The copper and water do not take long to reach equilibrium. Stir the water a bit. Don't wait too long, or unaccountable energy will seep out of or into the system. Thirty seconds is usually long enough, certainly no more than one minute.
- If there are time constraints, have half the class do problem 1 and half do problem 2, then share the results before moving ahead.
- For best results use water at room temperature. Raise or lower the initial temperature of the copper.
- Have your class make a plot of heat transfer versus initial temperature of the water. For a class discussion, have all groups compile their data.

WARNING: The hot plate and the heated water can both burn you!

Sub-Problem Analysis:

You want to show your students how the energy transferred between the system and environment depends on time. Have the students set aside a cup of hot or cold water and periodically make temperature measurements. A cup of hot water will drop in temperature very quickly because of the evaporation. A cup of cold water will rise in temperature, but not so quickly as the hot water drops.

Predictions and Warm-up:

$$E_{final} - E_{initial} = E_{transfer}$$
$$\Delta U_{water} + \Delta U_{copper} = \Delta Q$$

where ΔQ is the energy transfer and ΔU is the change in internal energy. In this case ΔU=m*c* ΔT for the respective values of copper and water.

Sample Data:

Here are five trials for a variety of different initial conditions: two with room temperature water and heated metal, three with heated water and room temperature metal.

M_{water} (g)	To_{water} ('C)	M_{copper} (g)	To_{copper} ('C)	T_f ('C)	ΔQ (cal)
73.5	21.8	70	**45.0**	23.6	**-5.5**
64.0	21.8	70	**38.9**	23.1	**-18.6**
63.5	**65.5**	70	22.8	57.5	**-284**
62.0	**51.0**	70	24.8	47.5	**-70.8**
61.0	**51.5**	70	21.8	46.9	**-120**

Here are five trials with roughly the same initial conditions for the mass and temeperature. Notice how a measurement of the heat transferred can vary from trial to trial despite similar initial conditions. There are many factors that can cause this variation. Ask students to comment on their results and stress the importance of having a consistent measurement plan.

M_{water} (g)	To_{water} ('C)	M_{copper} (g)	To_{copper} ('C)	T_f ('C)	ΔQ (cal)
106.1	23.2	70	50.0	25.0	**23.8**
102.9	22.7	70	50.0	24.2	**-16.8**
111.1	23.2	70	50.0	24.4	**-35.3**
98.0	22.7	70	50.0	23.9	**-54.2**
109.0	22.8	70	50.0	24.4	**4.1**

The average energy transferred from the system to the environment was roughly 15 calories for these trials.

Possible Discussion Questions:

1) What does a negative ΔQ stand for? What about a positive ΔQ?
2) What are the best techniques to minimize energy transfer?
3) Why do people use insulation in their homes in the winter? the summer?

Problem 3: Identifying Unknown Metals

Purposes: 1) To use the conservation of energy to determine the property of a material.
2) To show students that specific heat capacity is unique to each material.

Equipment:

Teaching Tips

- It is a good idea to have some room temperature water on hand. Water from faucets will often be colder or warmer then room temperature, so fill some containers ahead of time and let them get to room temperature.
- The metal and water do not take long to reach equilibrium. This allows students to perform 5-6 different trials. Make them work. Don’t let them relax and tell you, “We’re waiting for the system to reach equilibrium. There is always something that someone can be doing.
- Use two cups instead of one. Cut one in half and use it as a lid. Poke a hole through the lid to insert the thermometer.
- There should be enough water in the cup to submerge the metal, but not too much more water than that. Lots of water means smaller changes in temperature, and less noticeable results.
- Advise students to use their results from the first two problems to minimize the heat transferred from the system to the environment. Let your students decide whether they should estimate the heat lost in their calculations based on the initial conditions of their experiment, or whether they can neglect the heat lost in their calculations. Make sure they justify their decision.

- Tell your students to use page 25 to find the specific heat of their unknown metal. The two metals are **Aluminum** and **Magnesium alloy**.
- Students can double check the identity of the metal by finding its density. Densities are listed on the same page as specific heat capacities, and it should take no longer than 5 minutes to find the metal's mass and volume.
- Have the groups write their results on the blackboard. Lead a discussion on uncertainty. Debate whether values that are slightly off can be considered the same value or not.

WARNING: The hot plate and the heated water can both burn you!

Difficulties and Alternative Conceptions: Students tend to forget that they are measuring a change in internal energy, not internal energy itself. Net internal energy would be very difficult to measure since it would require knowing velocities on the molecular level. Remind students that temperature and internal energy are not the same thing. When objects are in thermal equilibrium, they have the same temperature, but not always the same internal energy.

Predictions and Warm-Ups:

$$c_m = \frac{\Delta Q - m_w c_w \Delta T_w}{m_m \Delta T_m}$$

Where ΔQ is the energy transferred between the system and environment. m_m, c_m, and ΔT_m are the mass of the metal, the specific heat capacity of the metal, and the change in temperature of the metal respectively. m_w, c_w, and ΔT_w are the mass of water, specific heat of water, and the change in temperature of the water respectively.

Possible Discussion Questions:

1) Were you satisfied with the accuracy of this problem? Remember, these are crude tools because you are out on an archeological dig.
2) What are some other applications where knowing the specific heat capacity of a metal might be important? (think architecture - many 1101 students are architecture majors.)

Problem 4: The Composition of a Compound Object

Purpose: 1) To show students that a compound object can be studied as two individual pieces.

Equipment:

Teaching Tips:

- The mathematics and physical principles behind this problem are similar to those in problem 3. Tell the students that now their equations have two unknowns, the mass of the copper and the mass of the aluminum. The added unknown requires an added equation.
- This is a powerful example to elucidate the difference between internal energy and temperature.
- The compound object is made of **40% aluminum**. This can be determined by analyzing the geometry of the object, the densities of each metal, and the mass of the object.
- This problem lends itself to a discussion on uncertainty. Look at the uncertainty from the temperatures of water and metal, the masses of water and metal, and the heat lost or gained by the system. Discuss the final results as a class. Ask questions about uncertainty range, accuracy and precision, and percentage error.
- Reference page 25 for a table of densities. Check the density of the total object and its constituent parts.
- Since it is so difficult to estimate the heat lost, your students will get some bad trials. Suggest using initial conditions that will minimize the heat transfered. In their calculations, let them decide if they can neglect the heat lost to the environment. Have them do several trials - they

don't take very long once everything is set up. Have them do their calculation in class and ask them if the number they are getting makes sense. They can see the different metals in the object and can get a rough estimate from that of what the ratio should be.

WARNING: The hot plate and the heated water can both burn you!

Difficulties and Alternative Conceptions: Similar to problem 3. This lab allows students to see how the metals behave independently in the component system.

Predictions and Warm-Ups:

$$\%Al = \frac{m_{Al}}{m_m} \bullet 100 = \frac{m_w c_w \Delta T_w + m_m c_{Cu} \Delta T_m - \Delta Q}{m_m (c_{Cu} - C_{Al}) \Delta T_m} \bullet 100$$

$$m_m = m_{Al} + m_{Cu}$$

Sample Data

M_w (g)	M_m (g)	T_{ow} ('C)	T_{om} ('C)	T_f ('C)	%Al
101.5	71.7	23.1	61.5	26.4	33
103.8	71.7	23.4	55	26.1	35

There is a large error (>10%) because we neglected the heat lost. These initial conditions are similar to those listed in the second table in problem #1. If we estimate the heat lost to the environment to be 15 calories, we end up with the
%Al to be 38% and 41%, respectively. This estimate isn't completely justified since in the first problem, the object was entirely composed of copper.

Possible Discussion Questions:

1) Are the two metals making up the compound system in thermal equilibrium? Do they have the same internal energy?

Problem 5: Latent Heat and the Mass of Ice

Purposes: 1) To introduce the concept of latent heat.
2) To show that energy is required to change an object's phase.

Equipment:

Things to Remember:

- Check to see there is ice in the cooler before starting the problem. If you have lab later in the week, you may need to request more!
- Make sure students weigh the water in the cup before they add the ice. This is the best way to know the actual mass of the ice.
- This problem is very similar to one that students might see on an exam. Be slow and patient in discussing the prediction and Warm-Ups.
- 10-20 grams of ice is the best amount to use for a cup that is about 3/4 full of water. If you use too much ice, it takes too long to melt and much energy can be transferred into and the system. If a group uses too much ice, have them start over. Their results will be poor even if they run the lab to completion.
- Make sure that students report how close their calculated mass of ice was to the actual mass of ice used. Will uncertainty account for the discrepancy?
- If done carefully, this problem can yield pleasing results.

Difficulties and Alternative Conceptions: Latent heat represents another example of the difference between internal energy and temperature. Remind students that as the ice melts, its internal energy rises but its temperature is constant.

Prediction and Warm-Ups:

$$m_{ice} = \frac{\Delta Q - m_w c_w (T_{wf} - T_{wi})}{L_f + c_w T_{wf} - c_I T_{Ii}}$$

Here, T_{Ii} and C_I refer to the initial temperature of the ice and the specific heat of ice. If the ice is immersed in a water bath initially, we can assume its initial temperature is zero. In that case, the prediction simplifies to

$$m_{ice} = \frac{\Delta Q - m_w c_w \Delta T_w}{L_f + c_w T_{wf}}.$$

Sample Data:

In these trials, the initial temperature of the ice is 0^o C.

M_w (g)	T_{ow} ('C)	T_f ('C)	Mice(g)(actual)	M_{ice}(g)(pred.)
119.2	19.5	11.2	10.6	10.9
116.6	29.4	27	3.8	3.6

I neglected the energy transferred between the system and the environment in these calculations.

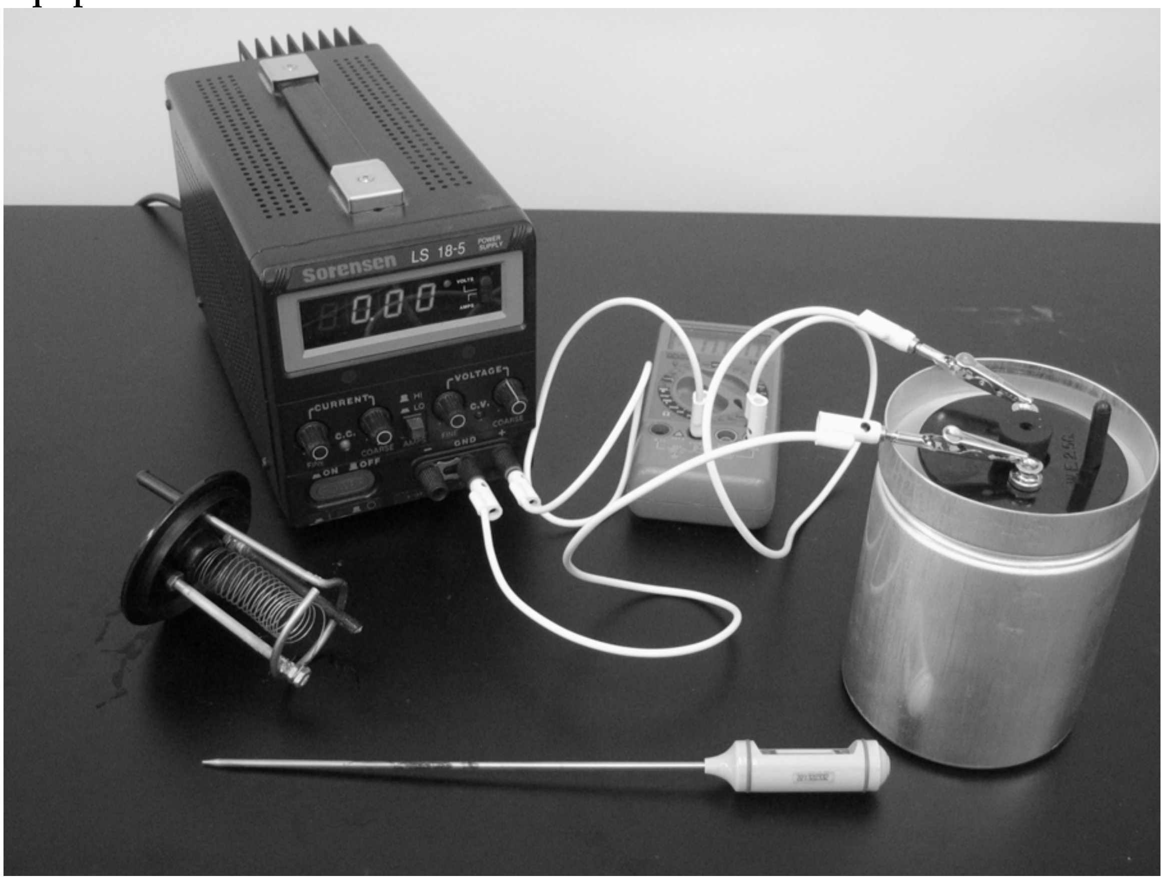
Possible Discussion Questions:

1) What groups obtained the closest results? What methods did you use? How much ice did you use?
2) What is the effect of using a large amount of ice?
3) Does a pot of cold water boil any faster than a pot of warm water? (No, of course not! That is a popular legend. Test it for yourself.)
4) What would be the optimal method for performing this problem? Is this useful for the coffee machine?

Problem 6: Electrical Energy and Heat

Purpose: 1) To show students that the light bulb is emitting energy.

Equipment:



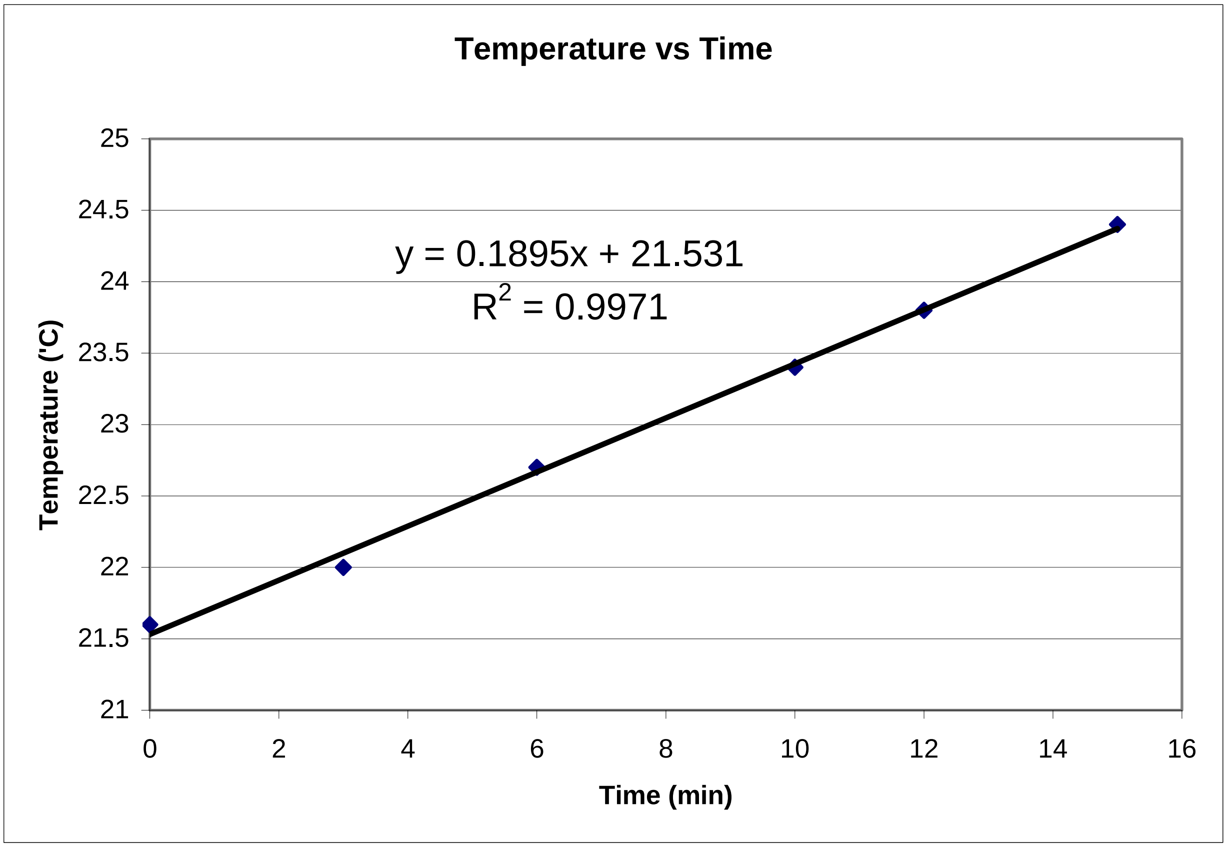
Teaching Tips

- Make sure students don't immerse the entire bulb socket into the liquid. If half the metal base is submerged their results should be good enough.
- Students should first try using alcohol. Alcohol has a lower specific heat, .58 cal/g*K, and alcohol comes to equilibrium at room temperature faster than water. Alcohol also evaporates, so cover the cup with a lid.
- Don't use too much liquid or the rise in temperature will be too slow to observe.
- Make sure the batteries are fresh. Use the digital multimeters. A bulb should emit 1.2 Joules per second. (8 volts)(.14 amps)
- Do not leave the light bulbs in the water when you are not using them. The metal will rust and the connection will corrode.
- Assume that no energy was transferred to the environment. Ask students if this is a good assumption.

WARNING: Denatured alcohol contains a small amount of methanol mixed with the ethanol. Methanol causes blindness and death in very small quantities! **UNDER NO CIRCUMSTANCES SHOULD DENATURED ALCOHOL BE INGESTED!**

Difficulties and Alternative Conceptions: Most students know that light is measured in Watts, energy per time, but they do not know how to apply the energy to any given case. Make the connection that here is an example of electrical energy and thermal energy in conversion.

Sample Data



This was done with a 6V battery and it was drawing .14A.

Using the fact that the power dissipated by the light bulb is given by $P = IV$, it worked out that about half of that power was going to heat the water. The rest would be the light that the bulb is still emitting.

Possible Discussion Questions:

1) What is the effect on our results of the alcohol evaporating?
2) Electrical energy changes to thermal energy. Is there a way to change this thermal energy into mechanical energy? Where do you suppose the original electrical energy came from?
3) Tropical fish need a constant temperature to their environment. What are some factors that one should look out for in setting up a tropical fish tank?

Check Your Understanding:

1. These questions can be answered by referring to the text.

2.
   a) They have the same magnitude.
   b) The lead will undergo a greater change in temperature since it's specific heat is less than that of water.
   c) The final temperature will be less than 50^o C.

3. Water (1), Aluminum(2), Iron(3), Copper(4), Silver(5), Lead(6). This is because a substance with a relatively large specific heat will undergo a relatively small temperature change.

4. Lead(1), Silver(2), Copper(3), Iron(4), Water(5), Aluminum(6). This is because a substance with a relatively small latent heat of fusion will melt faster.

5. Water (1), Aluminum(2), Iron(3), Copper(4), Silver(5), Lead(6). This is because a substance with a relatively large specific heat will transfer more energy to the environment assuming for a given change in temperature.

6. During cooling, $Q_1=mc(T_f-T_i)=m$(1cal/g ^{o}C)(25^o C). During freezing, $Q_2=mL=m$(80cal/g). The ratio of these is Q_1/Q_2=0.3125. Hence, more heat is transferred during freezing.

7. d

8. Since both pans have boiling water, the water in each pan has the same temperature of 100^o C, the potatoes should cook at the same rate if they are not in contact directly with the pan. If the potatoes are in contact with the bottom of the pan, one pan will have a higher temperature than the other, and will transfer energy to the potato at a faster rate.

TA Lab Evaluations
Physics 1102 Lab 1

We strongly encourage you to fill out this evaluation as soon as you are done teaching the labs. If you had issues or problems with any of the lab please submit available information through the LabHelp system or email lab@physics.umn.edu.

Instructors Pages:

Did you find the instructors pages useful? (circle one) yes / no

What additional information would you include in these pages?

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Students:

Did the students find these exercises: (circle one) enlightening / boring / fun / other?

Do you have additional comments regarding student learning and these labs?

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TA:

Given the choice, would you teach these exercises again? (circle one) yes / no

Why or why not?

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Results:

Did the students obtain sensible results from these exercises? (circle one) yes / no

What were the best / worst sets of results? Why?

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Lab Room:

Was the room kept neat and clean by your class and other classes? yes / no

Was the equipment functioning properly? Could you fix it? yes / no

Any other comments regarding the room and equipment?

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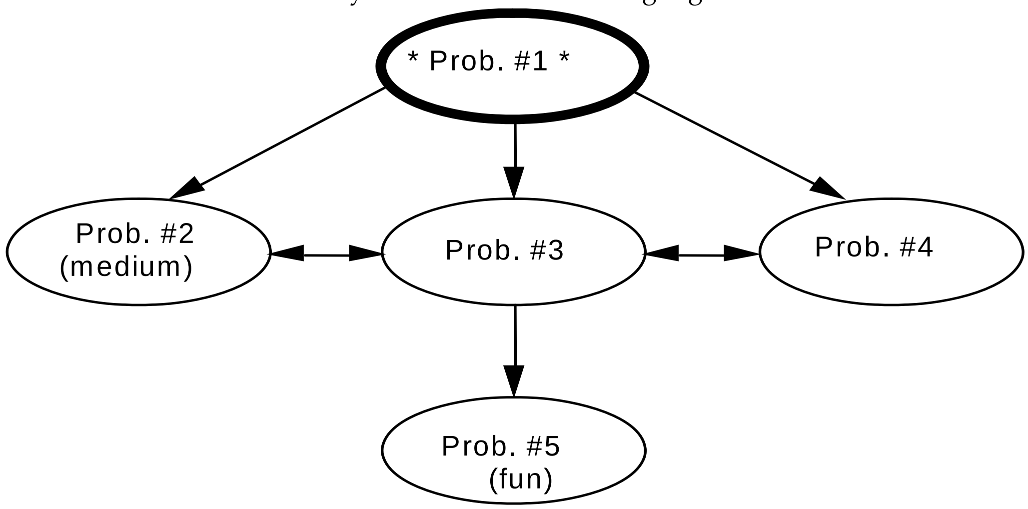
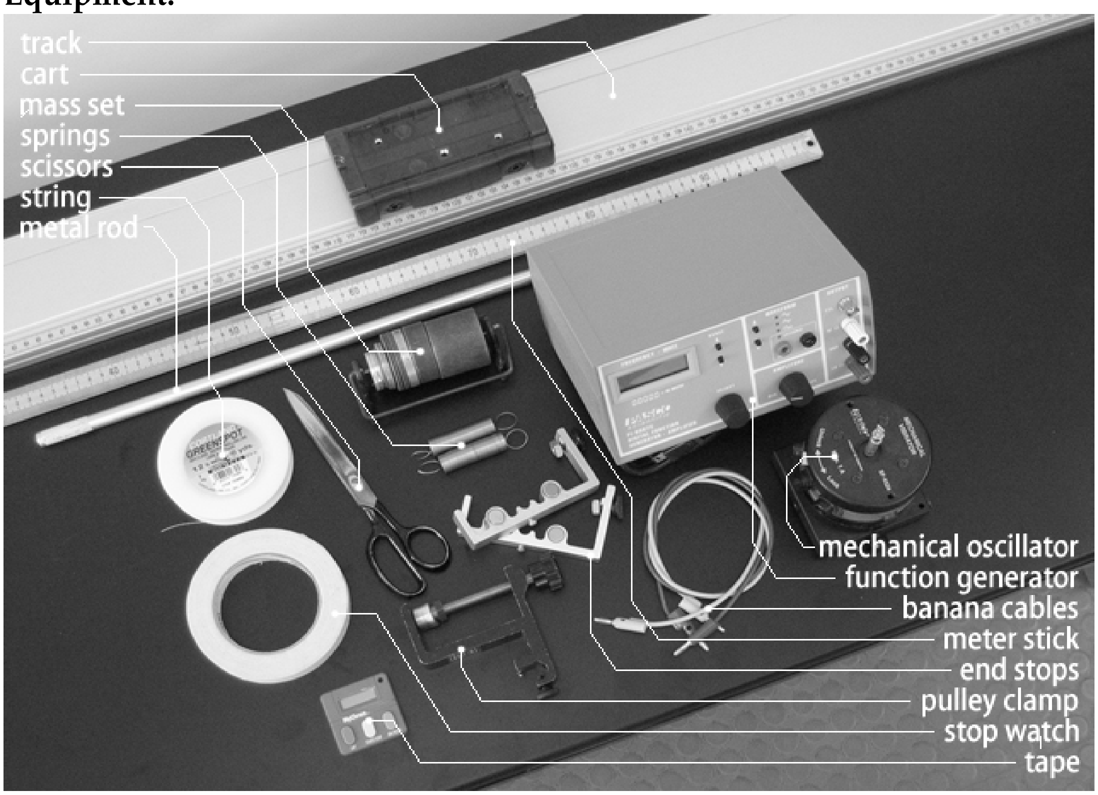
Laboratory II:
Mechanical Oscillations

Laboratory II introduces the students to simple harmonic or oscillatory motion. This is the first time that most of the students will experience a non-constant acceleration in lab. They did the circular motion last semester, but here the magnitude of acceleration is changing. This lab will focus on Hooke's law-type forces, where the acceleration is proportional to the distance from equilibrium. It is good to point out that this type of motion can describe many things. Students often start to think that constant acceleration is the only thing that exists in the real world, since that is all that they have experienced in lab thus far.

This is the flow chart for Laboratory II. Problem #5 is the highlight of this lab.



Equipment:



By the end of lab students should be able to:

- Provide a qualitative explanation of the behavior of oscillating systems using the concepts of restoring force and equilibrium position.
- Identify the physical quantities, which influence the period (or frequency) of the oscillatory motion and describe this influence quantitatively.
- Demonstrate a working knowledge of the mathematical description of an oscillator's motion.
- Describe qualitatively the effect of additional forces on an oscillator's motion.

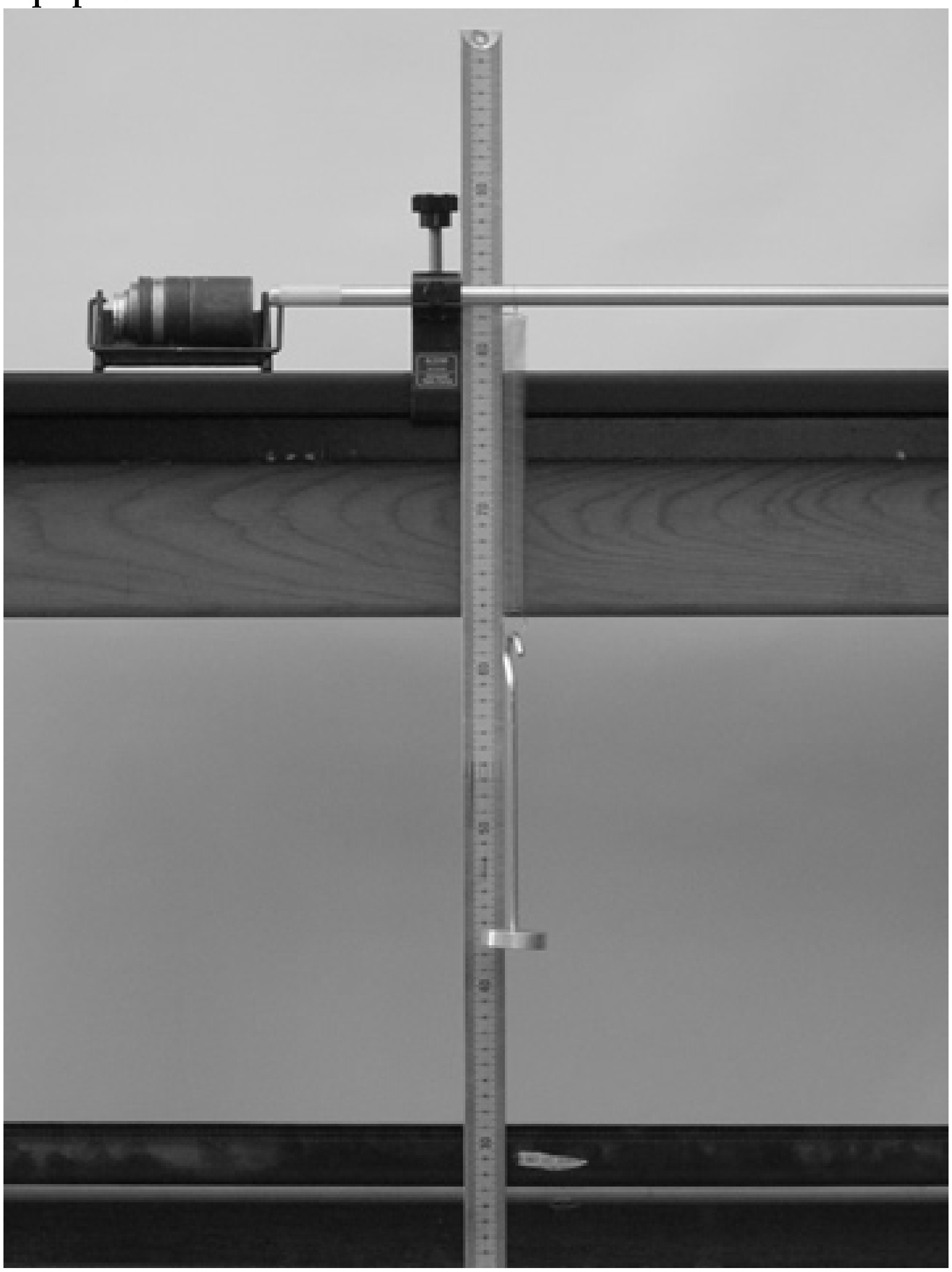
Things to check fifteen minutes before lab:

- See how stiff the various springs are. Check the mass limits so as not to damage the spring. Make sure you know how to set up the equipment for problem #5 (see diagram). It is fun to see the resonance for yourself also.
- Check the limits of how far the end stops should be separated in problems #3 and #5. About 30 cm worked well with the small springs.
- The tracks may be rather dirty - check that the carts roll smoothly on the section of track being used. The masses make a big difference in the frequency, and they are fun to watch!

Problem #1: Measuring Spring Constants

Purpose: 1) To introduce simple harmonic motion and help students to understand the different concepts, such as period, amplitude, frequency, etc.

Equipment:



Things to Remember:

- The students may not remember Hooke's law. It is in the assigned reading, so **DO NOT LECTURE**. Instead refer them to their textbook.

- The students have not had differential calculus yet, so do not expect them to solve the equations of motion for an oscillating system. The problem solving technique used in the manual is the best way around this deficiency.
- You should discuss with the class the relative merits of both measuring techniques since the result of this discussion is relevant to the next problem.
- Remind students that simple harmonic motion is a special kind of motion present in nature that can be modeled with a spring and a mass. We don't care so much about the spring and mass themselves, but we do care about understanding this kind of motion and then applying that understanding to other circumstances.

Difficulties and Alternative Conceptions: This is the students' first experience with a non-constant force. It may not be as intuitive for them as you might expect. Ask your students to explain the negative sign in Hooke's law. Second, the students are not familiar with simple harmonic motion. They may not understand the difference between period and frequency.

Predictions and Warm-up:

Remember, your students are doing these predictions without calculus. Below is a method to find the relationship between frequency, mass, and spring constant that does not include the analysis of derivatives. Students compare simple harmonic motion with circular motion to find the frequency of oscillation.

1) For an object moving in a uniform circle, $v_o = \frac{2\pi A}{T}$ where A is the radius of the circle, or amplitude of oscillation, and T is the period (time to go once around).

2) Write the maximum amount of kinetic and potential energy possible, then equate the two: $\frac{1}{2}kA^2 = \frac{1}{2}mv_o^{\ 2}$.

3) Solve for $\frac{A}{v_o} = \sqrt{\frac{m}{k}}$

4) Combine this equation with the first one and show that:

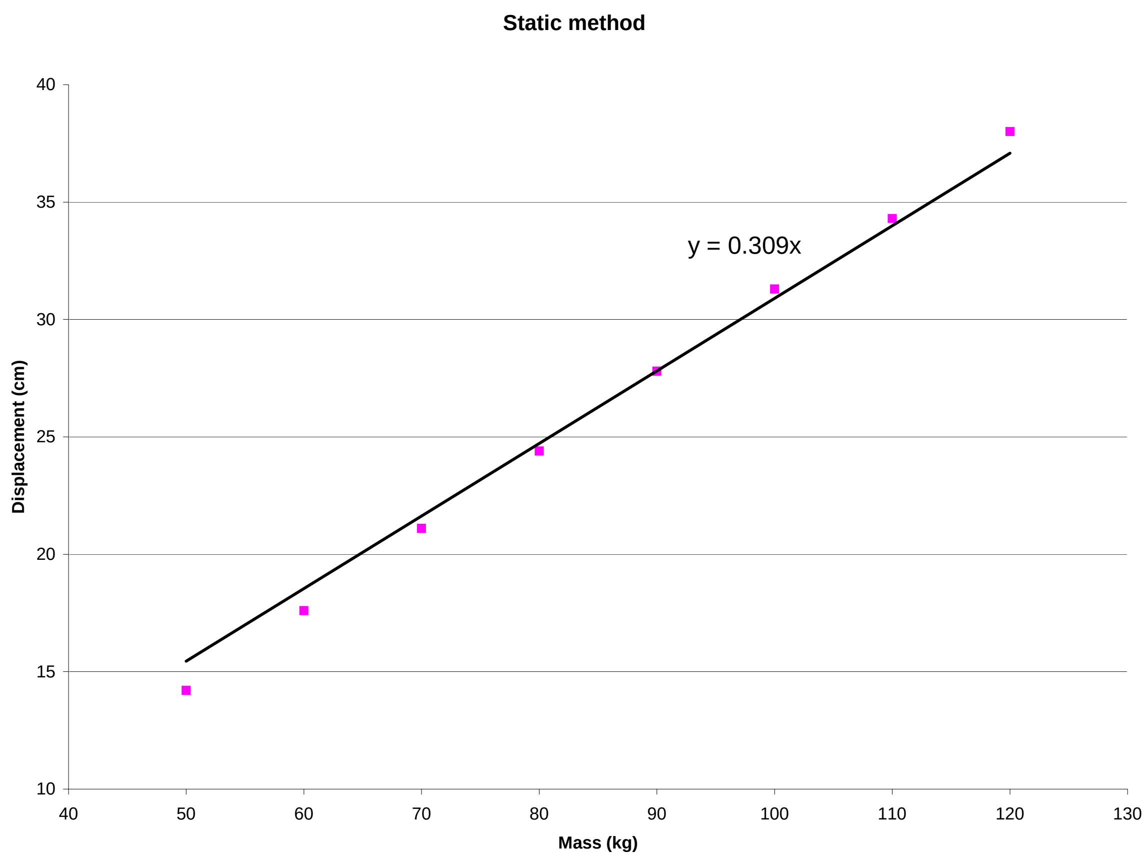
$$T = 2\pi\sqrt{\frac{m}{k}} \quad \text{,or} \quad f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Sample Data

- **Static Approach**

Measuring the spring constant works well in both the static and dynamic method. One problem your students might have in using the each method is trying to calculate the spring constant from individual data points. Have them plot the data and ask them how they can use that to find the spring constant. They may have trouble relating the spring constant to the slope of the graph. Below is the data and a graph from a sample experiment. All displacements were taken from a rest position where there was no load.

Mass (g)	Displacement (cm)
50	14.2
60	17.6
70	21.1
80	24.4
90	27.8
100	31.3
110	34.3
120	38



$$\sum F = k\Delta x - mg = 0 \rightarrow \Delta x = \frac{g}{k}m$$

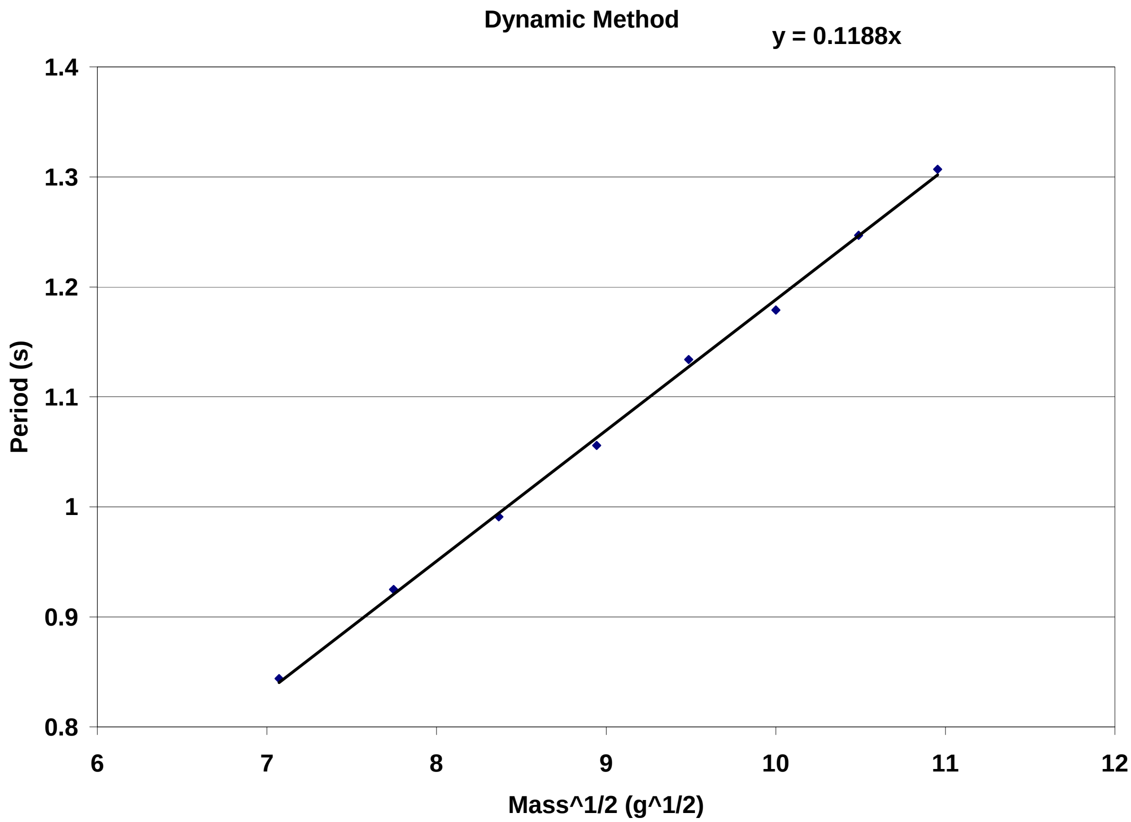
Therefore, the slope of this graph is g/k. Thus, the spring constant is 3171 g/s^2,
or 3.171 N/m.

- **Dynamic Approach**

Again, you would like your students to make a graph in order to find the spring constant instead of trying to calculate it from individual data points. The lab manual directs the students to linearize their data. They can do this by plotting T^2 vs. m or plotting T vs. $\sqrt{m}$, and then relating the slope to the spring constant. For the latter case, we have

$T = 2\pi\sqrt{\frac{m}{k}} \rightarrow$ slope = $2\pi\sqrt{\frac{1}{k}}$. Here is data and a graph from a sample experiment:

Period (s)	Mass (g)
0.844	50
0.925	60
0.991	70
1.056	80
1.134	90
1.179	100
1.247	110
1.307	120



Thus, the spring constant is 2797 g/s^2 or 2.797 N/m

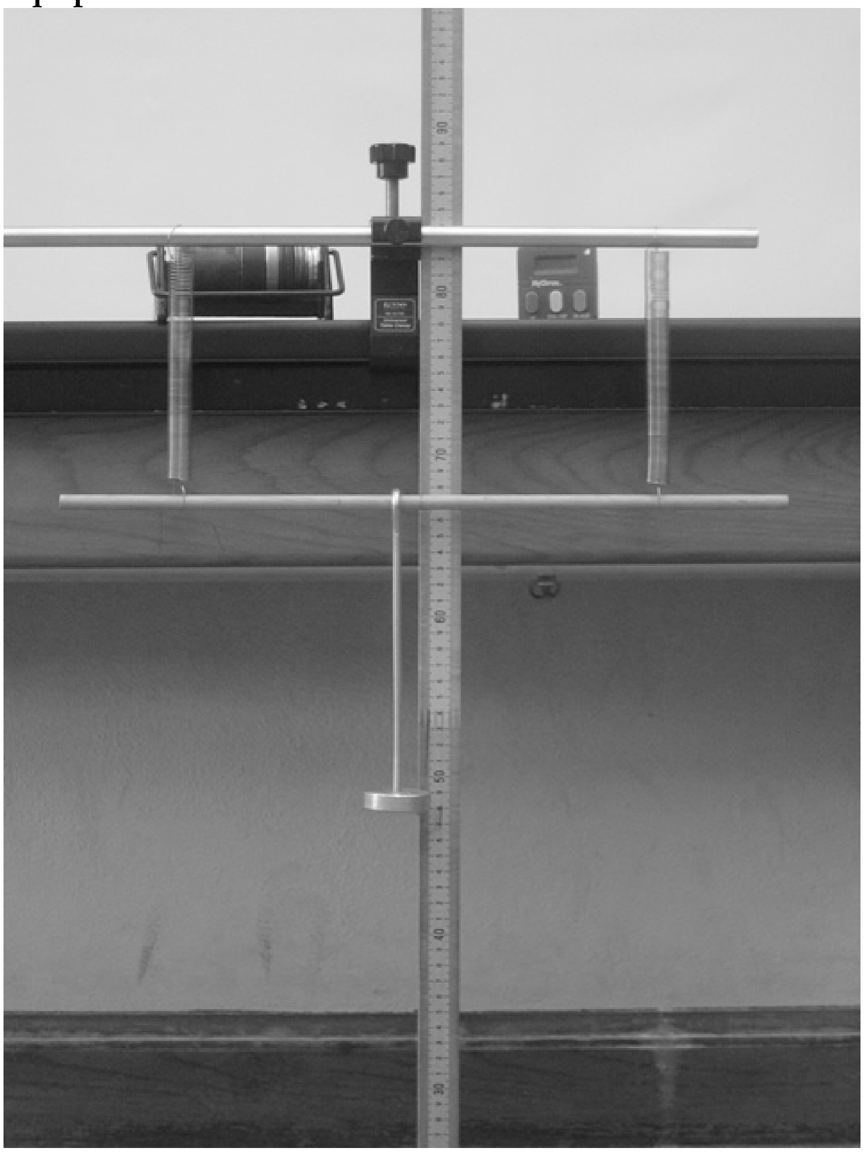
Possible Discussion Questions:

1) Where else in nature do we see oscillations and simple harmonic motion?
2) We just finished studying conservation of energy. Can you describe a new form of energy in the system of spring and mass? (potential energy of the spring)
3) Why is it better to count ten or twenty oscillations and divide by the total time than to watch and time a single oscillation?

Problem #2: The Effective Spring Constant

Purpose: 1) To apply the method of adding forces in a more complex environment and help students understand non-constant forces and acceleration.

Equipment:



Teaching Tips

- This problem takes advantage of the results of problem #1. The students cannot do this problem without first having done problem #1.
- Effective spring constants are not discussed in their text. You may need to sell the class on the advantages of this concept **at the end of the lab**.
- You may need to tape the spring to the rods.
- Use the dowel rods to keep the parallel springs separated. In the past, students frequently tangled up the springs. The rod should help.

- The prediction for the parallel springs should be solved assuming that the amount of stretch of each spring is the same. If this assumption is not made, the only way to solve the problem is to consider the torque on the rod.
- The dynamic approach is the faster method for measuring spring constants, there is no graphing involved or slope calculating.

Difficulties and Alternative Conceptions: First, this is the student's first experience with adding non-constant forces. Second, the students are not familiar with simple harmonic motion. They may not understand the difference between period and frequency.

Prediction and Warm-up: Springs add like capacitors:

End-to-end: $k_{eff} = \dfrac{k_1 \cdot k_2}{k_1 + k_2}$ Side-by-side: $k_{eff} = k_1 + k_2$

Data

Either method (static or dynamic) will work, but the dynamic method is easier in this manual's opinion. In the data below, the individual springs had measured spring constants of 61 N/m and 78 N/m. Using the same formula as before,

$k = (2\pi f)^2 m$

Side to side

Mass (kg)	*Frequency (Hz)*	*K (N/m)*
.85	2.0	**134**
.95	1.9	**135**

Theory predicts $k_{eff} = k_1 + k_2$ =61 N/m + 78N/m=**139**N/m

End to end

Mass (kg)	*Frequency (Hz)*	*K (N/m)*
.35	1.6	**35**
.45	1.9	**36**

Theory predicts $k_{eff} = \dfrac{k_1 \cdot k_2}{k_1 + k_2}$ =**34** N/m

Possible Discussion Questions:

1) How would accounting for the mass of the springs affect our results?
2) How the potential energy of the spring system change when it is in a new configuration?

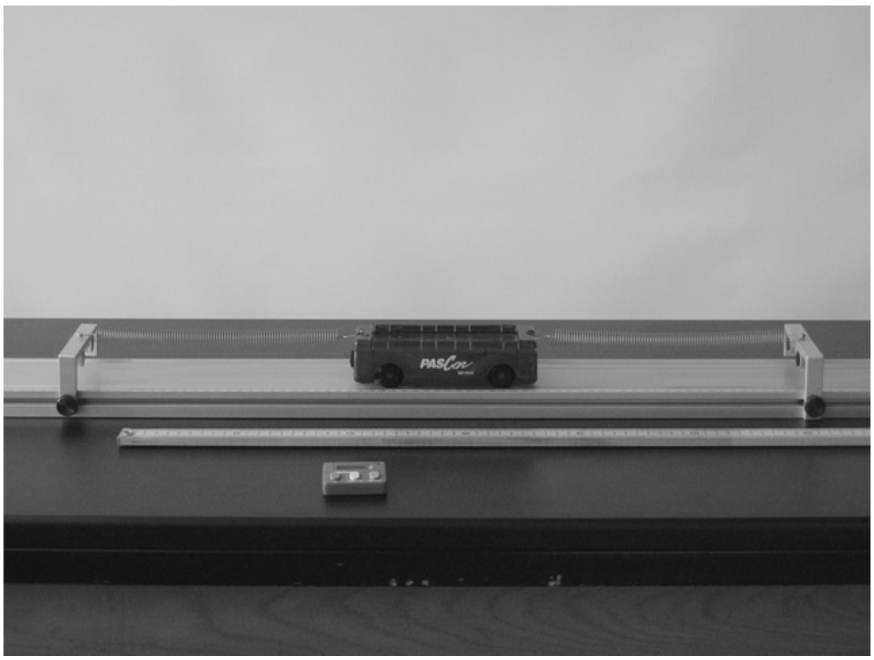
Problem #3: Oscillation Freq. with Two Springs
Problem #4: Oscillation Freq. of an Extended Body

Purposes

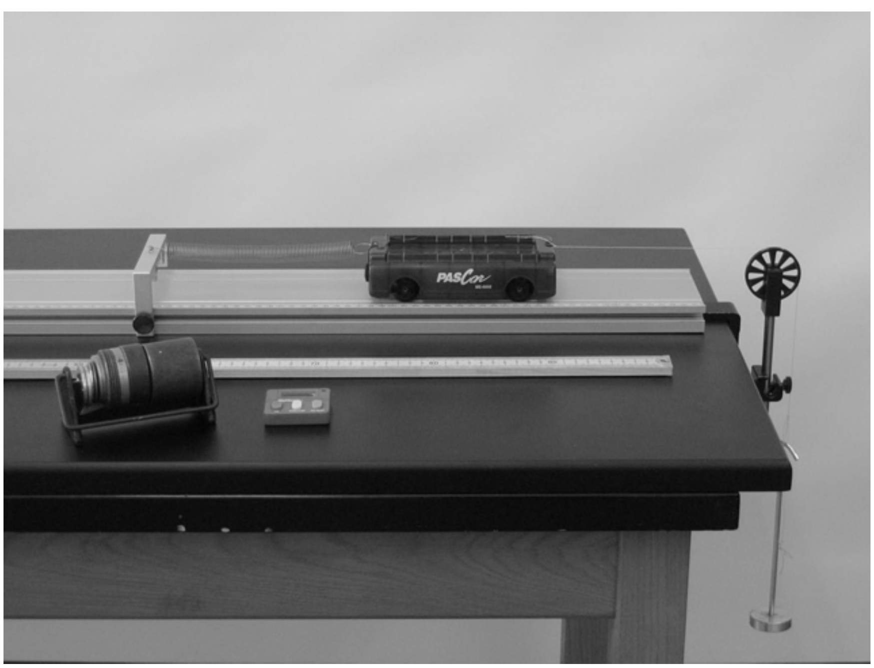
1) **(Pr. 3)** To determine how the more complex system of two springs and one mass behaves in comparison to the one spring, one mass system.
2) **(Pr. 4)** To determine how the more complex system of one spring and two masses behaves in comparison to the one spring, one mass system.

Equipment:

Problem #3



Problem #4



Things to Remember:

- Do not stretch the springs too far. The springs are fragile. They will not obey Hooke's law if they are stretched too far.
- Your students will need to determine the spring constants for their springs. They should use the period of oscillation and suspend a *very* light mass.
- The oscillations for the springs are measurable. Keep the endstops at a reasonable separation - about 30 cm.

Difficulties and Alternative Conceptions: Students who cannot explain the negative sign in Hooke's law will have difficulty deriving the equation of motion for problem #3. For problem #4, there may be some confusion over the role of the hanging mass. Both of these problems are excellent opportunities for students to practice with force diagrams, choose an appropriate coordinate system, and understand acceleration.

Note: The students will reach a point in their derivations where, after combining the force diagrams, they find $a+\left(\frac{k}{m1+m2}\right)x=\left(\frac{m2}{m1+m2}\right)g$. Here, they do not have the calculus ability to solve the differential equation. Make sure they know how they can disregard the constant term, and how to determine the frequency from the equation $a+\left(\frac{k}{m1+m2}\right)x=0$.

Predictions and Warm-up:

(Problem #3) $$f=\frac{1}{2\pi}\sqrt{\frac{k_1+k_2}{m}}$$

(Problem #4) $$f=\frac{1}{2\pi}\sqrt{\frac{k}{m_1+m_2}}$$

where m_1 is the mass of the glider and m_2 is the hanging mass.

Sample Data

(Problem #3)

The spring constants were individually measured using the dynamic method.

$k_1 = 2.84N/m$, $k_2 = 2.61N/m$, $m = .222kg$

The prediction says $\underline{f = .79Hz}$. The measured frequency was $\underline{f = .8Hz}$.

(Problem #4)

$k = 2.84N/m$, $m_1 = .222kg$, $m_2 = .05kg$.

The prediction says $\underline{f = .51Hz}$. The measured frequency was $\underline{f = .5Hz}$.

Possible Discussion Questions:

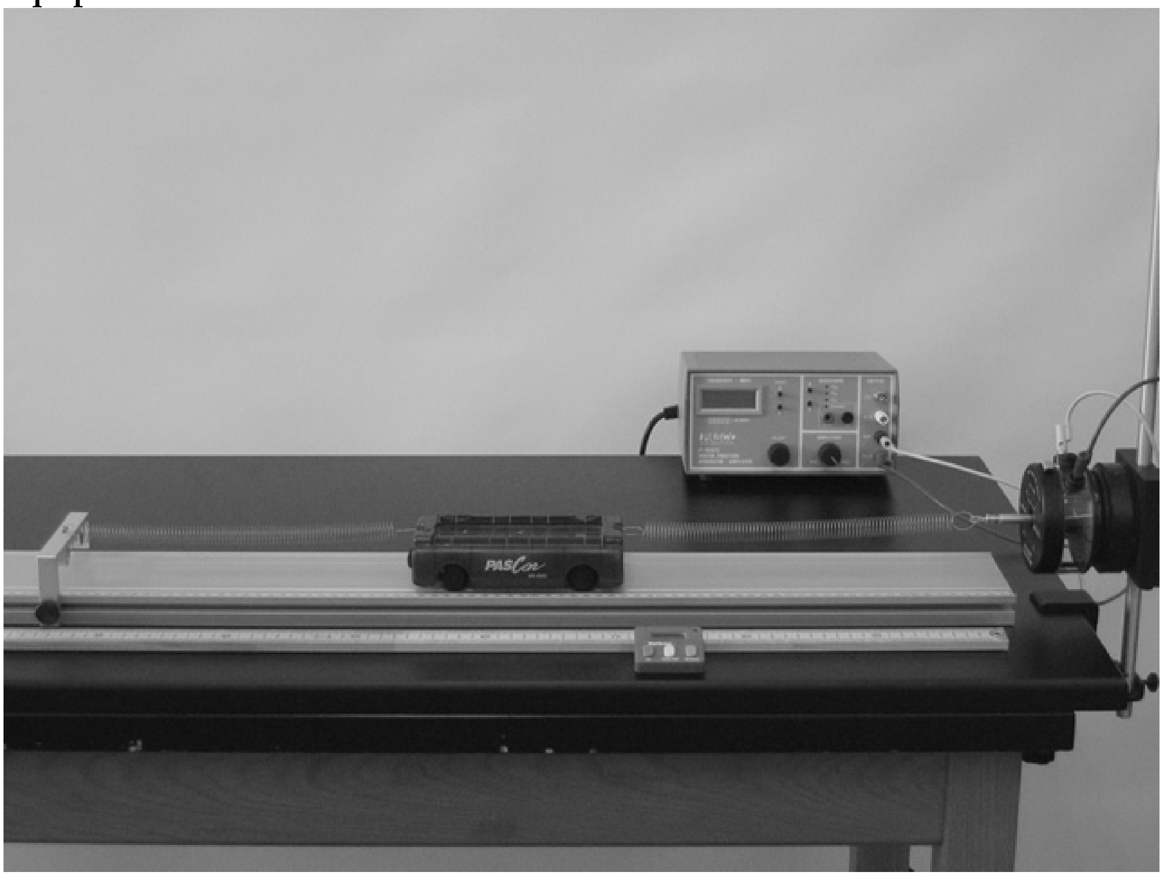
1) Does frequency depend on amplitude? What happens to the maximum speed as the amplitude becomes smaller?

2) Are there physical situations where a central object might feel the attraction of two spring-like systems? Think about the attraction between molecules.

Problem #5: Exploring Driven Oscillations

Purpose: 1) **(Pr. 5)** To introduce the students to resonance.

Equipment:



Teaching Tips

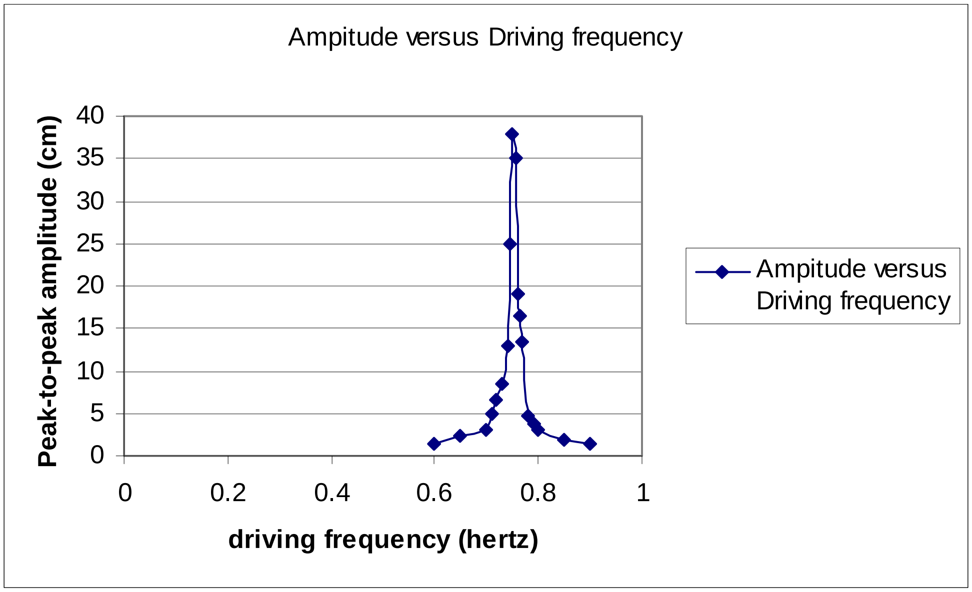
- This problem is designed to introduce resonance to the students. The material is not covered in class, nor is it in the text. Even so, **DO NOT LECTURE**, let the students uncover these concepts themselves. Don't cheat yourself out of the fun of seeing the students 'accidentally' finding the resonance frequency. This is one of the few truly exciting labs for the students; do not spoil it by lecturing. If you want to say something, save it until the end of lab. Problem #5 is an exploratory lab. If you want to have your students explore the concept of damping qualitatively without graphing, go ahead.
- The mechanical drivers are expensive and of limited quantity. Use them with caution and follow the directions in the manual carefully.
- Notice that the frequency range on the function generator can be adjusted, which may be important depending on the natural frequency of the cart and mass.

Predictions and Warm-up:

There should be single frequency on the function generator that makes the glider and spring system resonate. Don't get caught up in any mathematics here. Let the students explore. Encourage them to wander about and watch other groups in action.

Have your students compare their results to those of problem 3. Ask them to see if the resonance occurred at the natural frequency of the system.

Have fun!



An example of what the graph should look like

Check Your Understanding:

1.

t	x	v	a	KE	PE
0	A	0	$-w^2A$	0	$kA^2/2$
T/4	0	$-wA$	0	$kA^2/2$	0
T/2	$-A$	0	w^2A	0	$kA^2/2$
3T/4	0	wA	0	$kA^2/2$	0
T	A	0	$-w^2A$	0	$kA^2/2$

2.

a. The period of oscillation doesn't depend on the amplitude. Hence, they will both take the same amount of time to reach the equilibrium position.

b. The acceleration is proportional to the distance the spring is stretched, so the B will have a greater acceleration initially.

c. B will have a greater velocity since it has more energy.

d. The acceleration is 0 for each since the spring is unstretched.

3. $w_A=w_B$ -> $(k_A/m_A)^{1/2}=(k_B/m_B)^{1/2}$

a. Since m_A is larger than m_B, k_A must be larger than k_B.

b. $x = mg/k = g/w^2$. Since $w_A=w_B$ both springs are stretched the same distance at equilibrium

c. Since they are initially stretched the same distance from their equilibrium position and the frequencies are the same, they will have the same acceleration.

d. If the initial displacement below the equilibrium is A, then the total energy for each system is proportional to the mass: $E=kA^2/2-mgA=m(w^2A^2/2-gA)$. Therefore, system A has a greater total energy.

e. Since system A has a greater total energy and the potential energy is 0 at the equilibrium, then A will also have a greater kinetic energy as it passes through equilibrium.

f. At equilibrium , the kinetic energy of each is given by $mv^2/2= m(w^2A^2/2-gA)$. This implies that the velocity is the same for each system since the mass cancels out.

4. The effective spring constants are $k_A = k$, $k_B = 2k$, $k_C = k/2$.

a. $x = mg/k$, so $x_C>x_A>x_B$

b. answer above.

c. T is proportional to $k^{-1/2}$. Therefore $T_C>T_A>T_B$

TA Lab Evaluations
Physics 1102 Lab 2

We strongly encourage you to fill out this evaluation as soon as you are done teaching the labs. If you had issues or problems with any of the lab please submit available information through the LabHelp system or email lab@physics.umn.edu.

Instructors Pages:

Did you find the instructors pages useful? (circle one) yes / no

What additional information would you include in these pages?

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Students:

Did the students find these exercises: (circle one) enlightening / boring / fun / other?

Do you have additional comments regarding student learning and these labs?

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TA:

Given the choice, would you teach these exercises again? (circle one) yes / no

Why or why not?

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Results:

Did the students obtain sensible results from these exercises? (circle one) yes / no

What were the best / worst sets of results? Why?

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Lab Room:

Was the room kept neat and clean by your class and other classes? yes / no

Was the equipment functioning properly? Could you fix it? yes / no

Any other comments regarding the room and equipment?

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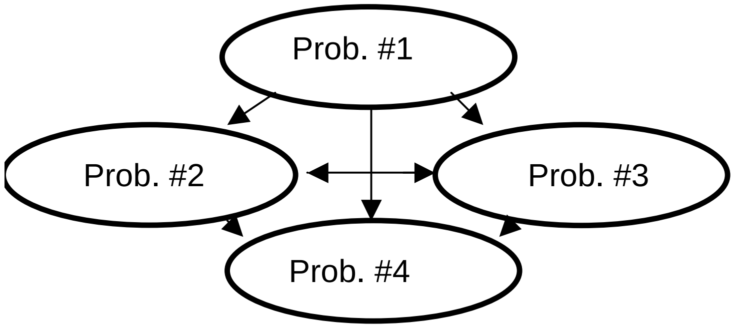
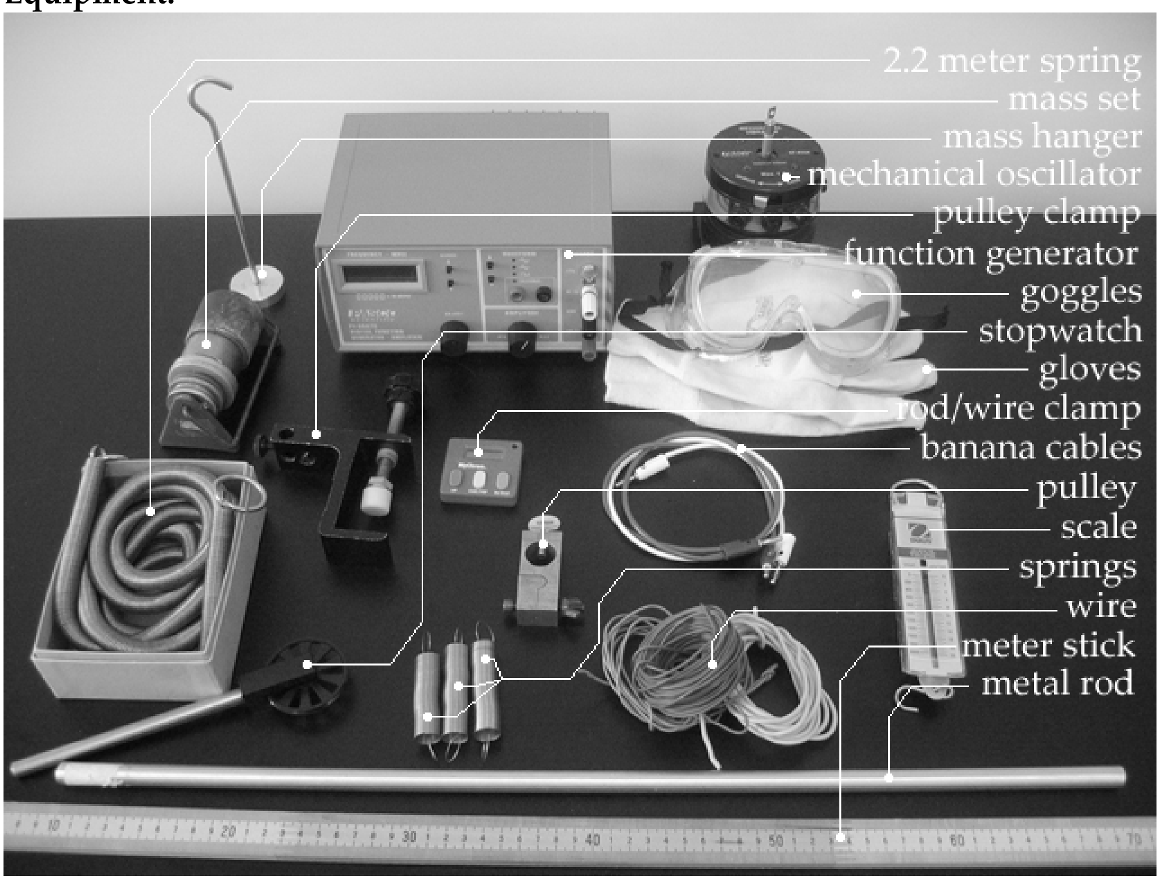
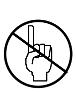
Laboratory III:
Waves

Laboratory III introduces the students to waves. Keep in mind that these problems do not go in depth in the mathematical description of waves. They do not cover waves long enough in lecture to make this feasible. Please stay within the bounds outlined in the lab so as not to confuse the students. The basic concepts covered are wave speed and standing waves.



Equipment:





WARNING: Never release one end of a spring that is under tension. Its snapping motion could injure somebody. Always release the tension slowly. **Wear** safety goggles while in the vicinity of the springs.

By the end of lab students should be able to:

- Distinguish between the motion of a particle in a medium and the motion of the wave in the medium.
- Identify the difference between traveling and standing waves.
- Understand how standing waves arise from the superposition and interference of traveling waves.
- Identify the properties of the medium which determine the wave velocity.
- Connect real systems to the mathematical description of waves.

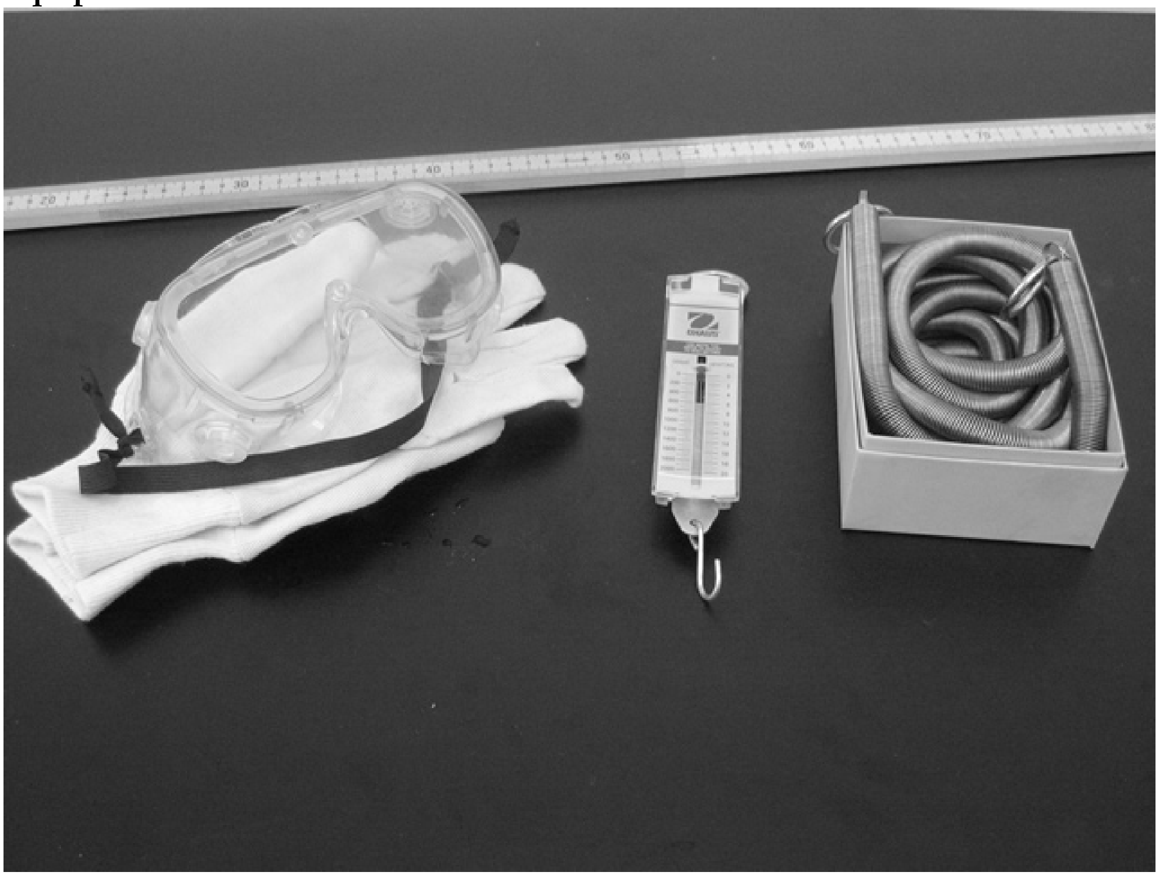
Things to check fifteen minutes before lab:

- Find a friend and play with the springs.
- See if you can make the various shapes shown in Problem #1. Some of the shapes are difficult, and students really don't need to make them. Only have them worry about making all the shapes if you've got a lot of time.
- Try creating a standing wave on the spring.
- Set up Problem #3. Check that you can get standing waves on the wire.

Problem #1: (Exploratory) Wave Speed

Purpose: 1) To show students the difference in pulse speed for transverse and longitudinal waves.

Equipment:



Teaching Tips

- The students should measure the velocity of the pulse using the definition of velocity, namely displacement divided by time. Some students will want to use $v = \lambda f$, but the pulses do not have a well-defined wavelength. Have them use the more fundamental definition.
- This problem allows the students a hands-on experience making waves on a medium and thinking about waves scientifically. Most students lack any meaningful experience with waves.
- You cannot make the square wave without help and it is not easy. It is less important that they succeed than that they try. The half-round and triangle pulse are easier.
- Masking tape is provided in the lab room. Take a small piece of it and attach it to the center of the springs. Ask the students what will happen when the longitudinal wave passes by the string. Most will answer that it will go back and forth as the wave passes. In reality the tape will appear to go forth when the wave passes the first time, then back after it reflects and comes back. This simple experiment allows the students to see in a little more detail through what motion the spring is moving.

- The prediction is probably too difficult for the students to derive from a physical model. Therefore, use a dimensional analysis argument to arrive at the correct answer. For transverse pulses, $v = \sqrt{\frac{T}{m/l}}$, where *T* is the tension in the spring and *m/l* is the mass per length of the spring. The velocity of longitudinal pulses is different and can be related to Young's modulus. Let the students discover that longitudinal pulses travel at a different speed than transverse pulses.

Difficulties and Alternative Conceptions: Make sure that students witness the inversion of a traveling wave at the boundary. This will help them understand the phenomenon of standing waves better.

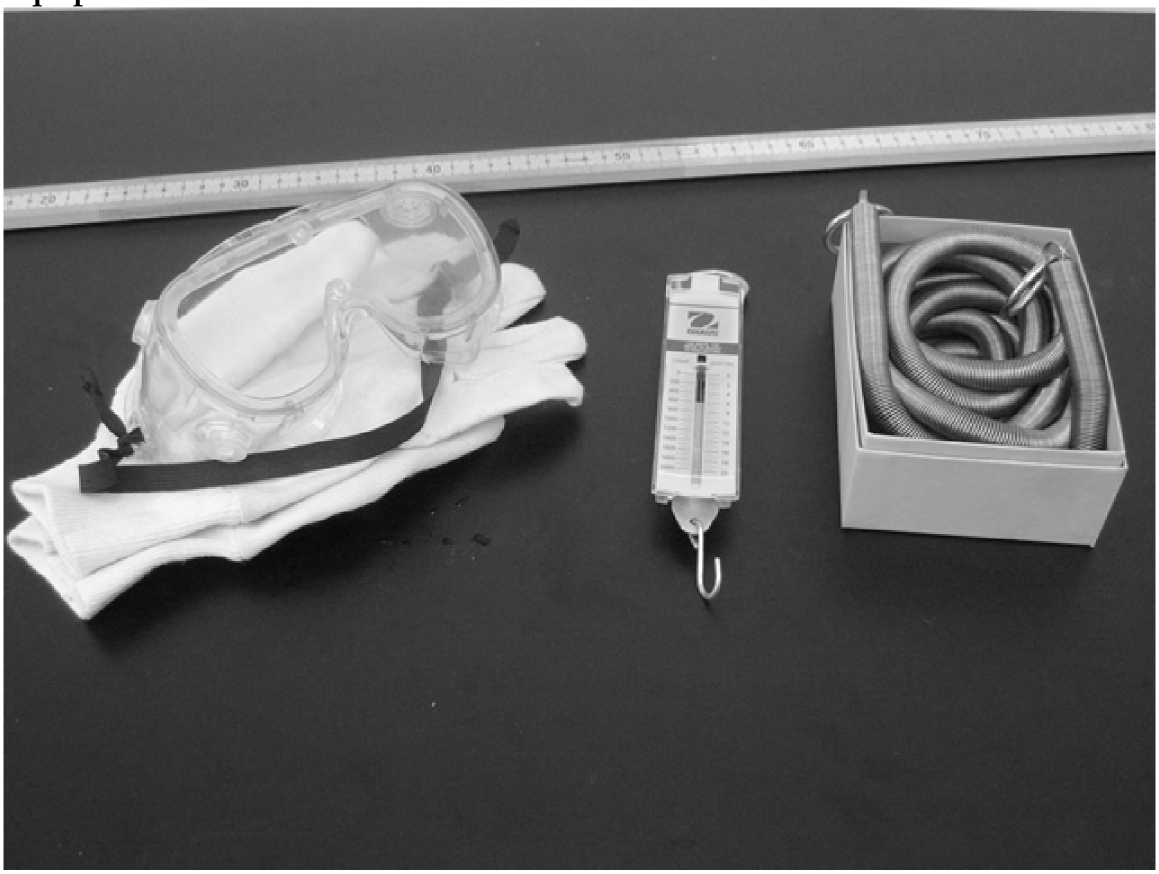
Possible Discussion Questions:

1) What does the speed of a wave depend on? (stiffness, size, of the spring). Think about sound and light traveling through different media, the density and composition of the media.
2) What happens to wave speed as the tension increases? Can you explain this by analyzing the strength of the restoring force on a portion of the spring that is displaced?

Problem #2: Standing Wave Patterns
Problem #3: Standing Wave Veloctiy

Purpose: 1) To introduce the students to standing waves.

Equipment:



Teaching Tips

- When learning about standing waves, students often have trouble calculating the wavelength of the standing wave for different patterns. Problem #2 focuses on that difficulty.
- One of the strange things about standing waves is that they have a wave speed associated with them. After all, how can a wave that doesn't travel have a speed? Problem #3 explores this question.
- These problems are also about how standing waves are created and they invite the students to see their development. The exploration section is full of questions, so be sure your students answer them.
- The prediction for problem #2 is $\lambda = 2L/n$, where L is the length of the spring and n represents the particular mode or harmonic of the pattern. When the students actually measure the wavelength in lab, they should automatically discover this relationship if they were unable to derive it in the prediction.
- For problem #3, the students should determine the velocity from the slope of their λ vs. T graph and compare to the calculated velocity for a single pulse. Make sure the students

measure the tension and keep it constant as they change the pattern. The period (or frequency) measured is that of the hand they use to create the standing waves.

WARNING: **Never** release one end of a spring that is under tension, because its snapping motion could injure somebody. Always release the tension slowly. **Wear** safety goggles while in the vicinity of the springs. **Wear** a glove on the hand holding the spring.

Difficulties and Alternative Conceptions:

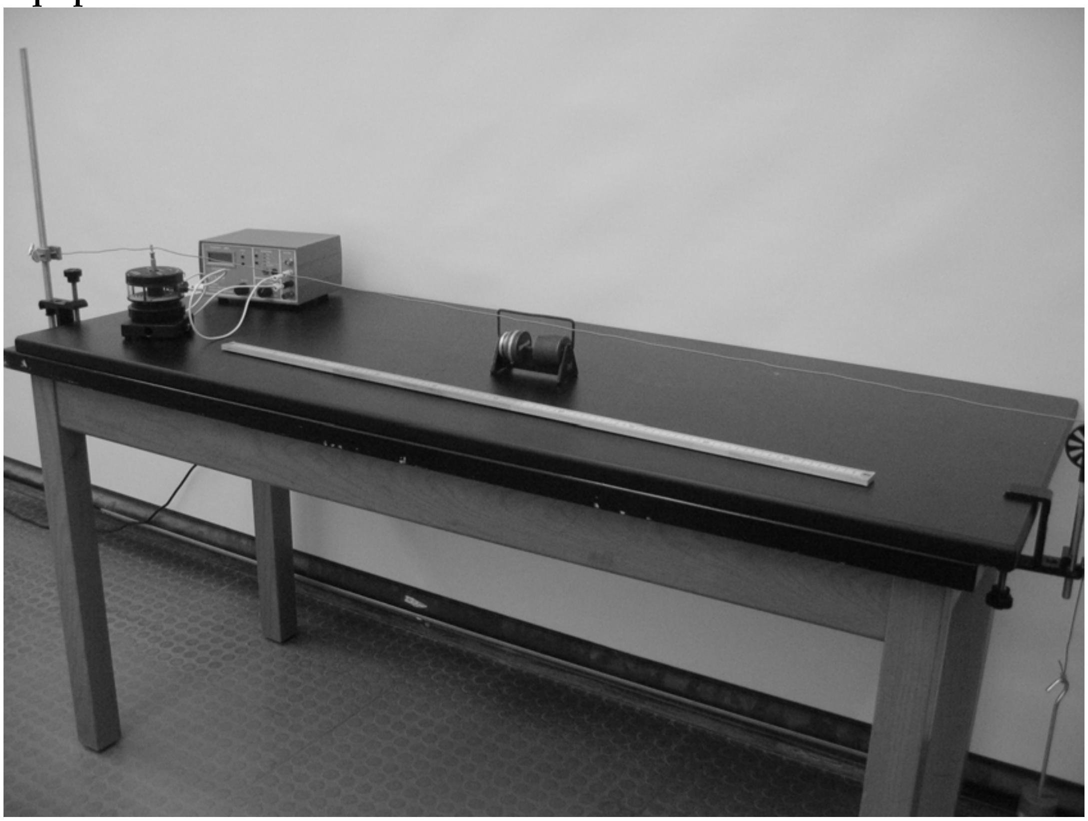
For problem #2 - Remind the students that they want to determine how the wavelength depends on the particular pattern or mode. Therefore, it is important to keep the length of the spring the same when changing patterns.

For problem #3- In drawing their pictures of standing waves, many students fail to realize that a standing wave is two waves overlapping to make the pattern. They tend to think that the string or spring is in two different places at the same time. The standing wave problem addresses this difficulty. Students will use their hands to make the waves at just the right frequency.

Problem #4: Standing Waves

Purpose: 1) To present the case of standing waves with quantitative example.
2) To see how changing the tensions will effect the frequency.

Equipment:



Teaching Tips

- This is a great lab for finding standing waves, but again the students only need to know $v = \lambda f$ and $v = \sqrt{\frac{T}{m/l}}$ to complete their predictions and the Warm-up.

For your information only!! It is provided so you can check their results. There are wires of different colors, each with a different linear mass density. The following values of the linear mass density were measured by the supplier: **If you are uncertain, you can measure a couple of meters on the scale!**

white (16 gauge)	15.6 g/m
red (18 gauge)	11.2 g/m
blue	7.44g/m
green	5.74 g/m
yellow	3.08 g/m
purple (20 gauge)	6.9 g/m
yellow (14 gauge)	25.5 g/m
green (16 gauge)	15.8 g/m

- The lab manual does not ask the students to find the mass density explicitly, so you will have to ask them to combine their equations from the prediction to get the mass density as a function of the tension in the wire, the wavelength of the wave and the frequency of the mechanical driver.
- For this exercise the groups will use only one wire. You may assign a particular wire to your groups in order to allow a class comparison later.
- Very rarely does the amplitude need to be turned all the way up on the function generators. Turning the amplitude all the way up will lead to a few broken wires. The broken wires themselves are not a problem it is the person standing next to the wire when it breaks that we are worried about. **You can hear it when the amplitude is turned up too high.** It makes a staccato or a kind of slapping noise that reduces to a hum if the amplitude is turned down a bit.
- The wire is threaded through an eyelet. We do not know if this will cause the wires to break. Once the students have looked at the effect of the placement of the mechanical oscillator and have decided on a position have them tape the wire to the eyelet. Don't forget to have them remove the tape before the next class.

Prediction and Warm-up:

$$v = \lambda f$$

$$v = \sqrt{\frac{\tau}{\mu}}$$

$$f = \frac{1}{\lambda}\sqrt{\frac{\tau}{\mu}}$$

where v is the velocity of the wave, λ is the wavelength, f is the frequency of the mechanical driver, τ is the tension on the wire and μ is the mass per unit length of the wire.

Sample Data

In this trial, the yellow wire was loaded with 550g. The measured wave velocity came out to

$$v = \lambda f = (1.4m)(30.2Hz) = 42.2m/s$$

Calculating it by means of the tension, we get

$$v = \sqrt{\frac{\tau}{\mu}} = \sqrt{\frac{(550g)(9.8m/s^2)}{3.08g/m}} = 41.8m/s$$

Possible Discussion Questions:

1) What are some other physical examples of standing waves, or waves that interfere constructively? (waves on the ocean, sound waves interfering in a pipe, light waves and fringe patterns of interference)

2) Why is it that in mechanics we can assume massless strings, but we cannot do so when dealing with waves on a string?

Check Your Understanding:

1. Yes

2. The string will be flat when the pulses overlap. The pulses are always there. The string is never really "flat", but has two pulses that cancel each other out.

3. $f = v/\lambda = (1/\lambda)(T/\mu)^{1/2}$. If the same pattern (wavelength) is produced, the frequency will increase. If the frequency is held constant, the wavelength must change, which means a new pattern can be produced or the pattern will be lost and there will be traveling waves on the wire.

TA Lab Evaluations
Physics 1102 Lab 3

We strongly encourage you to fill out this evaluation as soon as you are done teaching the labs. If you had issues or problems with any of the lab please submit available information through the LabHelp system or email lab@physics.umn.edu.

Instructors Pages:

Did you find the instructors pages useful? (circle one) yes / no

What additional information would you include in these pages?

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Students:

Did the students find these exercises: (circle one) enlightening / boring / fun / other?

Do you have additional comments regarding student learning and these labs?

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TA:

Given the choice, would you teach these exercises again? (circle one) yes / no

Why or why not?

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Results:

Did the students obtain sensible results from these exercises? (circle one) yes / no

What were the best / worst sets of results? Why?

___

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Lab Room:

Was the room kept neat and clean by your class and other classes? yes / no

Was the equipment functioning properly? Could you fix it? yes / no

Any other comments regarding the room and equipment?

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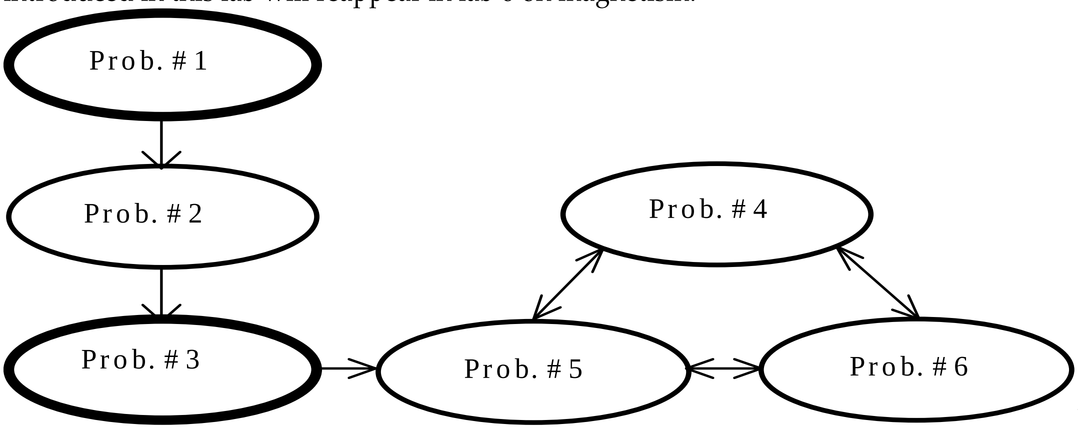
Laboratory IV:
Electric Fields and Forces

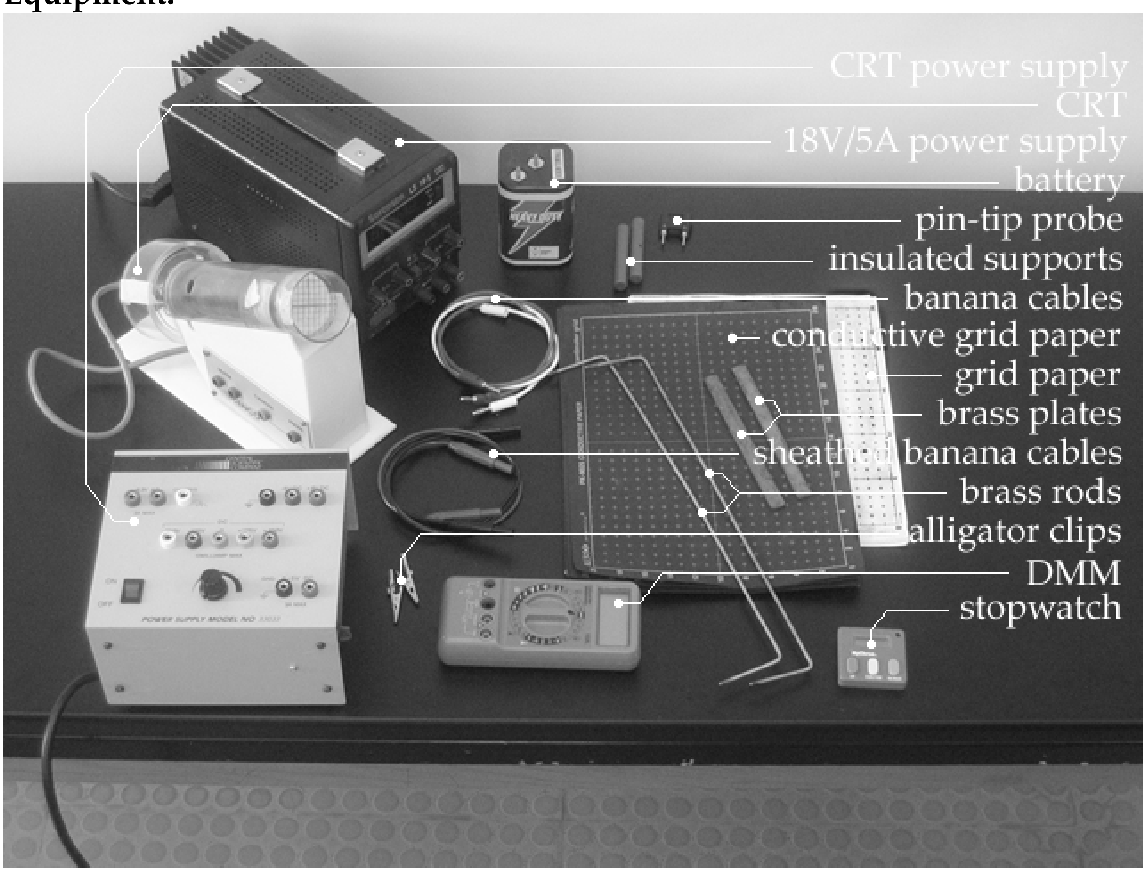
Computers, radios, traffic lights, electric stoves and a thousand other devices that affect our life everyday are made possible with human understanding of the laws of electricity and magnetism. Laboratory IV introduces the basic concepts behind electrostatic fields and forces.

You can do the first flow chart tree for the first week and the other tree for the next week depending on how your team wants to proceed. Some of the equipment and field concepts introduced in this lab will reappear in lab 6 on magnetism.



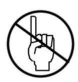
EquiE

Equipment:



General Teaching Tips:

- Talk about the language. Students are comfortable with terms like “energy,” “momentum,” “velocity.” However, terms like “potential difference” and “voltage” confuse them. I spend a lot of time reminding students that potential difference is energy per charge.
- The study of electricity is a major stumbling block for a majority of the students you will teach. Unfortunately, the pace of the class far exceeds the rate at which the average student can absorb this material. Encourage the students to take extra time and have added patience with them. No one can learn this material thoroughly the first time around.



REMINDER: Your students will be working with equipment that generates large electric voltages. Improper use can cause painful burns. To avoid danger, the power should be turned OFF and you should WAIT at least one minute before any wires are disconnected from or connected to the power supply.

By the end of lab students should be able to:

- Know qualitatively where the electric field will be “strong” and “weak” in a charge distribution.
- Construct the electric field based on the geometry of charged objects.
- Determine the magnitude and direction of a force on a charged particle in a simple electric field.

Things to check fifteen minutes before lab:

- Hook up the conductive paper set up to convince yourself that it works.
- Make sure you know how to connect the CRT safely (see appendix for detailed instructions).
- Move the CRT around to see the effect of the earth's magnetic field.
- Try deflecting the beam in the CRT by changing the electric field between the parallel plates.
- Make sure all of the batteries are all right just before your lab. Make sure that they will light up a light bulb.

Problem #1: (Exploratory) Electric Field Vectors

Purpose:

- To show the students an example of a field (in this case an electric field). To emphasize that a field has a magnitude and direction at every point in space.

Teaching Tips

- Everyone should do this problem before doing Problem #2.
- The lab instructions use the term map to describe either a measurement or a prediction of the electric field at selected points in space. For each point there can be only one electric field vector.
- Be sure that the students use primarily (or exclusively) the electric field vector capabilities of EM Field. Some other possibilities from the pull down menu such as field lines are particularly dangerous in reinforcing student misconceptions and should be avoided if possible. The Directional arrows give the magnitude of the electric field vector in terms of color and can be useful, though are not good for printing in black and white.

Difficulties and Alternative Conceptions:

The field concept is a difficult abstraction for most students. It is difficult to envision that every point in space near a charge has a property called an electric field, which is affected by that charge. Many student misconceptions come from their interpretation of pictures of field lines. Many think that something is coming out of a charge, which exerts a force on another charge by “grabbing” it or “pushing” it away. Many students will draw pictures of electric field lines from the textbook, especially for the case of the electric dipole, without any knowledge of what these lines represent. If they do this, ask them what these lines correspond to, how do they show the strength and direction of the field at each point? Remind them that field vectors (which were requested in the question, and which do show the magnitude and direction of the field) must be represented by straight-line arrows.

Another misconception is that the electric field is not necessarily unique at a point. For example, many students will represent the electric field caused by a point charge with several electric field vectors, at the location of the charge, pointing out in all directions.

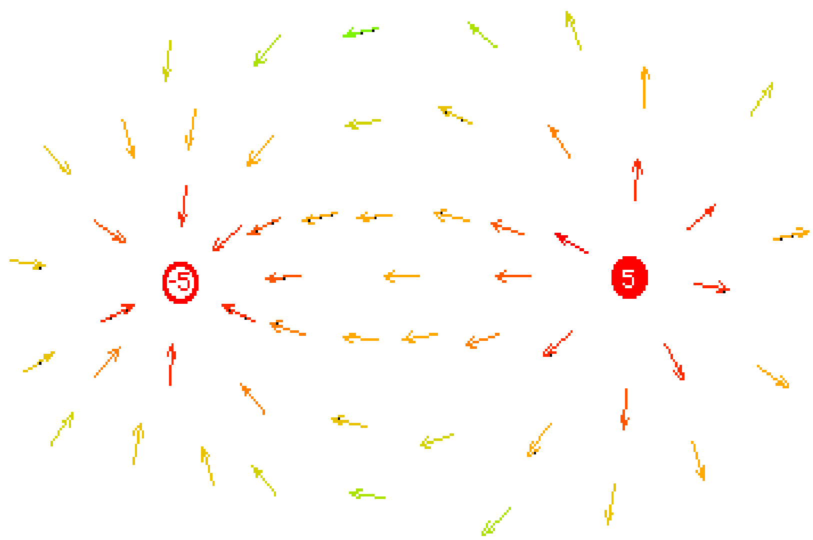
The field idea that objects interact with space and not with each other is a difficult one to understand. This is not a strict Newtonian view of the world. For example, Newton’s 3rd law, with which they had so much trouble at the beginning of the course, no longer applies in a straightforward manner.

Prediction:

Make sure that field vectors go from positive to negative. Make sure no field vectors originate from a point charge. Remember there can only be one field vector at each point in space. The electric field at a point charge is undefined.

Warm-up:

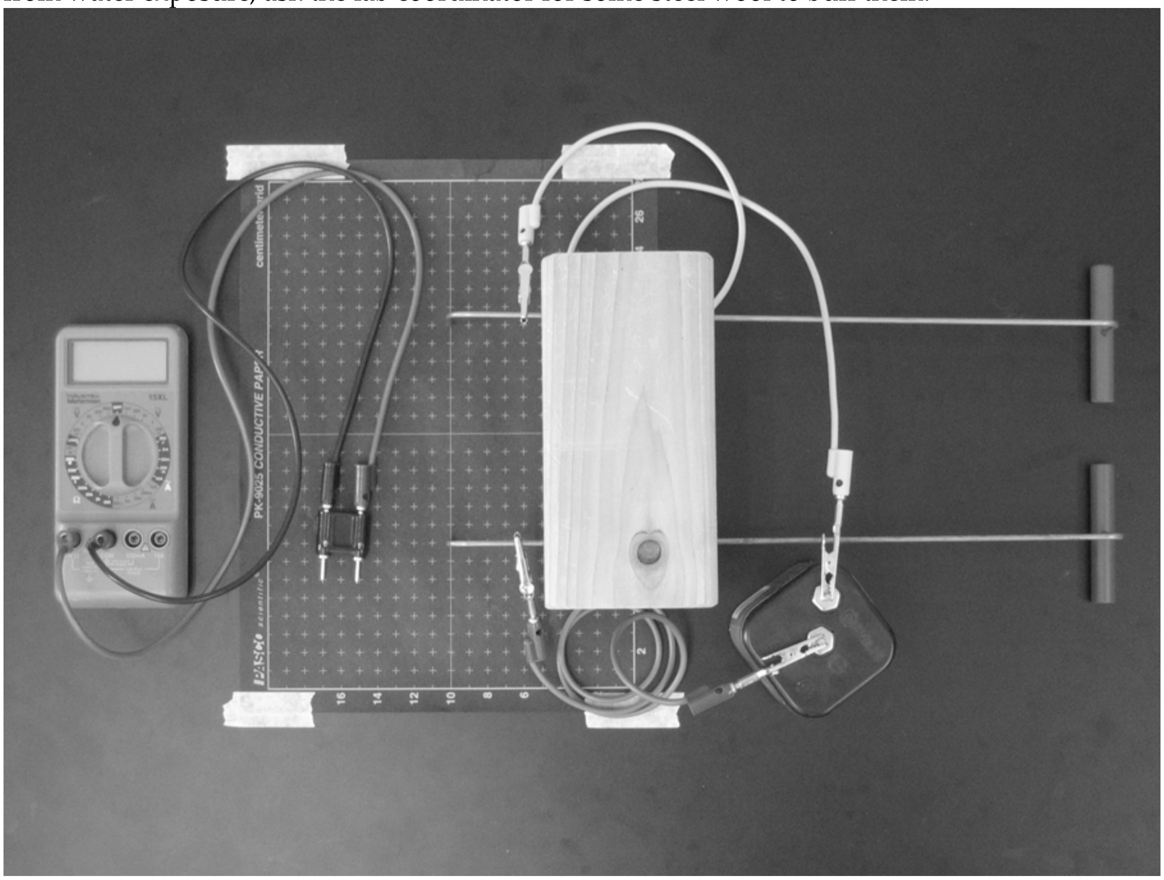
Below is a picture of a dipole field drawn on <u>EM Field</u> with "Directional arrows." Unfortunately, you can't see the color, which represents the magnitude of the electric field, in this black and white copy. This type of representation can be misleading if students don't remember that when they use "Directional arrows", the magnitude of the vector is represented by color, not by length. Check it out on the computer screen.



Problem #2: The Electric Field from a Dipole

Purpose: 1) To show students the electric field is a plausible theory for describing the space around electric charges in the real world.

Equipment: ** EQUIPMENT NOTE: To make a stable connection you can place a wood block on the top of the brass rods to increase the contact pressure. If the brass rod tips are corroded from water exposure, ask the lab coordinator for some steel wool to buff them.



Teaching Tips

- Emphasize that the electric field at a point in space caused by a group of charged objects is the vector sum of the electric fields at that point from each charged object.
- The numerical values from this problem do not give a true inverse r-cubed result. The relationship is far more complex. However, you are determining the general shape of the field.
- Make sure that you **rotate the probe to maximize the positive voltage reading**. This is a crucial step that many students do not realize that will help establish the direction of the electric field.

Things to Remember

- **Make sure you check out all of the batteries before the beginning of class.** If the batteries are dead, the power supply (5, 8, or 16 volts) works fine. Anything higher than 16V is unsafe. If you use the power supplies, be sure you instruct your students in their safe use. **Remember you are always responsible for your student's safety**.

- Put the bad batteries on the chalkboard tray or mark them in some way. If you can remove them from the lab and take them to the laboratory coordinator's office, that's even better. The laboratory coordinator will exchange them for new ones when he is on his rounds but that may not be for several hours.
- It seems that the probes used for this lab work better when the tips are dull. The newer probes will have sharp tips and it seems that this makes the reading off the DMM to jump around. If you find this, ask the laboratory coordinator for a file and dull them down.

Difficulties and Alternative Conceptions: Many student misconceptions come from their interpretation of pictures of field lines. They may think that something comes out of a charge and grabs or pushes another charge. Remind them that the fields interact, and that with **every charge there is a field, but you need two charges to have a force**. Another alternative conception is for students to think that one point in space can have many different values for the electric field. Remind them that field strength is unique at each point in any configuration.

The field idea that objects interact with space and not with each other is a difficult one to understand. They can, however, remember that even in electrostatics, the forces between two given charges are equal and in opposite directions.

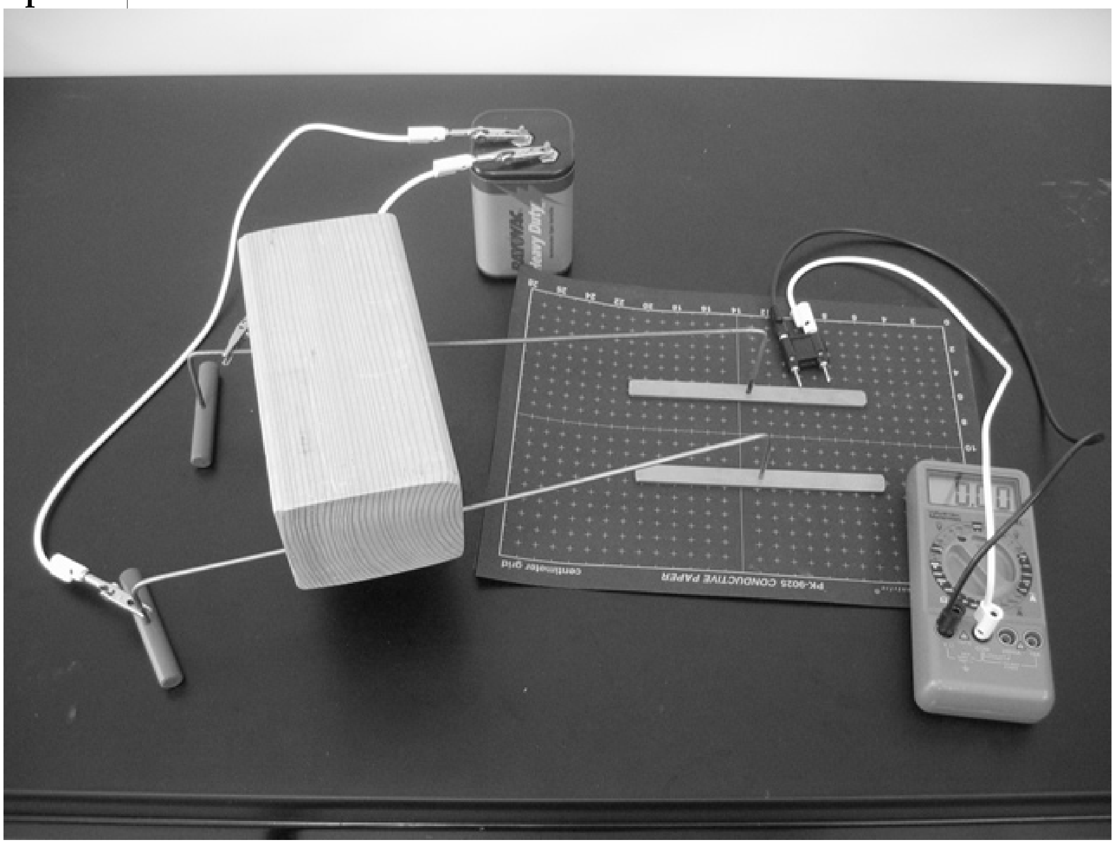
Prediction and Warm-up:

Make sure that field vectors go from positive to negative. Remember, there can only be one field vector at each point in space. The electric field exactly on point charge is undefined since field strength goes like $\frac{1}{r^2}$, and when you are on the point charge r=0.

Problem #3: Electric Field of Parallel Charged Plates.

Purpose: 1) To show that the field between the plates is much larger than the field outside, and it is fairly uniform between the plates except for near the edges.

Equipment:



Teaching Tips

- This experiment generally works out well. The field is fairly constant between the plates if there is a reasonable potential difference across the plates (6 or 12V).
- The students generally haven't learned the concept of potentials for this lab and they don't need it. **Do not lecture on potentials.** This will confuse and frustrate the students. Concentrate on the qualitative behavior of fields. For now, a "volt" is just a measure of the "strength of the battery" or power supply.
- Make sure your students investigate the field outside the two parallel plates.

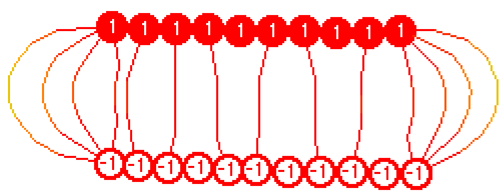
Things to Remember

- It seems that the probes used for this lab work better when the tips are dull. The newer probes will have sharp tips and it seems that this makes the reading off the DMM to jump around. If you find this, ask Shawn for a file and dull them down.

Difficulties and Alternative Conceptions: Students believe that the electric field should be stronger when you are nearer to the charged plate. They have a great deal of difficulty accepting that the electric field is constant between the plates. Students continue to have difficulty with the vector addition of quantities as abstract as fields. Once again the idea of field lines that students have seen in books will continue to confuse them. It is better to simply stick to field vectors and not to use field lines.

Prediction and Warm-up:

Between the plates, the field vectors point directly towards or away from the plate depending on whether the charge on the plate is positive or negative. For true infinite parallel plates in three dimensions, the field should be constant between the plates. The parallel bars in the two-dimensional water tray simulate this to a certain degree, but there will be some variation in the strength of the field as you get closer to the plates.



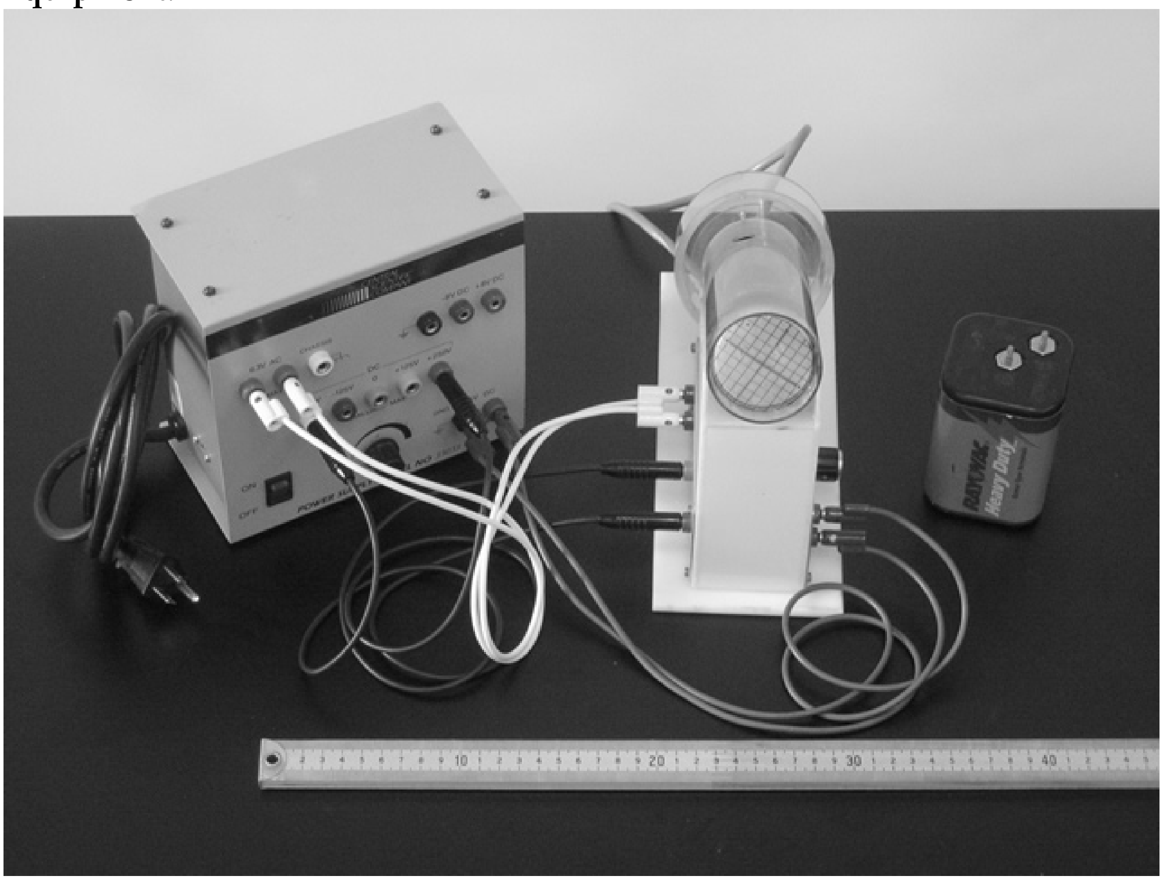
Possible Discussion Questions:

1) What are some advantages, simplicities, behind the parallel plate configuration?
2) What are the limitations on the strength of the electric field? What factors make the field strong or weak?

Problem #4: Gravitational Force on the Electron

Purpose: 1) To remind the students that they can determine an electron's motion using the familiar concepts of forces and kinematics.
2) To help students see how much larger EM forces are compared to gravity.
3) To show students that the new forces can be discovered (magnetic) using basic physics.

Equipment:



Teaching Tips.

- The deflection in the tube from the gravitational field of the Earth is on the order of 10^{-13} mm. This obviously is not observable, but have your students move the CRTs anyway. We want the students to recognize that the electric force (and magnetic force) is much greater than the gravitational force. This is hard for some students to really believe since the gravitational force is the main force they deal with in every day life. When they do see an effect, they may not believe their calculation or they may decide that the apparatus "does not work." Such responses are "unscientific," and prevent intellectual growth. Students will need your help wrestling with both these issues.
- Make sure you do not let students come away with the misconception that the gravitational deflection is small due to the small mass of the electron. Remind them that a large mass and a small mass when dropped hit the ground at the same time. Have them consider how fast the electron is moving.

- When the tube is moved from a horizontal position (maximum deflection) to vertical (zero deflection) the beam spot will visibly move perpendicular to the expected deflection. This is due to the Earth's magnetic field. It is this discrepant event that we want the students to observe. **Do Not Lecture on the Earth's Magnetic Field before class or there will be no point in doing this lab**. Save any comments until the end of lab. Here we simply want to raise the question of an "unknown" force and its property. For now let your students have the fun of thinking about what it could be. They should be able to determine, with your help, that the “unknown” force does not have the properties of the gravitational force. At the end of the lab, lead a discussion to get their ideas but don’t steal their opportunity to really apply physics and make a discovery on their own by telling them the answer. You should return to this observation later in the course when we are investigating magnetic fields.
- Remember that Minneapolis is not at the equator, so the earth’s magnetic field has a large vertical component. The net field is not restricted to the horizontal north - south direction.

WARNING: You will be working with equipment that generates large electric voltages. Improper use can cause painful burns. **To avoid danger, the power should be turned OFF and you should WAIT at least one minute before any wires are disconnected from or connected to the power supply. Never touch the conducting metal of any wire.**

Things to Remember:

- The pertinent dimensions of the CRT are in the appendix. Be confident in setting it up.
- The retractable banana leads are to be used **ONLY** for the connections between the Cathode, Anode and the power supply. **DO NOT** use them with the DMM's, the Heater, or the x-y deflections. The retractable banana leads are there for **SAFETY REASONS** to prevent someone from getting zapped by the +/- 250 V and +/- 125 V supplies!
- If a student does not get the green dot on the CRT screen, check that the heater is working (you'll see a dull orange glow). If the heater is working the accelerating field may be backwards (actually stopping the electrons.) Try switching the anode and cathode potentials around. If the heater is out, get a replacement CRT from Room 233 (this is not a common problem).
- The CRT beams are not perfectly centered down the primary axis, and so there is a deflection of the beam just by rotating the tube about it’s center. If your students find this and are troubled by it, ask them what could be causing it. This could be a good chance to coax out their ideas about symmetry.
- **WARNING:** The PASCO power supply high-voltage terminals can really give a nasty shock, and even burn you. We have had a few students injured. It could kill a student with an undetected heart condition. Tell your students to:
- **NEVER CHANGE CONNECTIONS UNLESS THE POWER SUPPLY IS TURNED OFF**
- **NEVER USE MORE THAN ONE HAND WHEN CHANGING CONNECTIONS**.
- Make sure they obey the cautions in their lab book. Go over this in your introduction. **You are responsible for your students’ safety.**

Some useful information to complete the prediction:

m_e = 9.11×10^{-31} kilograms

e = -1.60×10^{-19} coulombs

1 eV = 1.6022×10^{-19} joules

A 500–eV electron has a speed of 1.32×10^{7} m/s.

Difficulties and Alternative Conceptions: As mentioned above, your students will STILL think that the gravitational deflection is small because the mass of the electron is so small. If you don't believe us, ask them!

Students have difficulty believing that the gravitational force is so much smaller than the electromagnetic force. Faced with an unexpected event, students are most likely to think that there is something wrong with the equipment, that they had made a mistake in the calculation, or that the physics they are using doesn't really apply. Occasionally, these are the difficulties and they need to be checked; but your students also need to build the confidence in themselves. This problem is not meant to fool students, but to spark their curiosity and exercise their critical thinking.

Prediction and Warm-up: Remind students that this is first semester kinematics. The full derivation is quite difficult algebraically. You may want to just have your students derive the answer for the case when the CRT is pointed horizontally.

$$y = -\frac{mgD^2}{4qV_{acc}}\cos\theta = 2.6 \times 10^{-16}\text{ m}$$

(calculated with 500 Volts)

where D = 9.6 cm, the distance from the accelerating plates to the screen, m is the mass of the electron, q is the charge of the electron, V_{acc} = 500 V, the accelerating voltage, and $\theta = 0$, the angle the CRT makes with the ground. In the derivation, a Taylor series expansion was made assuming that $q\,V_{acc} >> mgD$.

** Make sure your students put in the numbers and calculate a value for gravitational deflection. Few will predict how absurdly small this distance really is. Discuss with them how small this really is. An atom is typically 10^{-10}m across. This is one millionth of that!**

Possible Discussion Questions:

1) How could you minimize the effect of the Earth's magnetic field?

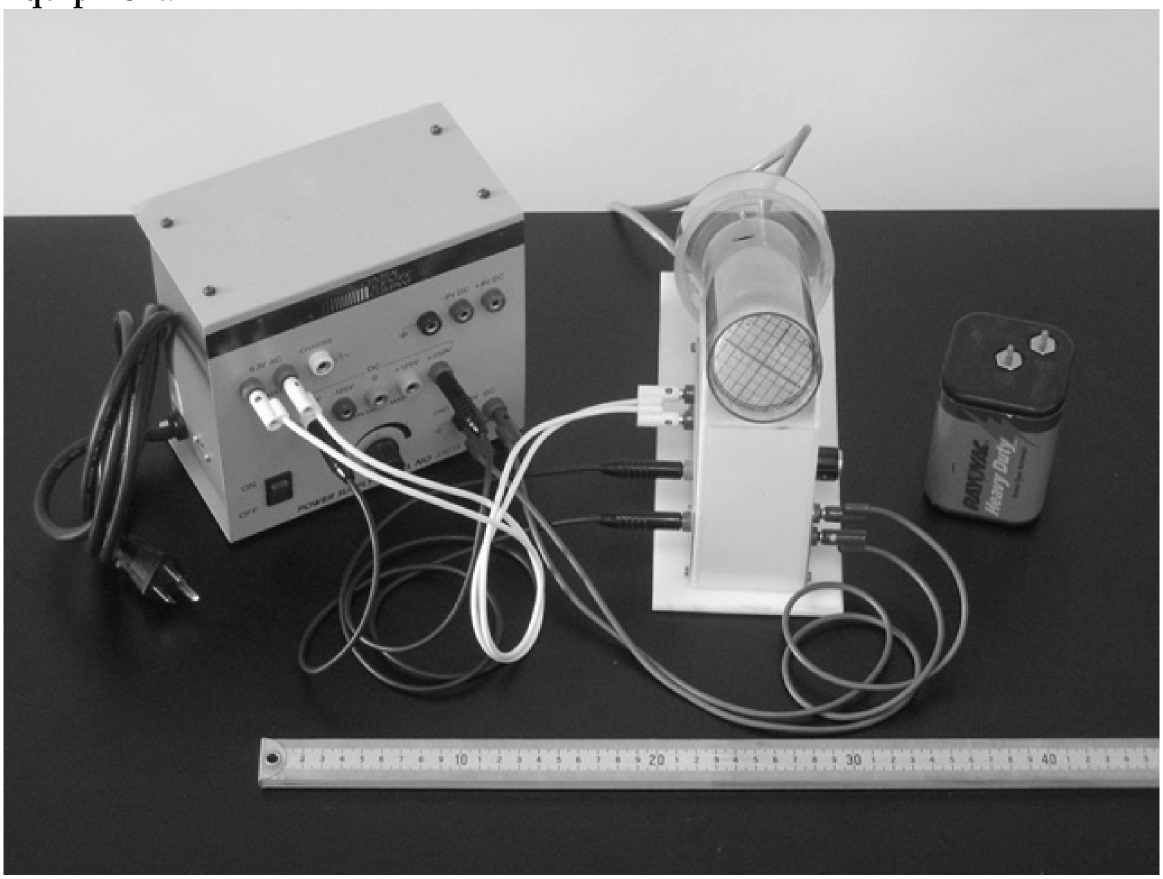
2) Is there a way you could use the cathode ray tube as a compass?

Problem #5: Deflection of an Electron Beam by an Electric Field

Purpose:

- To have students recognize that we are simply applying the same old physics to a new situation by giving them a projectile motion problem where the force involved is created by an electric field instead of the gravitational field.

Equipment:



Teaching tips:

- If the students haven't been introduced to potentials yet, don't bring it up. **Do not lecture about potentials**.
- The students must keep their CRT pointing in the same direction for all measurements (see Problem #4). The earth's magnetic field will displace the beam differently for different orientations.
- If you look at a CRT that's been broken open, the deflection plates do not have a uniform separation distance, i.e. they are BENT. This was taken into account by finding the effective length of the plates based on the plate separation. Your students do not have to account for this bend. The necessary measurements are in the appendix.
- **Be sure to warn your students of the danger when connecting the high voltage leads.**
- This is a difficult problem for students. They need to do it in an organized manner. Drawing a good picture is crucial.

WARNING: You will be working with equipment that generates large electric voltages. Improper use can cause painful burns. **To avoid danger, the power should be turned OFF and you should WAIT at least one minute before any wires are disconnected from or connected to the power supply. Never touch the conducting metal of any wire.**

Difficulties and Alternative Conceptions:

Many of the misconceptions about projectile motion will reoccur. Some students still do not really believe in the independence of perpendicular components of motion or in the vector nature of forces. Many students do not believe that there is an electrostatic force on the electron only in the region of electric field. Some students will not have a parabolic trajectory in the region of constant force and straight line motion in the region where there is no force. This is an excellent problem to determine what parts of mechanics you must work on with each student.

Prediction:

Deflection ought to vary linearly with the applied electric field.

Warm-up:

The total deflection is caused by two distinct regions of the CRT. The first part of the deflection is caused by the electric field between the plates; the second part is caused by the straight line path after the electron leaves the plates until it hits the screen. Your final result for the deflection should boil down to:

$$\text{Total Deflection} = \frac{EL\left(D + \frac{L}{2}\right)}{2V_{acc}},$$

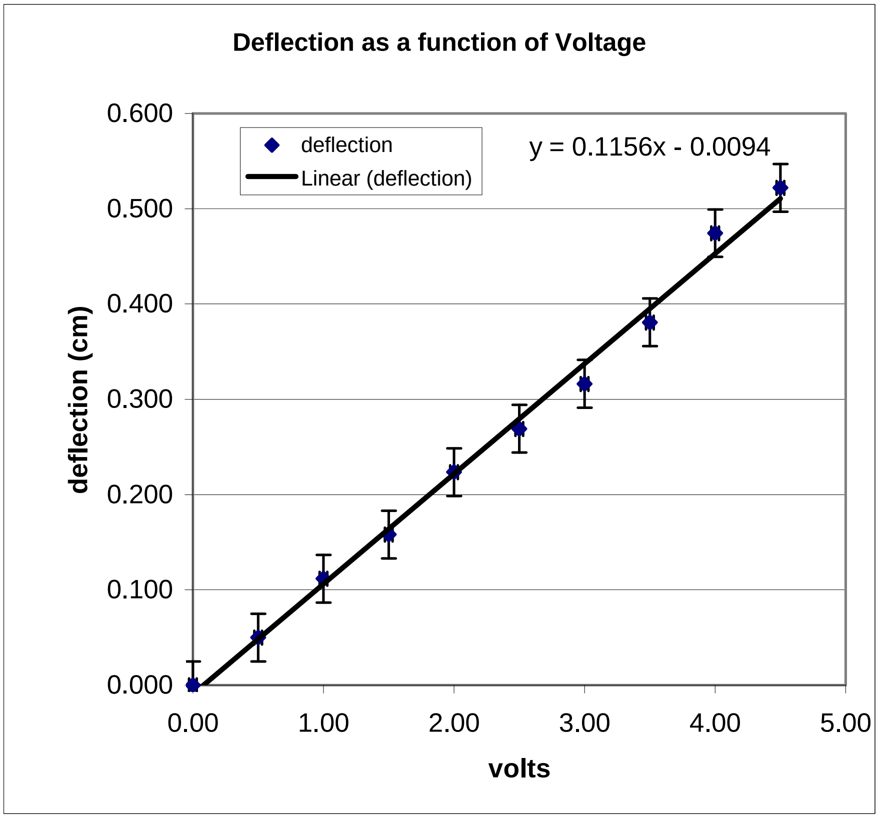
where E is the applied electric field, V_{acc} is the accelerating potential, L is the length of each plate, and D is the distance from the plates to the screen. Remember that the applied electric field is found from $E = V_x/S$, where V_x is the potential across the deflection plates, and S is the separation of the deflection plates. It's interesting to note that the result is independent of the mass and charge of the electron. In the lab summary you might conduct a discussion on why that might be reasonable.

Data:

voltage	deflection
0.00	0.000
0.50	0.050
1.00	0.112
1.50	0.158
2.00	0.224
2.50	0.269
3.00	0.316
3.50	0.381
4.00	0.474
4.50	0.522
5.00	0.585

from App D

D =	7.4
L =	2
S =	0.3
V =	250
m =	0.112

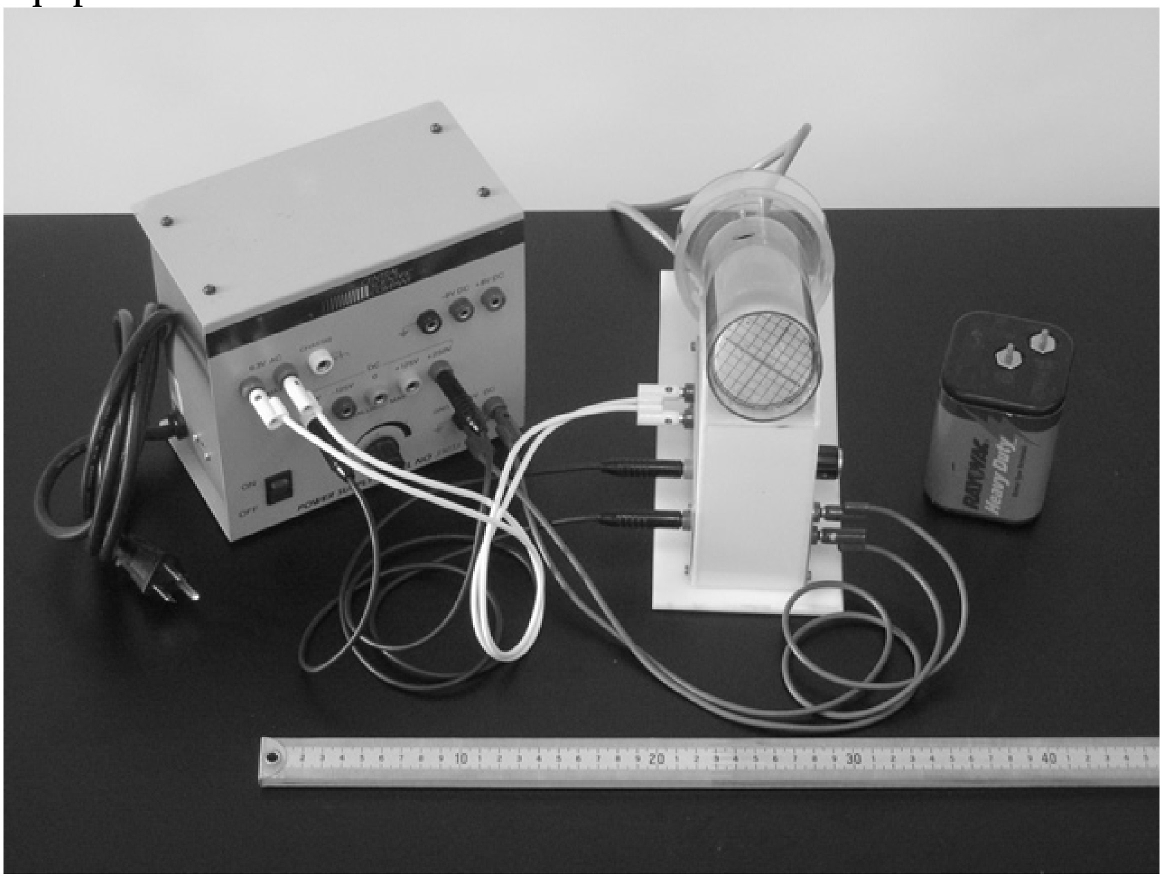


Problem #6: Deflection of an Electron Beam and Velocity

Purpose:

- To show the students how the deflection of the beam is affected by the initial velocity of the electron.

Equipment:



Teaching tips:

- An analogy, which might be useful in your summary discussion, is to consider three people aiming projectiles at the same target. One fires a bullet, the other shoots an arrow, the third throws a baseball. If all aim straight for the target, which one will be furthest from the mark?
- This is the problem where students have been hurt changing the high-voltage connections. **Make sure you warn your students of the danger.**
- The following are for your reference values (make your students figure these out themselves!):

> A 250eV electron has a speed of 9.37×10^6 m/s [$\beta = 0.0312$]
> A 375eV electron has a speed of 1.15×10^7 m/s [$\beta = 0.0383$]
> A 500eV electron has a speed of 1.33×10^7 m/s [$\beta = 0.0443$]

- The 500eV electron has $\gamma = 1.001$, so relativity isn't a factor here.

- You can refer your students back to Problem #4. Ask them why there isn't a deflection from the gravitational force. This problem should help them realize how the deflection over a fixed distance depends both on the magnitude of the applied force and the speed of the object.

WARNING: You will be working with equipment that generates large electric voltages. Improper use can cause painful burns. **To avoid danger, the power should be turned OFF and you should WAIT at least one minute before any wires are disconnected from or connected to the power supply. Never touch the conducting metal of any wire.**

Major Alternative Conceptions of Students:

Many of the misconceptions about projectile motion will reoccur. Some students still do not really believe in the independence of perpendicular components of motion or in the vector nature of forces. Many students do not believe that there is a force on the electron only in the region of electric field. Some students will not have a parabolic trajectory in the region of constant force and straight-line motion in the region where there is no force. This is an excellent problem to determine what parts of mechanics you must work on with each student.

Prediction:

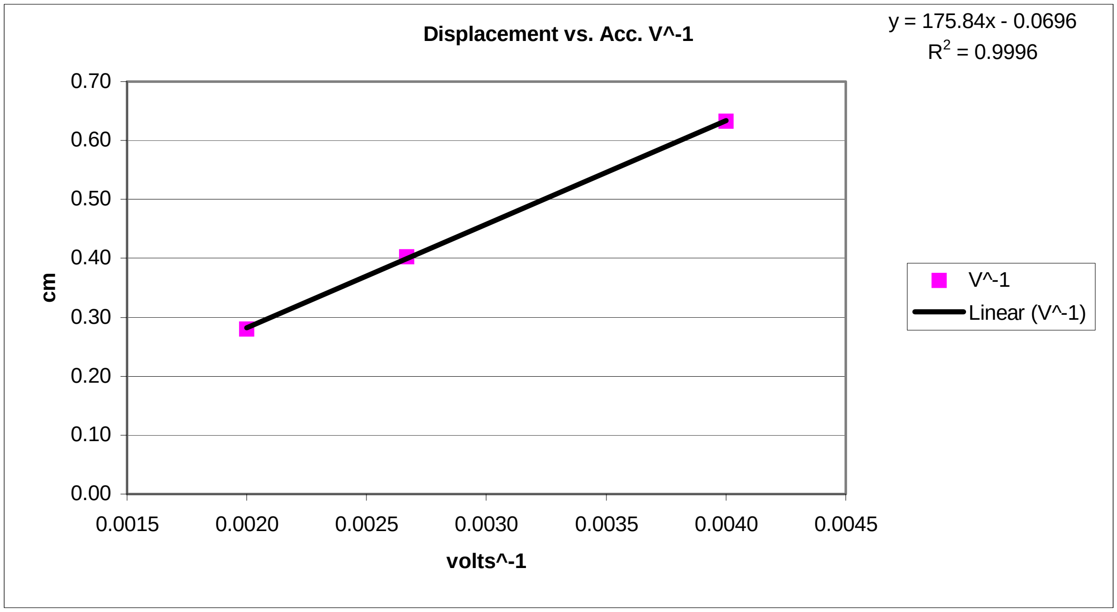
Deflection is inversely proportional to accelerating voltage, and hence increases as the initial velocity decreases.

Warm-up:

See the Warm-up for Problem #5.

Data:

voltage	V^-1	displacement				
			D =	7.4		
250	0.0040	0.63	L =	2	m =	156.24
375	0.0027	0.40	S =	0.3		
500	0.0020	0.28	V =	5.58		



This is a linearized plot of the displacement as a function of accelereating potential

Check Your Understanding:

1. Use the procedure suggested in problems 2 and 3 to get the correct maps.

2. Use the methods questions from problem 5 as a guide. This problem differs in that the distance to the screen is different for each plate.

$\Delta x = 0.89$ cm; $\Delta y = 0.27$ cm.

3. Since the field is the same everywhere between the plates, A=B=C.

TA Lab Evaluations
Physics 1102 Lab 4

We strongly encourage you to fill out this evaluation as soon as you are done teaching the labs. If you had issues or problems with any of the lab please submit available information through the LabHelp system or email lab@physics.umn.edu.

Instructors Pages:

Did you find the instructors pages useful? (circle one) yes / no

What additional information would you include in these pages?

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____

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Students:

Did the students find these exercises: (circle one) enlightening / boring / fun / other?

Do you have additional comments regarding student learning and these labs?

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TA:

Given the choice, would you teach these exercises again? (circle one) yes / no

Why or why not?

____

____

____

Results:

Did the students obtain sensible results from these exercises? (circle one) yes / no

What were the best / worst sets of results? Why?

____

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Lab Room:

Was the room kept neat and clean by your class and other classes? yes / no

Was the equipment functioning properly? Could you fix it? yes / no

Any other comments regarding the room and equipment?

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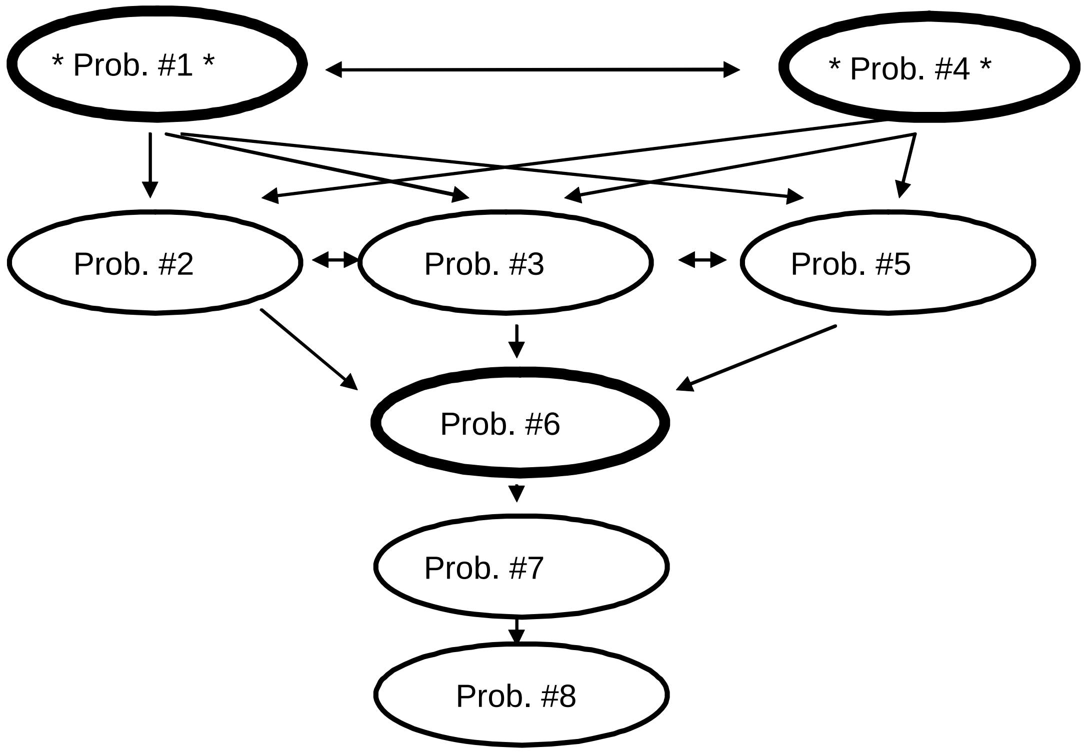
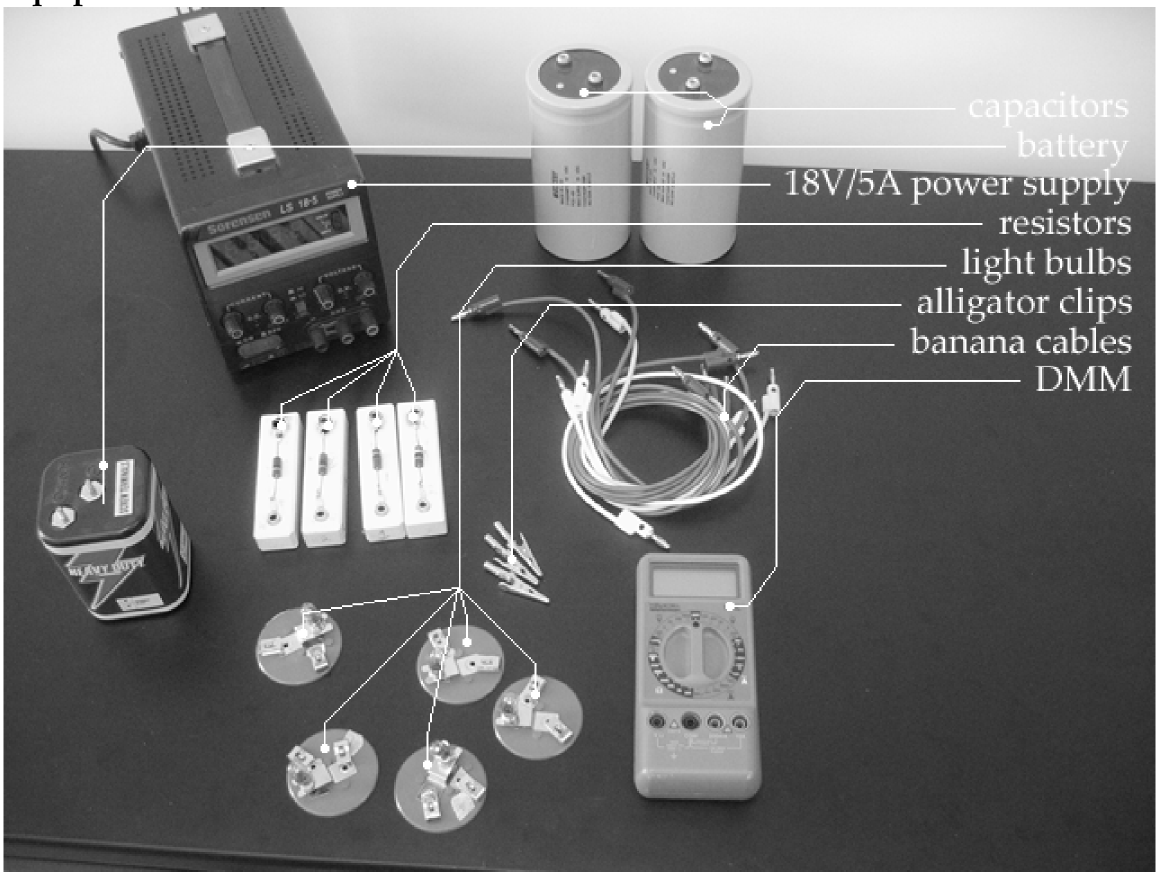
Laboratory V:
Circuits



Problem #3 should be especially assigned to those who short circuit their circuits.

Equipment



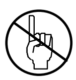
**EQUIPMENT NOTES: All values of capacitance printed on the capacitors have units of microfarads (μF) even though some might be labeled "MF". To find identical bulbs look for markings and check to see that the color of the bead separating the filaments is the same (clear or white).

<u>General Teaching Tips:</u>

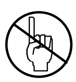
- Circuits provide the most immediate and practical application of electricity. However, it is difficult to connect circuits to simple calculations based on electric forces or electric fields. The two fundamental concepts most useful in understanding circuits are the conservation of charge and the conservation of energy. This lab applies these concepts using circuits with batteries (energy sources), resistors (energy transfer), and capacitors (energy storage). Remember that light bulbs do not obey Ohm's law perfectly, but they give the students immediate visual feedback for their predictions. Since students have serious misconceptions about circuits, many of the problems in this lab are qualitative. Coach your students to think about what is happening in terms of energy (voltage is energy per unit charge) and current.
- It is not unusual for students to finish these labs (and indeed all of E & M) and still not know how to use a DMM as an ammeter or a voltmeter in a circuit. This means they do not really understand the concept of current and potential difference. Make sure your students do not have this difficulty by always having them explain the behavior of the currents and potential differences in a circuit.

<u>Things to Remember:</u>

- Be sure to check the batteries before you let your students into the class. They wear out quickly, especially when students accidentally short-circuit their circuits. Use a light bulb to check the batteries; if the bulb lights brightly, it's okay. Make sure your students unplug the batteries when they are not using them!
- The DMMs are of high quality and durability. Count them at the beginning and end of each lab, as they occasionally tend to walk off. Don't "borrow" them from another room without leaving a note in the log book for that room.
- **DO NOT under any circumstances use the center strip (-250V, -125V, +125V, +250V) on the power supply!** Using these higher potentials on the light bulbs and resistors will damage them. The light bulbs will blow and the resistors will either break in half or the resistance will be permanently altered.



REMINDER: Your students will be working with equipment that can generate large electric voltages. Improper use can cause painful burns. To avoid danger, make sure your students turned OFF any power supply and WAIT at least one minute before any wires are disconnected from or connected to it.



WARNING: A charged capacitor can discharge quickly producing a painful spark. Make sure your students **do not** handle the capacitors by their electrical leads or connected wires by their metal ends. Make sure they **always discharge a capacitor when they are finished using it.**

What students should know by the end of the lab:

- The necessity of having a closed circuit for electric current flow.
- The behavior of current in a circuit with a capacitor.
- The relationship between electric current, resistance and voltage in the circuit.
- The relationship between the electric charge in a capacitor, the potential difference across that capacitor, and its capacitance.
- Proper application of conservation of charge and conservation of energy (Kirchoff's rules) to determine the current in a simple circuit.
- How to measure the current through a circuit element with a Digital Multimeter (DMM).
- How to measure the voltage difference between two points in a circuit with a DMM.
- How to measure the resistance of a circuit element, both with a DMM and by using Ohm's law.
- The role of a battery as a constant potential difference (not a constant current source) in a circuit.

Things to check fifteen minutes before lab:

- See how the non-ohmic light bulbs affect the results of the circuits by trying out some of the circuits.
- Set up the circuits in Problem #10. Determine under what conditions some of the bulbs are barely lit which might mislead your students.
- Make sure all capacitors are discharged before lab begins so that students don't accidentally injure themselves. To discharge a capacitor, use a banana cable to briefly connect the two terminals.

Problem #1: Basic Circuits
Problem #2: More Complex Circuits

Purpose: 1) To help students understand the qualitative aspects of circuits.
2) To use circuits as examples of the conservation of charge and the conservation of energy.

Equipment:

**EQUIPMENT NOTE: To find identical bulbs look for markings and check to see that the color of the bead separating the filaments is the same (clear or white).

Teaching Tips

- These are 'classic' problems and have proven to be effective. With your active coaching students will overcome their many serious misconceptions about circuits.
- Students who have already had circuits may get through these problems very quickly and still have serious misconceptions. Make sure you demand they explain their results without resorting to equations. Some students might take two hours to do the two problems. They will need help just formulating their ideas in an organized way. Be prepared for both and everything in between.
- These problems run down the batteries quickly. It should be possible to wean the students from the batteries and on to the power supplies after the first couple of problems -- some regard the power supply as a “black box” and may not immediately understand that it’s

similar to a battery. Do not let a group use a power supply until you are convinced they understand that a battery is a constant potential difference and not a constant current source.

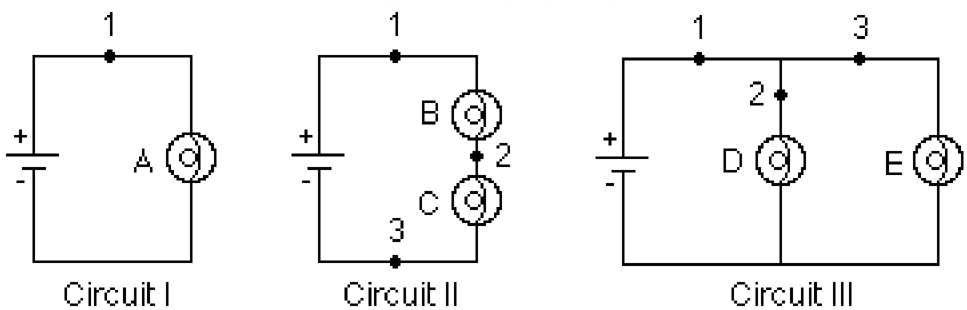
- REMEMBER, light bulbs are NOT quite ohmic. Although, the students will find that currents add properly and voltage loops sum very nearly to zero.
- To the students who finish quickly, assign the Check Your Understanding Problems #1 and #2.

Difficulties and Alternative Conception: The point of most of these problems is to challenge the misconception that current is somehow "used up" by circuit elements like a light bulb. Get students to think about conservation principles to explain what they see: conservation of charge (current) and conservation of energy (potential difference).

Prediction and Methods Questions:

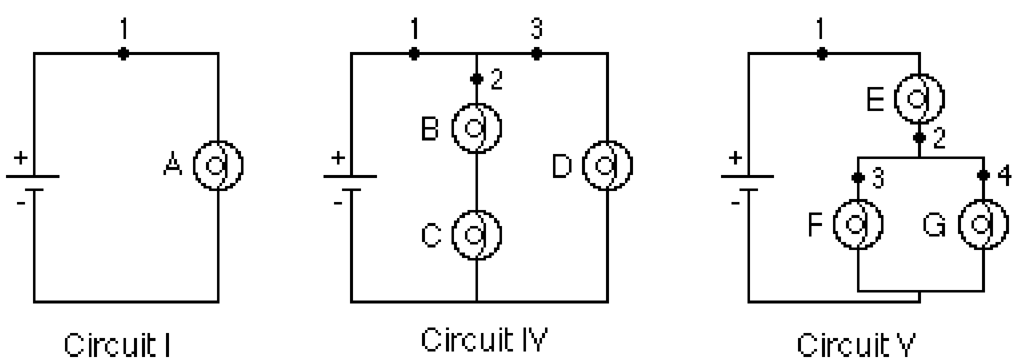
Ranking in brightness (brightest to dimmest)

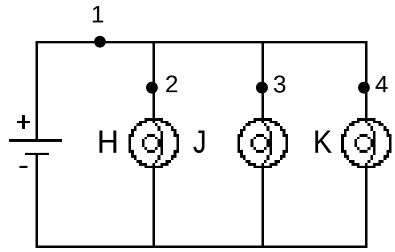
Circuits for Problem #1 (A = D = E) > (B = C)



Circuits for Problem #2 (A = D = H = J = K) > (E) > (B = C) > (F = G)

The most difficult step is determining that B and C should be dimmer than E.





Circuit VI

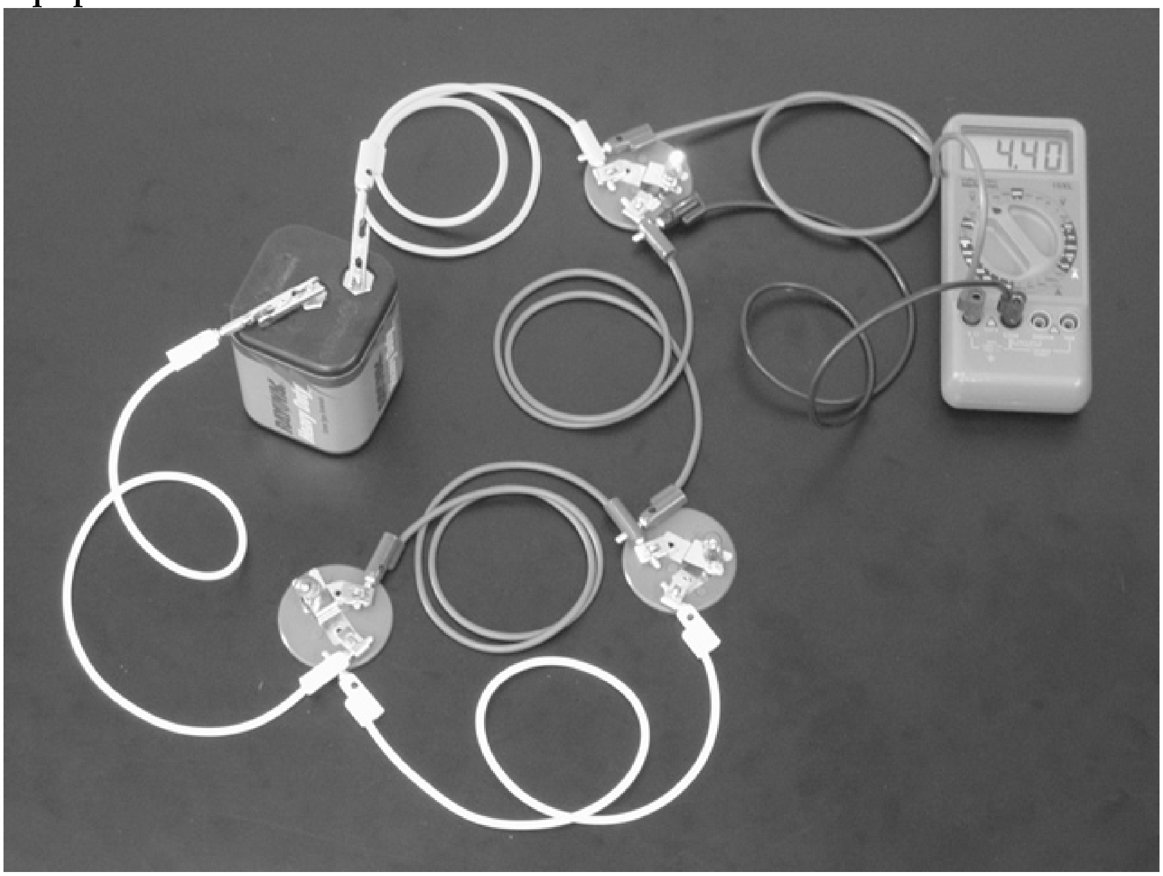
Possible Discussion Questions:

1) What factors decide the brightness of the bulb?
2) What circuit drains the most power? the least?
3) Can you think of a way to variably dim or brighten the bulbs?

Problem #3: Short Circuits

Purpose 1) To formally introduce the students to short circuits as a reasonable and potentially damaging consequence of Ohm's law.

Equipment:



Teaching Tips

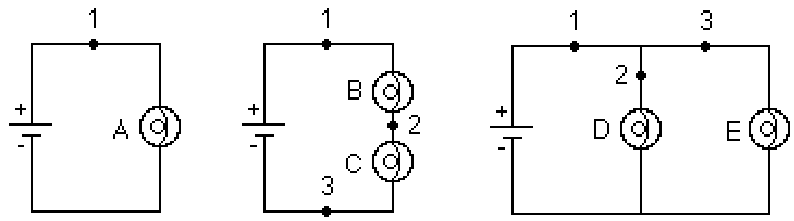
- This problem is primarily meant for those students who consistently set up a short circuit and don't understand the problem.
- This problem can be done quickly, and it is worth the time. If students are not having troubles, make your point and then move on.

WARNING: A short circuit is what happens any time a very low-resistance path (like a wire, or other piece of metal) is provided between points in a circuit that are at voltages, like the terminals of a battery or power supply. **Short circuits can destroy equipment and injure people! Always avoid short circuits in other circuits!** Short circuits damage equipment by creating large currents in a circuit that is not designed for large currents. These currents can cause great heat and cause damage to nearby circuit elements or measuring devices. Any short circuits suggested in this manual have been tested, and determined not to significantly damage the equipment.

Difficulties and Alternative Conception: Most students have heard the phrase "the current takes the path of least resistance," but really don't know what that means. Many believe that the amount of current through a part of the circuit is always the same and is not influenced by other connections in the circuit. Others believe that the current always splits in half when it encounters a branching point in a circuit. You will be surprised at the number of students who have incorrect predictions. The good news is that they tend to figure this problem out quite quickly and correctly once they actually see the results.

Prediction and Warm-up:

Circuit I: Bulb A will turn off when a wire is attached across it.
Circuit II: Bulb B should turn off. Bulb C should brighten.
Circuit III: Bulbs D and E should turn off when wire is connected across E.



Circuit I   Circuit II   Circuit III

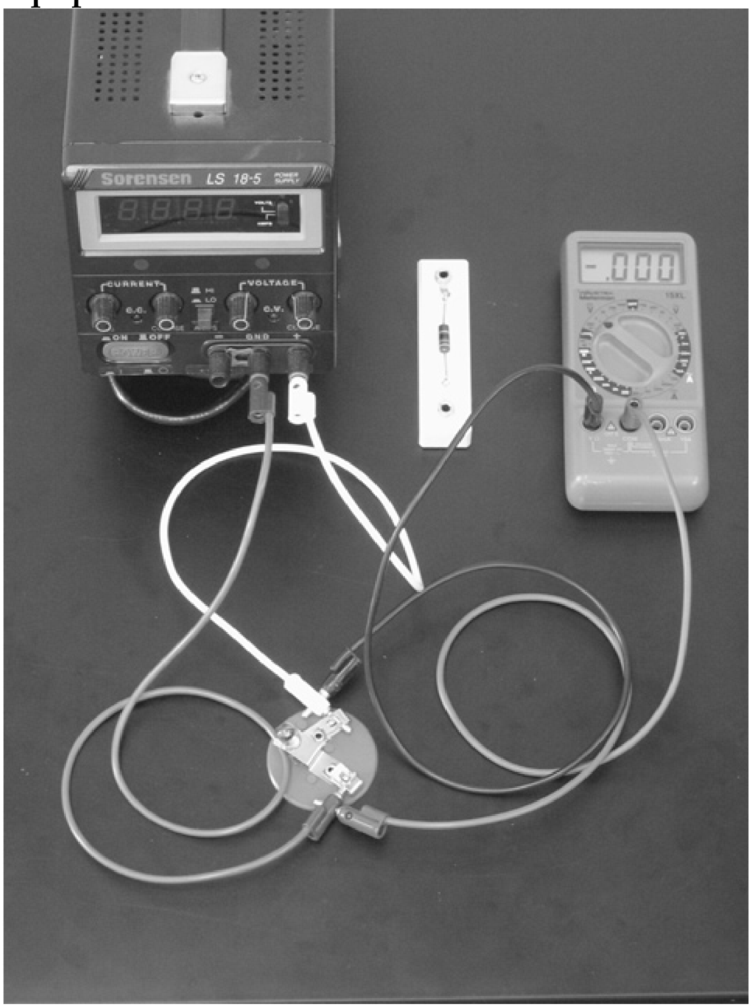
Possible Discussion Questions:

1) What are the dangers of a short-circuit?
2) Do you see why the current in a household circuit may increase dramatically if a short-circuit is introduced?
3) See Check Your Understanding Question #1. What happens when we blow a fuse in the house?

Problem #4: Resistors and Light Bulbs

Purpose 1) To show students explicitly that Ohm's law is a special case and it is a useful approximation for a light bulb for low currents.

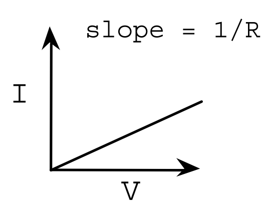
Equipment:



**EQUIPMENT NOTE: To find identical bulbs look for markings and check to see that the color of the bead separating the filaments is the same (clear or white).

Teaching Tips

- The students need to design their own circuit for this problem. They also must use some graphical analysis techniques -- getting the resistance of the resistor from the slope of the I vs. V graph, for instance. These are both places your students might get hung up.



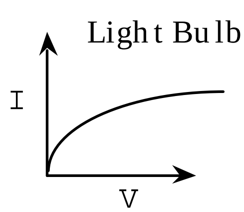
- This is a nice transition from Problems #1 and #2 to into the circuit analysis problems.
- The light bulb doesn't respond linearly. The resistor should. As the bulbs light up, the filament gets hot and the resistance goes up about a factor of 10 (from 4 Ω to 40 Ω, at least for the bulbs we tested). You might try using this change to measure the temperature of the filament. See the section on Thermal variation of Resistance in Serway and Faughn, section 17.5, page 564. The relation of resistivity and temperature is $\rho - \rho o = \alpha(\rho o)(T - To)$ The table on page 563 gives the temperature coefficient for various materials.
- It is good to bring up that resistors are only ohmic within a reasonable range (the students should NOT try to confirm this). Ask the students to estimate this range from their graphs.
- Using the batteries, a range of data from 0-12 Volts in 1.5 Volt increments can be taken. If you use the power supply, you can obtain a smoother range of data points.

WARNING: You will be working with a power supply that can generate large electric voltages. Improper use can cause painful burns. **To avoid danger, the power should be turned OFF and you should WAIT at least one minute before any wires are disconnected from or connected to the power supply. Never grasp a wire by its metal end.**

Difficulties and Alternative Conception:

Many students have over generalized to believe that every conductor obeys Ohm's Law. This problem disproves that concept yet shows that Ohm's law is a useful approximation within a region of behavior. (I know of one engineer who insists on calling Ohm's Law "Ohm's Suggestion.")

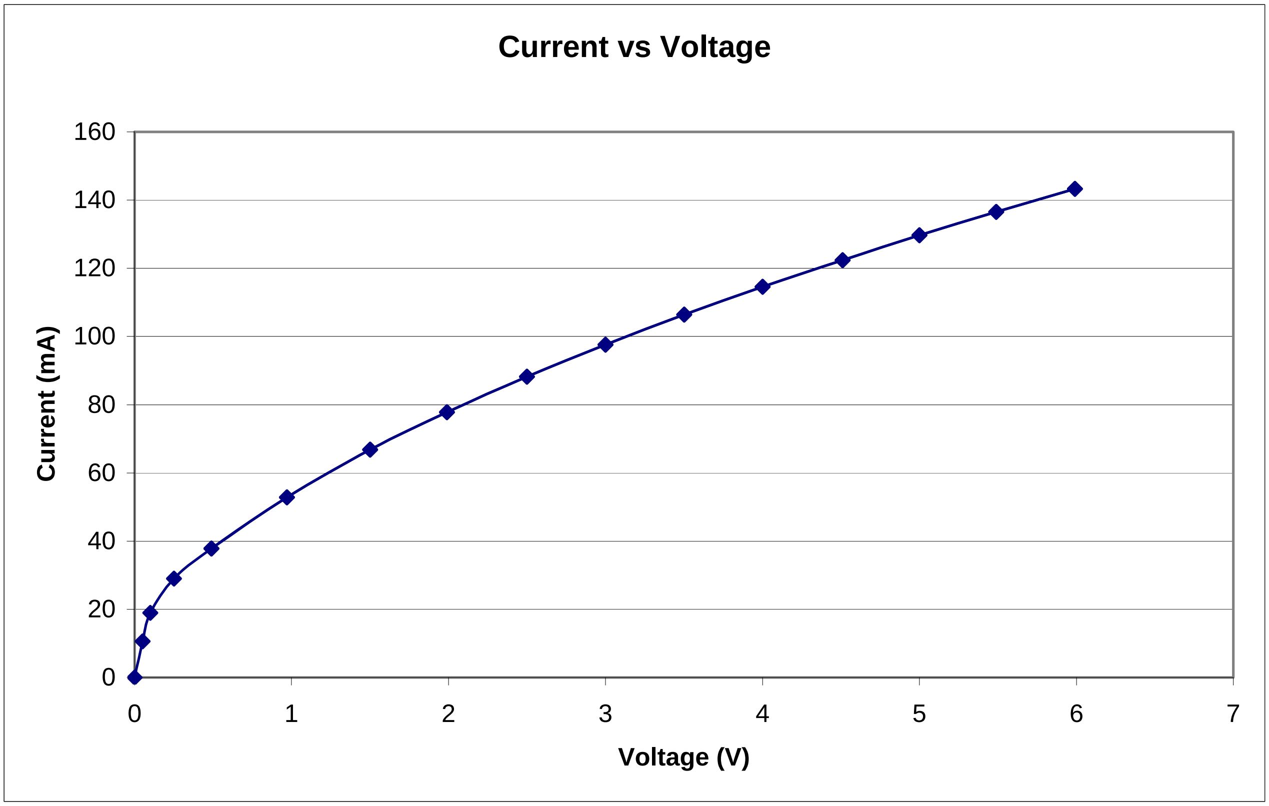
Prediction and Warm-up:



Increasing the voltage will also increase the temperature of the filament. A hot filament will be more resistive. Therefore, at high voltages, the current will start to level off.

Sample Data

The chart below is for a light bulb.



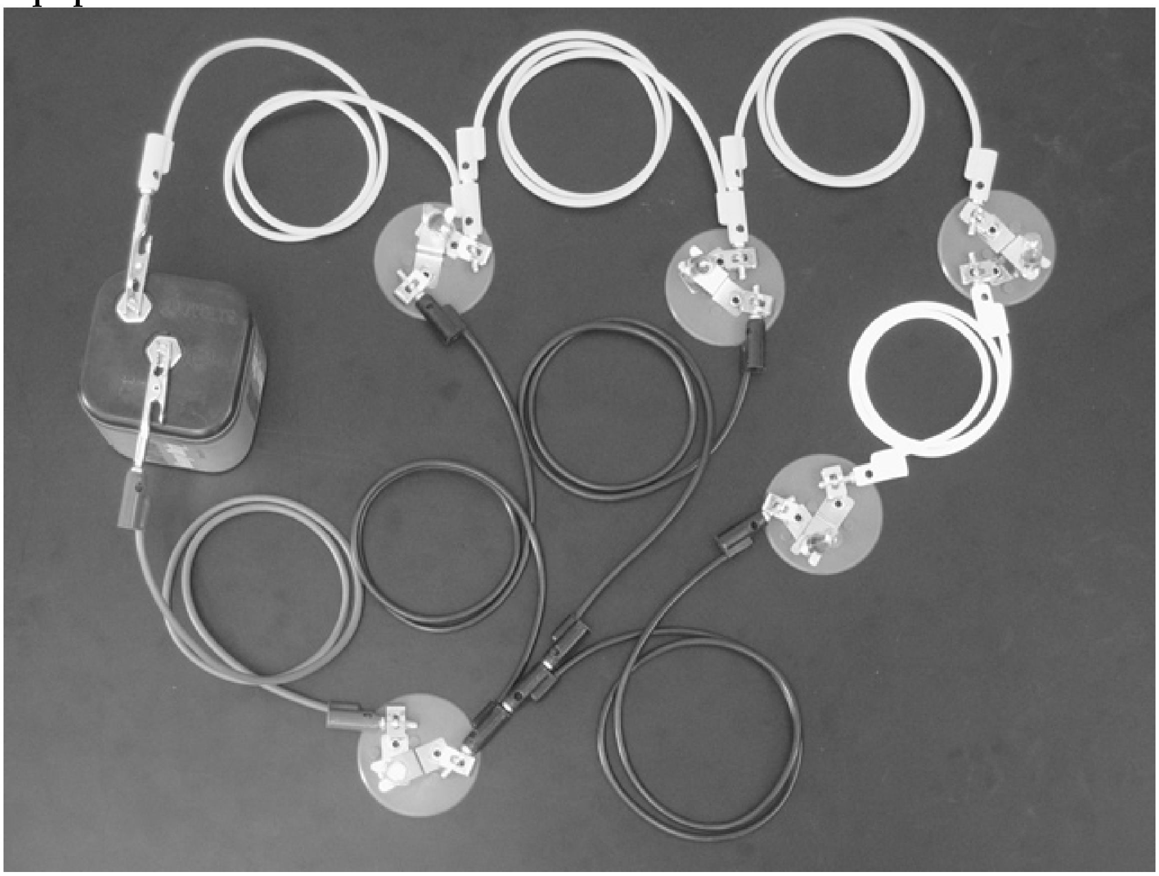
Possible Discussion Questions:

1) Where are the sources of uncertainty in this experiment?
2) How can resistance work to human benefit? (heating coils, etc...)

Problem #5: Circuit Analysis

Purpose: 1) To find qualitative rules to understanding how the conservation of energy, and Ohm's Law work in complex circuits.

Equipment:



Teaching Tips

- This problem helps connect the mathematics of Kirchhoff's rules to the basic physics of how circuits behave. Remind students the rules about series and parallel circuits.
- Do not let your students do their predictions only by solving equations. This problem is meant to build their confidence and intuition by using the rules of circuit analysis qualitatively.
- Remember, light bulbs are not ohmic. Calculations are approximations to the real situations.

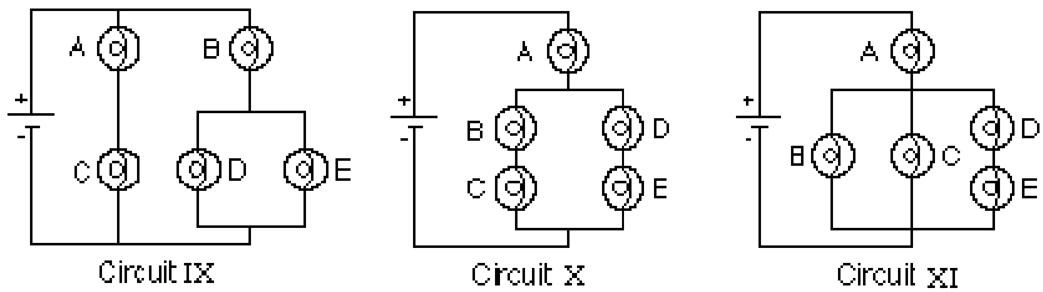
<u>Difficulties and Alternative Conception</u>: Many students still believe that a battery is a constant current source instead of a source of constant voltage (potential difference). Some students still believe that current always divides in equal parts at a junction.

Prediction and Warm-up:

All bulbs are ranked from brightest to dimmest:

Circuit IX: (B) > (A = C) > (D = E)

Circuit X: (A) > (B = C = D = E)
Circuit XI: (A) > (B = C) > (D = E)



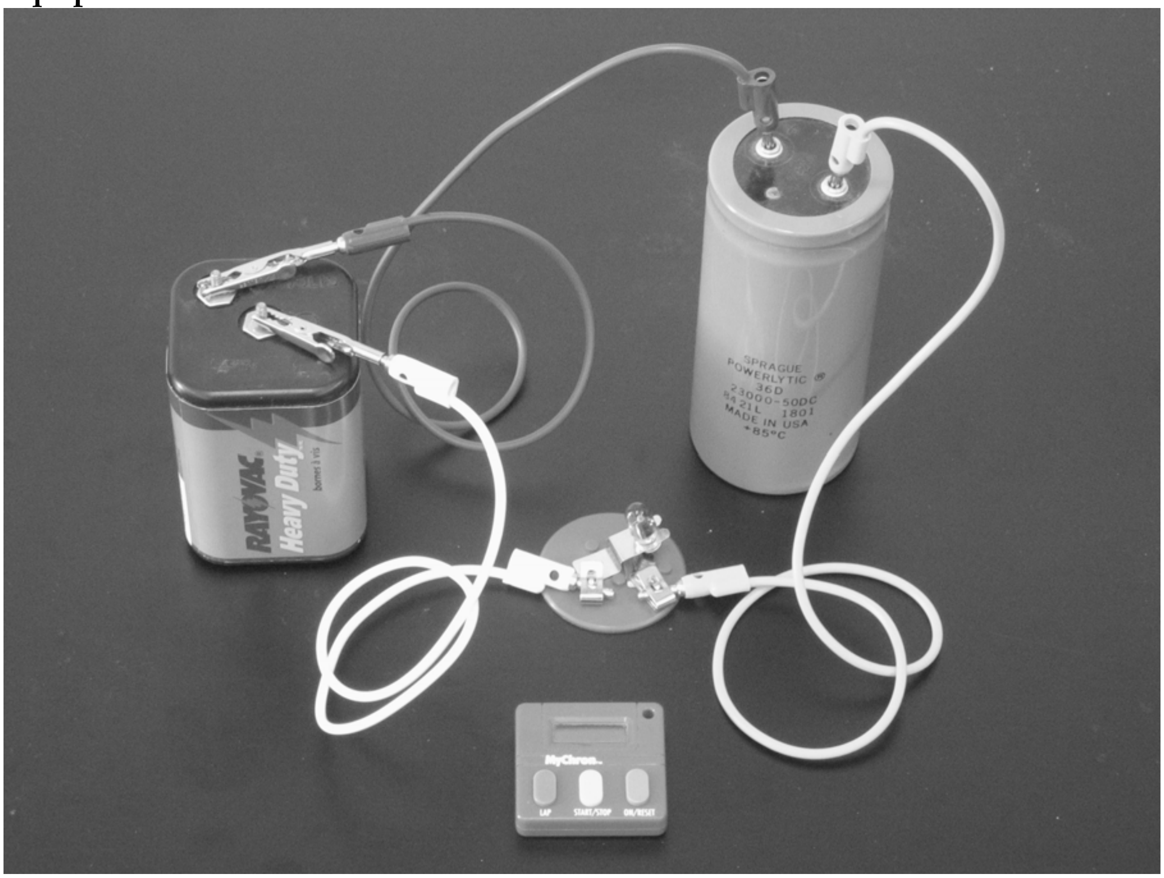
Possible Discussion Questions:

1) Does a battery produce constant current or constant voltage? How can you know this? (Students should see that with more light bulbs the circuit will draw more current if they are in parallel and less current if they are in series. With a larger current, there is more energy transferred from the battery and the battery is drained faster.)

Problem #6: Simple Circuits with Capacitors

Purpose 1) To show how charge flows in a circuit by slowing down the process so that students can get a feeling of the relationship between current and potential difference.

Equipment:



**EQUIPMENT NOTES: All values of capacitance printed on the capacitors have units of microfarads (μF) even though some might be labeled "MF". To find identical bulbs look for markings and check to see that the color of the bead separating the filaments is the same (clear or white).

Teaching Tips

- This problem gives an example of a circuit where the current is not in a state of equilibrium.
- Remember the bulbs are not exactly ohmic, so do not expect an exact exponential decay.
- This problem emphasizes qualitative understanding, not numerical wizardry. Lead a discussion on the concepts of conservation of charge and conservation of energy before moving on to the next problems.
- This is an exploratory problem. Have students connect the equipment with their diagrams through discussion.

Things to Remember:

- For safety reasons, be sure that all of the capacitors are at the front table and that each is discharged before your students enter the lab room.
- This problem demonstrates to the students a safe and effective way of discharging a capacitor. Every student should do this problem before moving on to the next.
- The capacitance is written on the side of the capacitors.

WARNING: A charged capacitor can discharge quickly producing a painful spark. **Do not** handle the capacitors by their electrical terminals or connected wires by their metal ends. **Always discharge a capacitor with a wire when you are finished using it.**

Difficulties and Alternative Conception: Capacitors are a mystery to most students, especially when we draw them as parallel plates, then present them with a cylinder. Most students expect the bulb to become increasingly brighter as the capacitor gains more charge.

Prediction and Warm-up:

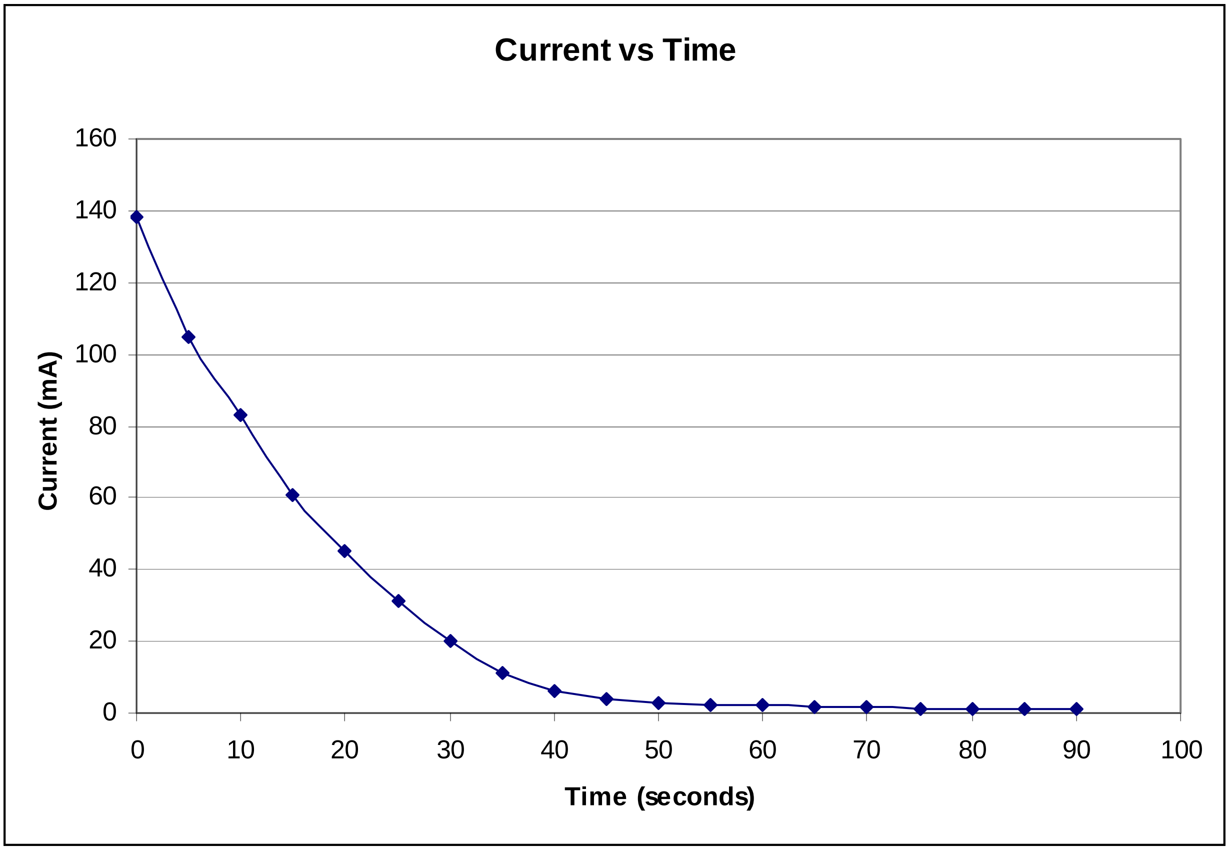
One should see the bulb grow dimmer over time.
There are no Warm-up here, but you should encourage your students to make a prediction as to what they think will happen and to defend that prediction.

Possible Discussion Questions:

1) Can you light the bulb with only a charged capacitor and no battery?
2) Capacitors are advantageous for the way they store and then expel an exact quantity of charge. Can you think of instances where a circuit might require an exact amount of charge? (cameras charge up a capacitor with the batteries, then discharge the capacitor with the flash bulb. That's why you have to wait a couple seconds between pictures. Also medical heart defibrillators rely on capacitors. You may have seen such a device on television: they hold the electrodes to someone's chest, "Clear!" . . . ."ZAP!"

Data:

The graph below was taken with a .28 F capacitor and a light bulb.



Problem #7: Capacitance

Purpose: 1) To further enforce the connection between capacitance and potential difference and how that can be used to explain how long it takes to dim a bulb.

Equipment:

**EQUIPMENT NOTES: All values of capacitance printed on the capacitors have units of microfarads (μF) even though some might be labeled "MF". To find identical bulbs look for markings and check to see that the color of the bead separating the filaments is the same (clear or white).

Teaching Tips

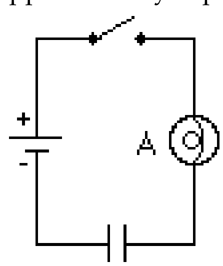
- This problem is a good confidence builder and transition between problem 6 and 8.
- Make a point to discuss the graph of the time for the bulb to turn off versus the capacitance of the capacitor. Ask what happens to the current, and hence brightness of bulb, over time.

WARNING: A charged capacitor can discharge quickly producing a painful spark. **Do not** handle the capacitors by their electrical terminals or connected wires by their metal ends. **Always discharge a capacitor with a wire when you are finished using it.**

Difficulties and Alternative Conception: Many students do not have clearly differentiated ideas of current and voltage. They may still believe that the battery supplies a constant current instead of a constant potential difference. Coach your students to build a physical model of individual charges moving to the capacitor plates. Emphasize what quantities change over time and what quantities do not change. Ask groups how the current through the bulb and the potential difference across the bulb change as the bulb grows dimmer.

Prediction:

The time for a bulb to completely turn off will increase with increasing capacitance. This is because the characteristic time of an RC circuit is $\tau = R*C$ where τ is the characteristic time (similar to a half life) of the circuit and R is the resistance and C is the capacitance. Thus increasing C increase the time the bulbs stay lit. Again there are no Warm-up, so get your students to voice their prediction and defend it. Students do not need any mathematical formula to answer this question qualitatively. They do need a physical model that capacitance means the device holds more charge at a fixed potential difference. The bulb brightness should decrease approximately exponentially with a time constant that increases linearly with capacitance.



Circuit XII

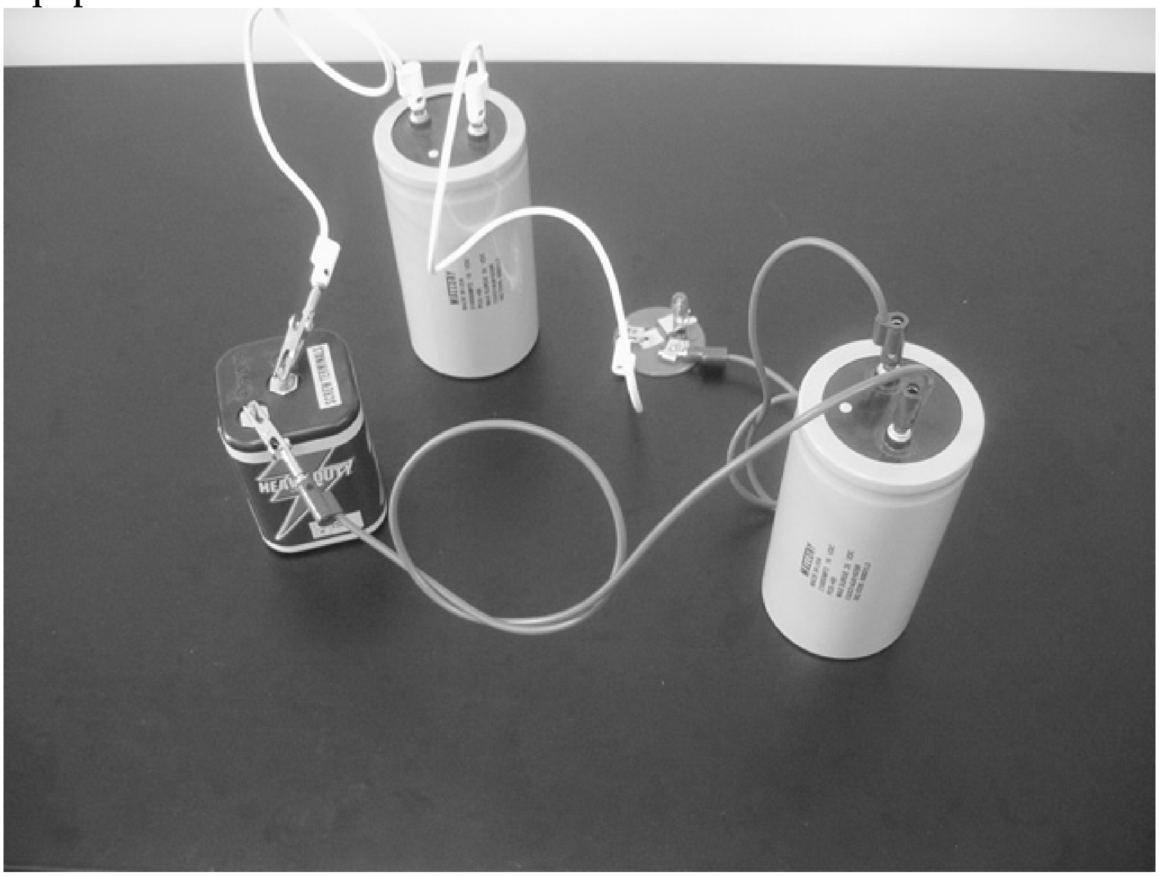
Discussion Questions:

1) If you see the bulb is not lit, does that mean there is no current through it?
2) Does the current every reach zero?
3) Is there a way to leave the capacitor in place, and let the bulb stay at constant brightness?
4) Can we use the capacitor somehow to build a circuit of variable brightness?

Exploratory Problem #8: Circuits with Two Capacitors

Purpose: 1) To continue to challenge your students' misconceptions about current,

Equipment:



**EQUIPMENT NOTES: All values of capacitance printed on the capacitors have units of microfarads (μF) even though some might be labeled "MF". To find identical bulbs look for markings and check to see that the color of the bead separating the filaments is the same (clear or white).

Teaching Tips

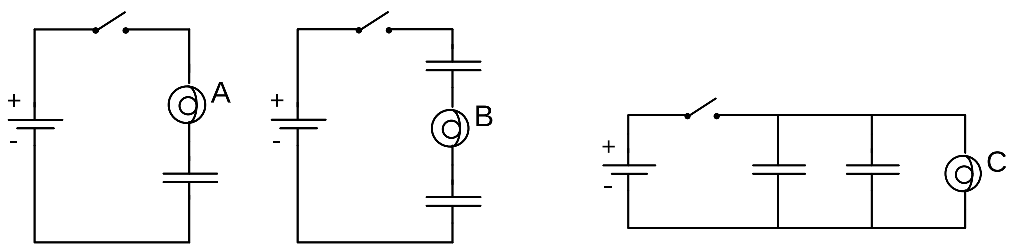
- Take this opportunity to use the word "induce." There is a current "induced in bulb B. When students encounter Faraday's law and the laws of induction, they have trouble not only because the physics is abstract, but also because they are not entirely comfortable with the word induction.
- This problem is similar to, but more complicated than Problems #6 and #7. It is good to have students draw the flow of charge through all parts of the circuit.

WARNING: A charged capacitor can discharge quickly producing a painful spark. **Do not** handle the capacitors by their electrical terminals or connected wires by their metal ends. **Always discharge a capacitor with a wire when you are finished using it.**

Difficulties and Alternative Conception: Many students will answer incorrectly because they have over generalized from their experiences from the previous problems. The students are probably "pattern matching" instead of using physical reasoning from a model of flowing charges. In circuits XIII, many students will reason that bulb B will not light because it is not really connected to the battery (open circuit). Some students might expect bulb C in circuit XIV to dim because they had previous experiences watching bulbs dim when they were connected with charging capacitors. Bulb C will dim if the battery is removed from the circuit, in fact it will discharge the qucikest

Prediction and Warm-up:

B takes less time to turn off than A. C never goes off. If you disconnect C from the battery, it will remain lit for a period of time longer than A. This is because the higher the effective capacitance, the longer the bulbs will stay lit. The values of capacitance form highest to lowest is Circuit XIV (parallel capacitances add) , XII, and XIII (capacitances in series add in a reciprocal fashion). Once again this is due to the formula $\tau = R*C$.



Circuit XII Circuit XIII Circuit XIV

Possible Discussion Questions:

1) How does bulb B have a current through it if it is not connected to the battery?
2) What happens in each of the pathways of current in Circuit XIV as time progresses?

Check Your Understanding:

1. If more bulbs were added as shown in the diagram, bulb A would grow brighter. The reason is that by adding bulbs in parallel, the net resistance is decreased and more current is drawn from the power source. A is the position of a circuit breaker to regulate the amount of current that flows through a circuit.

2. Circuit I, $R_{e\ quivalent} = \frac{R}{2}$, Circuit II, $R_{e\ quivalent} = \frac{6R}{11}$
   Circuit III, $R_{e\ quivalent} = \frac{3R}{7}$, Circuit IV, $R_{e\ quivalent} = \frac{R}{2}$
   So the current through point 1 in the circuits is ranked as follows

   (III) > (I = IV) > (II)

3. The brightness of bulbs A and C will remain the same since the voltage across these bulbs does not change. Now let's look at bulbs B and D. With E in the circuit, 2/3 of the battery's voltage is across B while 1/3 is across D. With E removed, B and D each share ½ of the battery's voltage. Therefore, bulb B becomes dimmer while bulb D becomes brighter.

4. $I_8 = I_{24} = 9/14$ A; $I_6 = 8/14$ A; $I_{12} = I_{36} = 1/14$ A.

5. a) $R = 8$ Ohms

   b) There is no resistance that will cause this to happen.

TA Lab Evaluations
Physics 1102 Lab 5

We strongly encourage you to fill out this evaluation as soon as you are done teaching the labs. If you had issues or problems with any of the lab please submit available information through the LabHelp system or email lab@physics.umn.edu.

Instructors Pages:

Did you find the instructors pages useful? (circle one) yes / no

What additional information would you include in these pages?

____

____

____

Students:

Did the students find these exercises: (circle one) enlightening / boring / fun / other?

Do you have additional comments regarding student learning and these labs?

____

____

____

TA:

Given the choice, would you teach these exercises again? (circle one) yes / no

Why or why not?

____

____

____

Results:

Did the students obtain sensible results from these exercises? (circle one) yes / no

What were the best / worst sets of results? Why?

____

____

____

Lab Room:

Was the room kept neat and clean by your class and other classes? yes / no

Was the equipment functioning properly? Could you fix it? yes / no

Any other comments regarding the room and equipment?

____

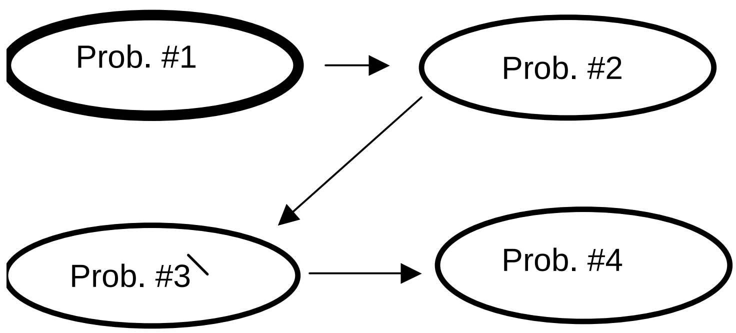
____

____

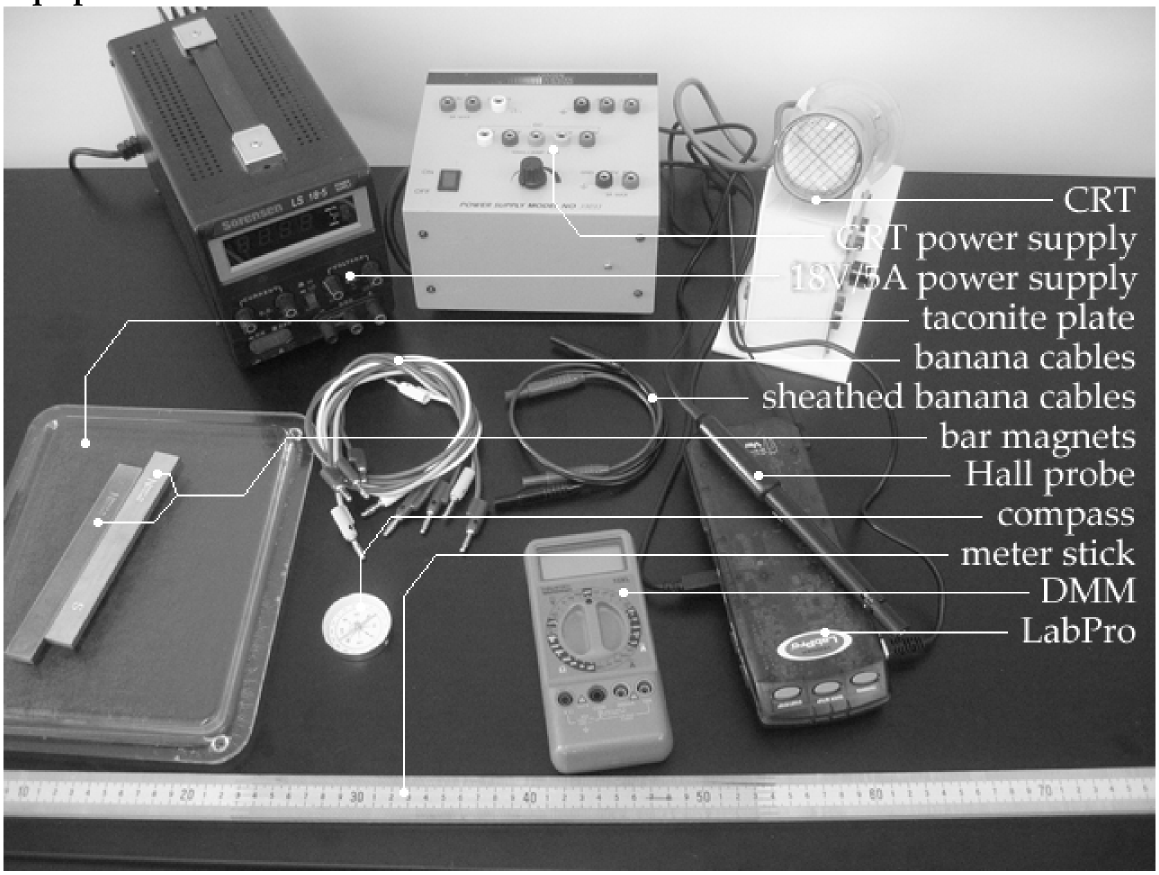
Laboratory VI:
Magnetic Fields and Forces

Laboratory VI parallels Laboratory IV (electric fields) in many respects. You should emphasize the differences and similarities between electric and magnetic fields at the end of these problems. Many students do believe that magnetic poles are just electric charges. As with electric fields, there will be a lot of confusion between magnetic field, magnetic force, and lines of force. Since lines of force are not useful for simple calculations and they often lead to student misconceptions, it is probably best to avoid them as much as possible. Just stick to what is closest to your measurements, the magnetic field vectors at various points in space.

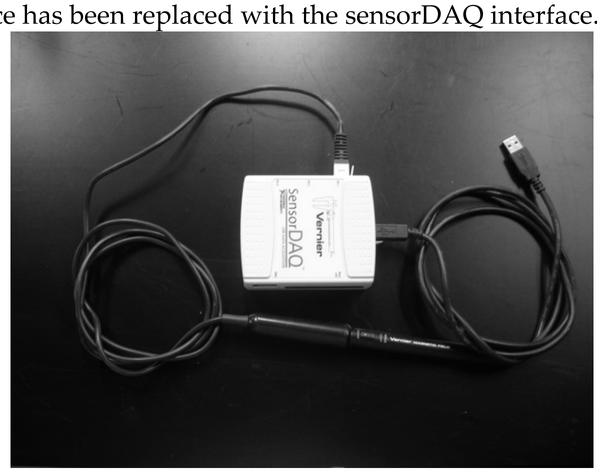
The flow chart for this lab is given below. Each of the problems emphasizes a different aspect of the magnetic field concept. Most of the problems are quick if the predictions are done ahead of time. You will need to ask a lot of questions when working with the groups to make sure your students are really making appropriate connections between these new concepts and fundamental physics.



Equipment:



** Note: the LabPro interface has been replaced with the sensorDAQ interface.



REMINDER: Your students will be working with equipment that can generate large electric voltages. Improper use can cause painful burns. To avoid danger, the power should be turned OFF and your students should WAIT at least one minute before any wires are disconnected from or connected to the power supply.

By the end of this lab students should know:

- The differences and similarities between magnetic fields and electric fields.
- The difference between an electric charge and a magnetic pole.
- The pattern of magnetic fields near various sources such as permanent "bar" magnets, straight current-carrying wires, and coils of wire.
- How to calculate the magnetic force on a charged particle moving in a uniform magnetic field and describe its motion.

Things to check fifteen minutes before lab:

- Make sure you know which direction is North in your lab room. Do not rely on your compasses for this.

- The taconite plates are fun to play with. Play with them to determine what suggestions to give students who are having difficulty getting clear patterns. Make sure you know how to explain how this pattern tells you about the magnetic field at each point of space. Do this without any reference to "lines of force."

- Make sure you know where to place the CRT in the magnetic field to get good results. Try various other configurations so that you can advise your students when they have difficulty.

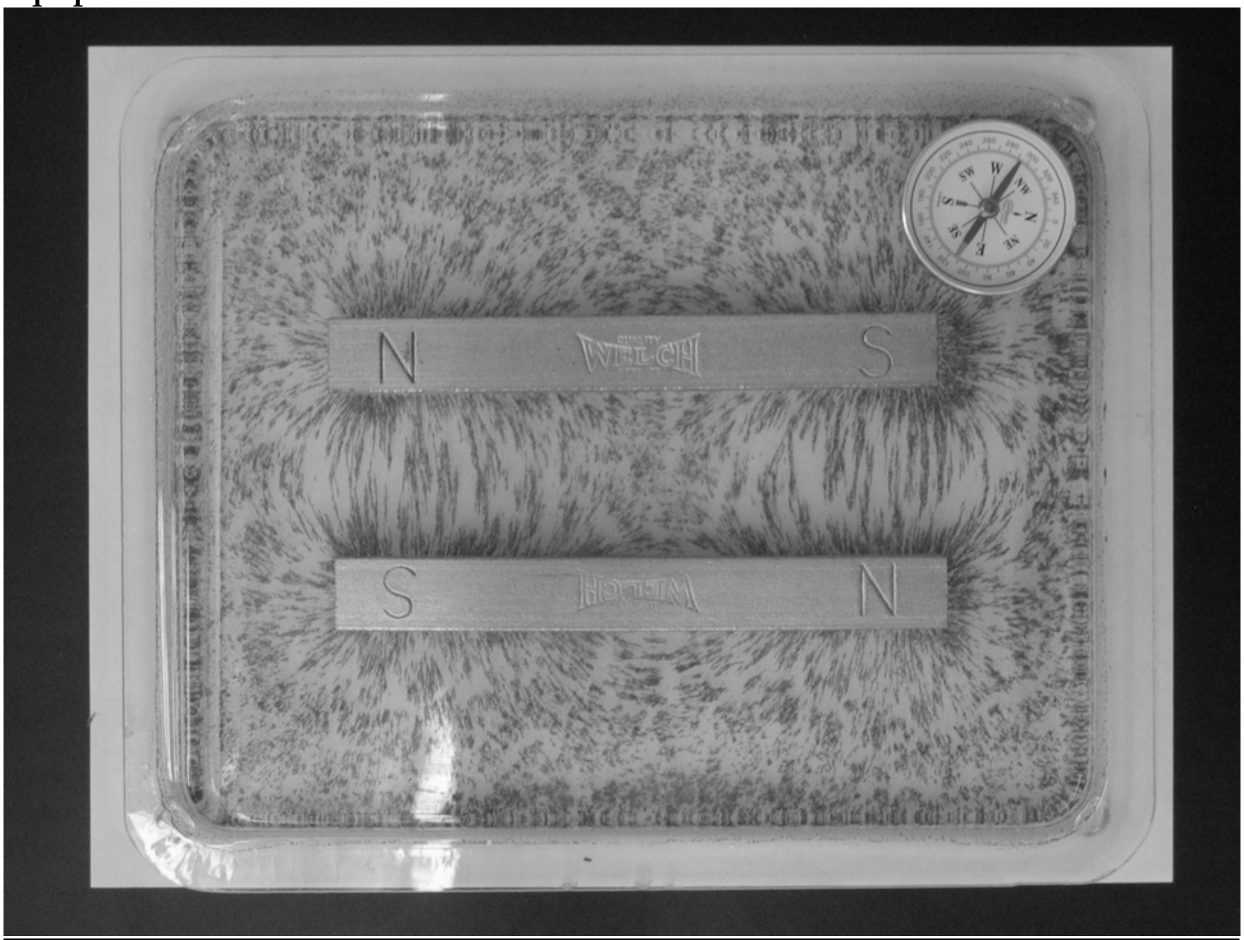
- **Just before your students enter class, re-magnetize every permanent magnet**. (Instructions are printed on the side of the magnetizer). Students can do amazing things which change the pole structure. Your students will really be confused and frustrated if you do not make sure that all the magnets are really dipoles before they start class. After you re-magnetize the magnets, check that they are now dipoles using the taconite plate. Just for fun, look at the magnets using the taconite plates before you re-magnetize them.

- **Just before your students enter class, make sure all of your compasses point North**. You can reverse the poles of the compass needle by bringing it close to a magnet. That is how students reverse them in the first place.

Problem #1: Permanent Magnets

Purposes: 1) To allow the students to become familiar with the magnetic fields of a bar magnet and how these fields combine by vector addition.
2) To show that magnetic poles are different than electric charges.

Equipment:



Teaching Tips

- This is a field-mapping problem and it is very similar to the electric field problems from the first lab. It might be helpful to explicitly say that the iron particles are like mini-compasses. We don't want this to be a magical apparatus.
- Make sure your students explore the properties of a compass. Have a short discussion after they have done so to make sure that every student knows that a compass is just a small dipole magnet. Emphasize the concept of torque by making a free body diagram of the compass needle in a magnetic field.
- Some of the configurations can be challenging. Encourage your students to follow the guidelines in method question 2 to help them through the analysis. Emphasize vector addition of the field from every magnetic pole.
- Since the compasses only give direction and not magnitude of the magnetic field, there is not enough information to make a complete translation between compass data and field maps. The students should be able to make educated guesses about the magnitude of the magnetic field and add this information to the maps.

- The taconite does take a little time to align with the field, be patient. If it takes more than 5 or so minutes let the lab coordinator know and he will adjust the viscosity of the glycerin. To distribute the taconite just shake or tap the Plexiglas frame. Once distributed keep the taconite plates flat on the table and don't leave the magnets on plates when the exercise is done. **Try putting the taconite plates on an overhead projector.**

Things to Remember:

- **Check the magnets!!** They can become different than simple dipoles when they are dropped or are in the field of another magnet. **Re-magnetize all the magnets in the lab.** Use a taconite plate to check the field of every bar magnet. If it is still not a dipole, demagnetize it again or replace it. Poor magnets are a large source of frustration to the students and can reinforce many misconceptions. It is necessary to re-magnetize the magnets before each class period!
- You may wish to consult a map to determine which way is north (North is basically pointing towards Morrill Hall). Remember the north pole of a magnet is the north seeking pole. That means the Earth's magnetic north pole is at the south pole. Also, remember that the earth's magnetic field has a large vertical component in Minneapolis. This is not shown on flat compasses.
- Be sure to warn your students not to get any glycerin on their hands in the event of a leak of the taconite plates. If they do make sure they wash their hands immediately. Glycerin is not dangerous, but it is a skin irritant. The iron powder suspended in the glycerin should not be ingested. If any plate leaks replace it immediately.
- DO NOT leave the magnets stuck together! This will demagnetize them and destroy them over time. There are boxes for the magnets to be kept in when not in use. Align the magnets with opposite poles together and put the keeper bars at the ends.

WARNING: The viscous liquid (glycerin) in the Taconite plate may cause skin irritation. **If a plate is leaking, please notify your lab instructor immediately.**

Difficulties and Alternative Conceptions:

Your students will have many misconceptions about magnetic fields. Many students believe that magnetic poles are just electric charges. They may even label their poles + or -. Make sure they explore the properties of their magnets enough to determine that they are not electrically charged. Your questioning is crucial here. Based on pictures of lines of force, many students believe that these lines come out of magnets and forces occur when these lines push on each other (repel) or grab each other (attract). The do not believe in the field concept that the object (magnet) modifies the space around it (field); that a group of magnets each independently modify the space around them so that the net effect (field) is the vector sum at each point in space of the field from each magnet; and that the force on yet another magnet is due to the interaction of its poles with the field (from the other magnets) at each of its poles. Most of your students probably do not separate the magnet causing the field from the magnet on which a force is exerted.

Prediction and Warm-up:

One interesting configuration is Figure III. There is a region where the field from each magnet is exactly opposite to the field from the other magnet. It is interesting to move the compass perpendicularly away from the center of the two magnets and watch what happens.

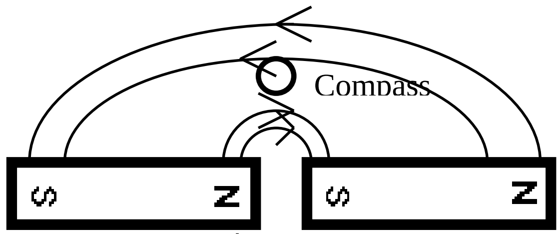


Figure III

Problem #2: Current Carrying Wire
Problem #3: Magnetic Field from a Current Carrying Wire

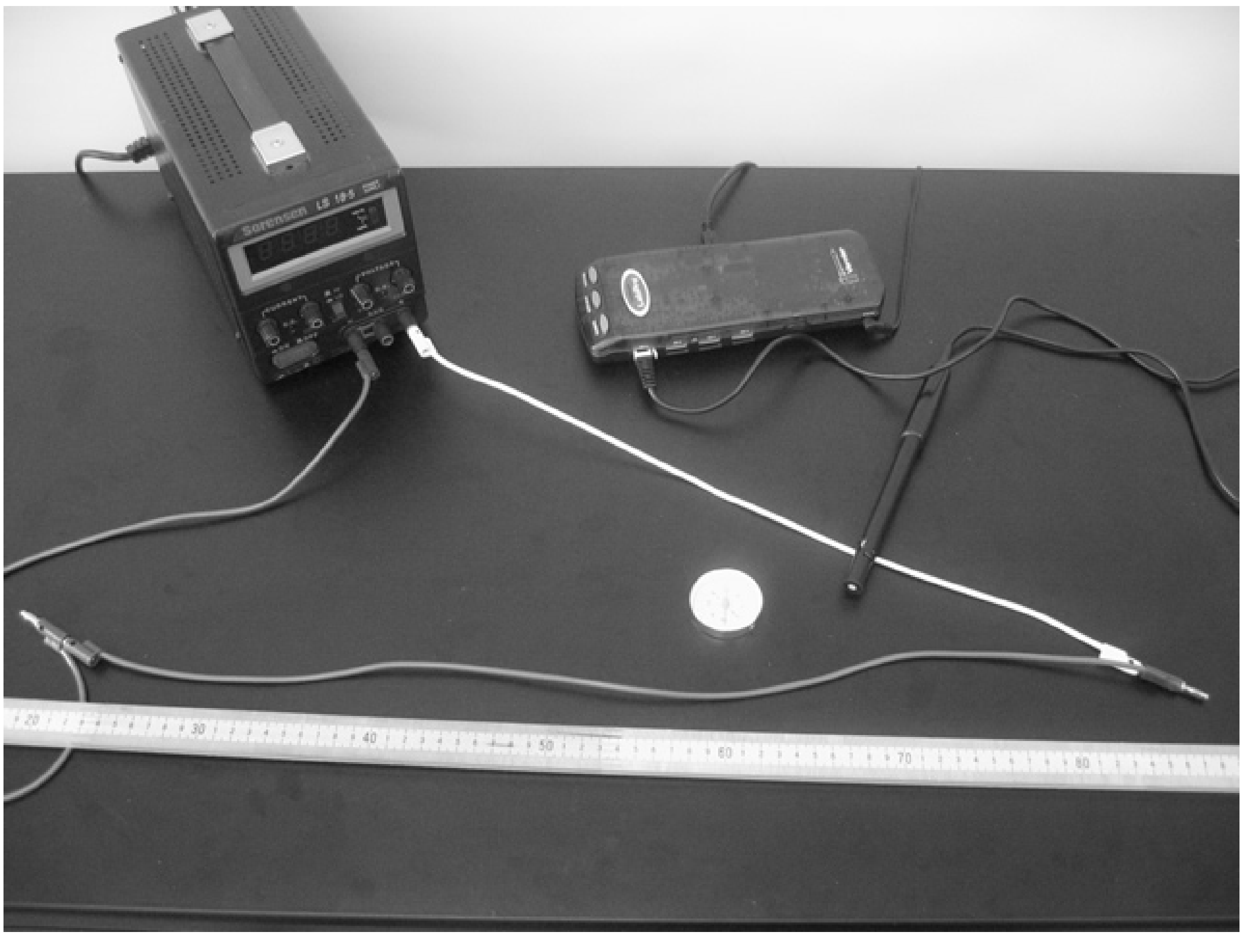
Purposes

1) To show students that magnetic fields are created by current carrying wires.
2) To allow the students to "see" that the field map curls around the wire and does not point away from the wire.
3) To assist students in applying Ampere's Law.

Equipment:

Problem #2

Problem #3



** Note: the LabPro interface has been replaced with the sensorDAQ interface.

Teaching Tips

- Make sure the students understand that the magnetic field at any point points in a straight line. The field vectors do not curve; the direction of each new vector in space is slightly slanted from the previous point. Field lines can be confusing because they do wrap around. Try centering the discussion and field mapping upon field vectors.
- This lab shows that the field from a current carrying wire exists and it introduces the right-hand rule for magnetic fields.

- To witness the magnetic field near a current carrying wire, the wire should be vertical and the compass needle must be horizontal. A second possible configuration is with the wire lying across the compass. Many students will want the compass to point toward the wire.
- For small currents, the earth's field is larger than the current's field when the compass is just a few cm from the wire. If a group does not observe a compass deflection, have them discuss how they think the field varies with distance from the wire and where the biggest effect would be observed. Then have them try it where the effect is largest.

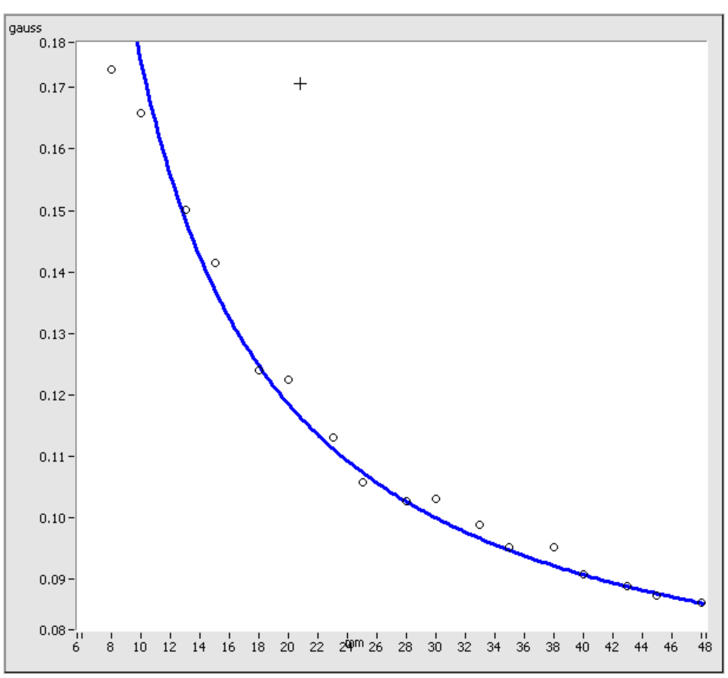
WARNING: You will be working with a power supply that can generate large electric currents. Improper use can cause painful burns. **To avoid danger, the power should be turned OFF and you should WAIT at least one minute before any wires are disconnected from or connected to the power supply. Never grasp a wire by its metal ends.**

For Problem #3

- An easy way to set up the loop is to lay the wire across the table. This allows for a very steady set up, for both the wire and the probe.
- Putting 5 amps through the wire is enough to get decent results, but only over a short distance. Your students will need to get about 15 to 20 readings withing a 5-8 cm range. Using a power supply that could give more then 5 amps would give more noticeable effects, but would increase the dangers of shock and injury. Even with only 5 amps **your students must be careful!**
- The probe will likely never read zero, so make sure that they know what the zero point is and stop taking data after they start reading that number consitantly.

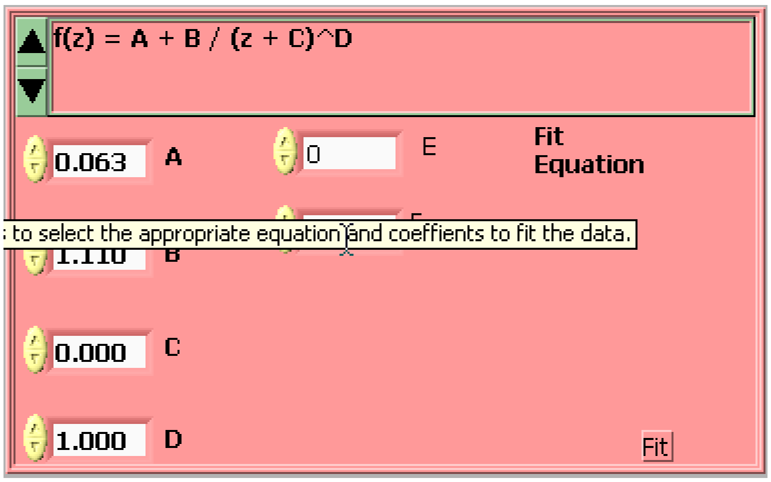
Things to Remember:

- Be sure to warn your students about the power supplies. They maintain a significant potential difference for at least a minute after they are turned off.
- Power supplies: Only use the Sorenson power supply! **Do not under any circumstances use +/- 125V or +/- 250V terminals!** The power supplies are current limited which means that these terminals will not give the students a larger current. Also, the transformers have been known to melt down when the students short the power supply across the +/- 125V or +/- 250V terminals.



This is a graph of data taken by the probe from a wire carrying 5.27 amps. There are offsets that depend on how the probe is calibrated. Note it is measured in mm and has a minimum around .09. Make sure to put the probe setting on **High amplification**.

<u>Difficulties and Alternative Conceptions</u>: Many students believe that magnetic fields, like electric fields, go from a source to a destination. Even students who are beginning to develop a field theory can over-generalize and think that field vectors must always point to physical objects. Students also believe the magnetic poles are the same as electric charges. You must work hard to point out the differences between electric fields and magnetic fields, between the electric force and the magnetic force.



Possible Discussion Questions:

1) If magnetic fields exist around current carrying wires, where are magnetic fields existent that you may not have previously realized?

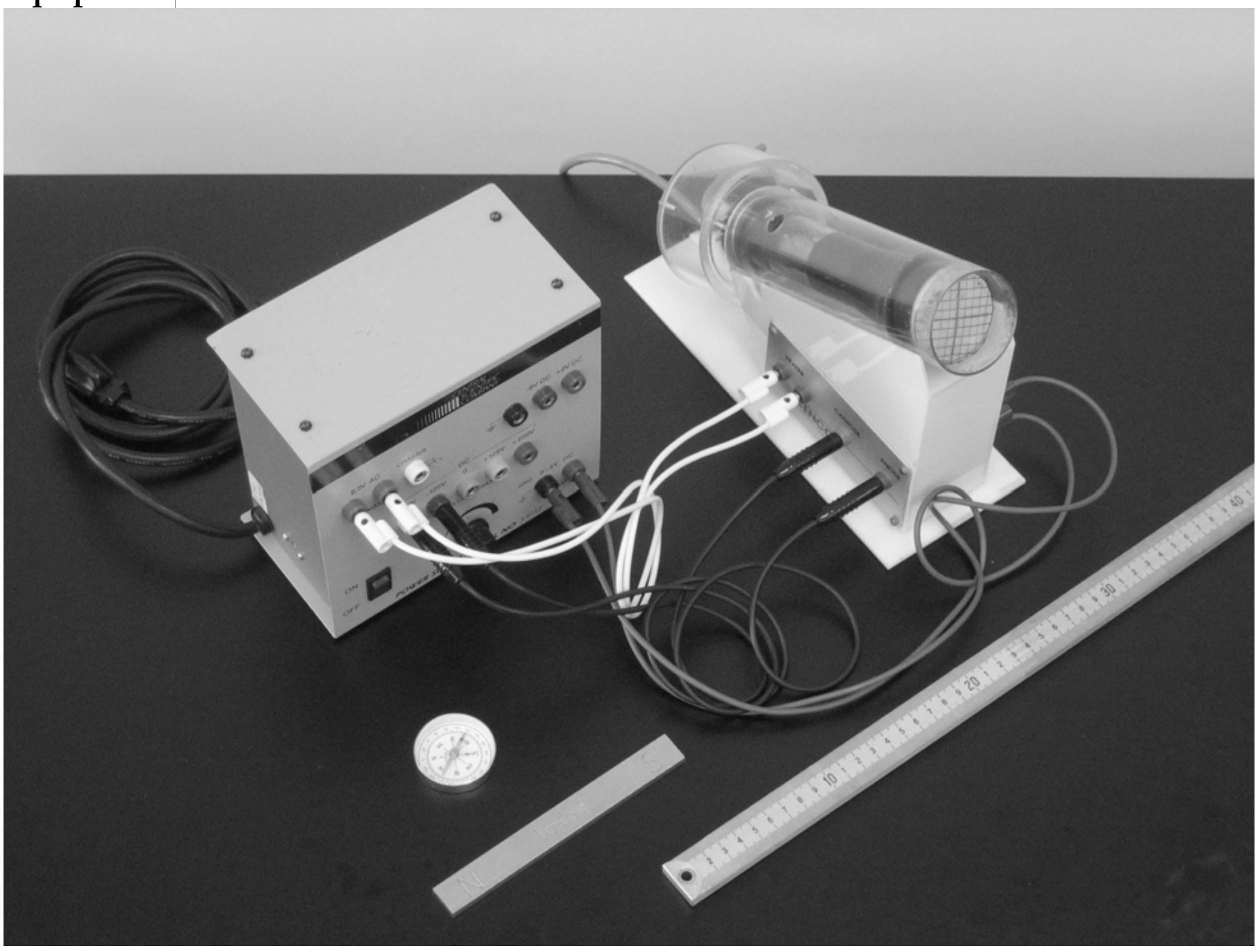
2) What will happen if two wires are hung close to one another and they are both carrying current in the same direction? In the opposite direction?

(If you have not talked about forced on a moving charge, wait with this question until you cover the next problem.)

Exploratory Problem #4: Magnets and Moving Charge

Purpose: 1) To introduce the force caused by a magnetic field on a charged particle.

Equipment:



Teaching Tips

- Many students find the concept that the force on a charged particle caused by a magnetic field is perpendicular to that field very difficult to grasp. This problem shows magnetic fields act differently than electric fields. Remember that electrons are negatively charged!
- The last paragraph in the exploration asks the groups to think up their own question and check it with you before they start. They are asked to check with you for safety reasons, but ask them why they chose the question they did. Try to make sure that they are not just copying what their neighbor did and that they have made a guess about the answer. Remember that a null result can be interesting, especially if they expect something to happen.
- When these measurements are finished, it is good to refer back to Lab 4, Problem #3, when the electron was deflected by the earth's magnetic field instead of the gravitational field. Ask the students which direction the magnetic field of the earth should be pointing based on those results.

WARNING: You will be working with a power supply that can generate large electric currents. Improper use can cause painful burns. **To avoid danger, the power should be turned OFF and you should WAIT at least one minute before any wires are disconnected from or connected to the power supply. NEVER GRASP A WIRE BY ITS METAL ENDS!**

Difficulties and Alternative Conceptions: Students may believe that if one object exerts a force on another object, that force must point toward (or away from) the object exerting the force. Many of your students will still believe that magnetic poles are the same as electric charges. There are also students who will confuse velocity and acceleration.

Prediction Warm-up:

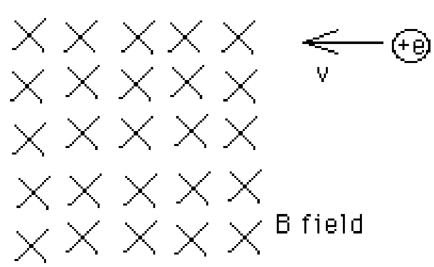
Magnetic Force = $q\vec{v} \times \vec{B}$ where q is the charge, v is the velocity and B is the magnetic field. (For the non-calculus course, do not mention the word "cross product." You will only create more confusion. Tell them that the magnetic force is mutually perpendicular to magnetic field and velocity. Tell them that the magnetic force never does work on the moving charge.)

Possible Discussion Questions:

1) What happens when you use more than one magnet in more than one place?
2) What if you move the magnets up and down the entire length of the CRT?
3) What happens if you deflect the beam with both the electrically charged plates and the magnet?
4) How is the deflection due to magnetic field different than the deflection due to electric field? (One answer is that the path of deflection is circular, not parabolic. Another answer is that magnetic deflection requires motion where electric deflection does not.)

Discussion Idea: This is a good opportunity to explain the path of a charged particle in a cyclotron. It's a great right-hand rule exercise. Some students are learning about vectors in calculus class, so here's your chance to integrate that knowledge into physics.

Describe the path of the positively charged particle:



This is one of the features of a cyclotron.

TA Lab Evaluations
Physics 1102 Lab 6

We strongly encourage you to fill out this evaluation as soon as you are done teaching the labs. If you had issues or problems with any of the lab please submit available information through the LabHelp system or email lab@physics.umn.edu.

Instructors Pages:

Did you find the instructors pages useful? (circle one) yes / no

What additional information would you include in these pages?

____

____

____

Students:

Did the students find these exercises: (circle one) enlightening / boring / fun / other?

Do you have additional comments regarding student learning and these labs?

____

____

____

TA:

Given the choice, would you teach these exercises again? (circle one) yes / no

Why or why not?

____

____

____

Results:

Did the students obtain sensible results from these exercises? (circle one) yes / no

What were the best / worst sets of results? Why?

____

____

____

Lab Room:

Was the room kept neat and clean by your class and other classes? yes / no

Was the equipment functioning properly? Could you fix it? yes / no

Any other comments regarding the room and equipment?

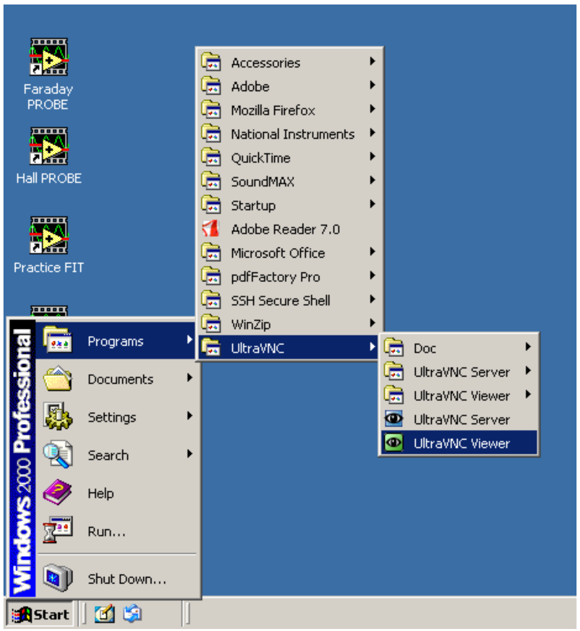
____

____

____

Reference Guide for Ultr@ VNC version 1.0.0

Ultr@ VNC is a computer program in the physics lab rooms that gives you the power to observe student computer screens and control a student's computer remotely via your keyboard and mouse. It is particularly useful for giving instructions about a program or displaying students' lab data.



To access Ultr@ VNC, log in to a lab computer with a TA username and password (most likely your physics department ID). If you would potentially like to broadcast a screen using the digital projector, log in to the instructor computer located near the printer. (Refer to the Digital Projector Reference for more information.) Access the program from the Start menu, Programs folder, UltraVNC, and UltraVNC Viewer. Refer to Figure 1.

You can also access the program from My Computer:
C:\Program Files\UltraVNC\UltraVNC Viewer

Fig. 1

The following pop-up window should appear, requesting the name of the display host:

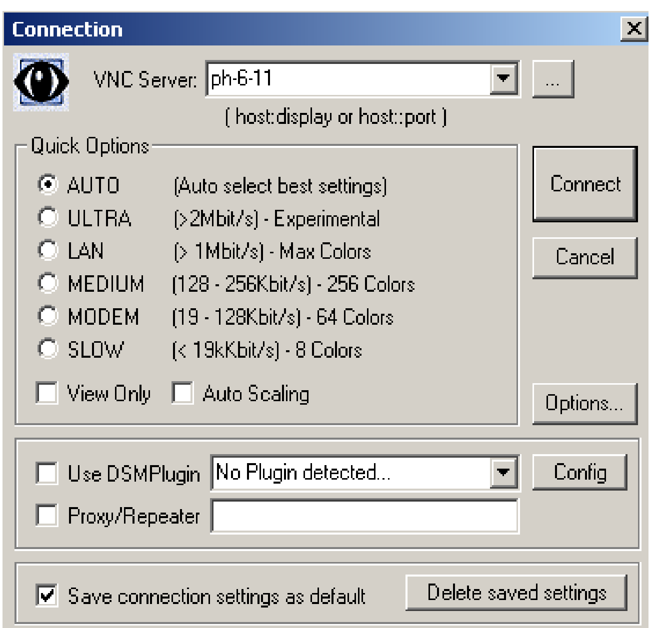


Fig. 2

In the *VNC Server* drop-down field, type the number of the student's computer that you want to observe. The numbers are printed on each computer and should be in the format ph-#-##.

If you want to change connection options, click the ***Options*** button. Another pop-up window will appear (Figure 3). *Auto select best settings* is the default. From this window you can change *Mouse Cursor* options and select *Display* options.

Click ***Connect*** to begin viewing the selected Desktop. An Authentication pop-up window will appear, requesting you to enter a username and password. Type in "vnc" and "labvnc". Click ***Log On***.

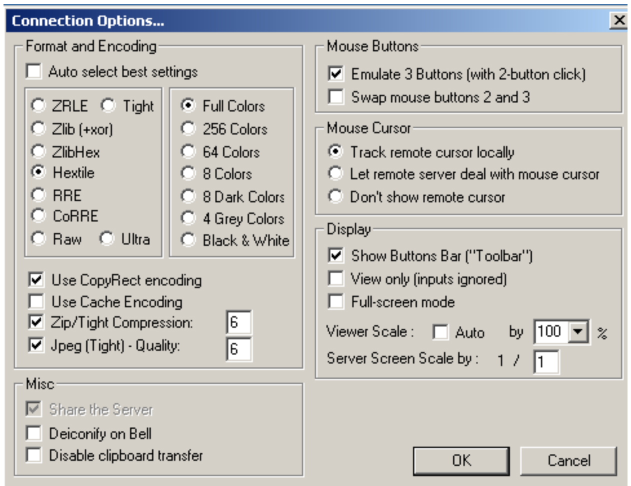


Fig. 3: Connection Options

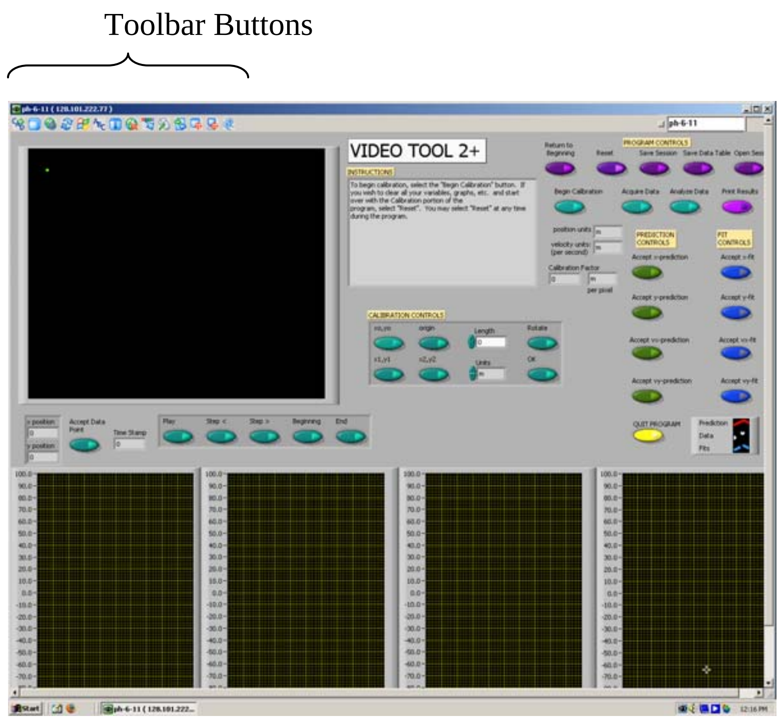


Fig. 4: Sample view of a student screen

Refer to Figure 4 for a sample view of a student screen. You can resize the window of the student screen using the arrows in the bottom right corner.

Use the toolbar buttons to navigate Ultr@VNC, as seen in Figure 5. Most buttons are self-explanatory, but selected descriptions are given on the next page.

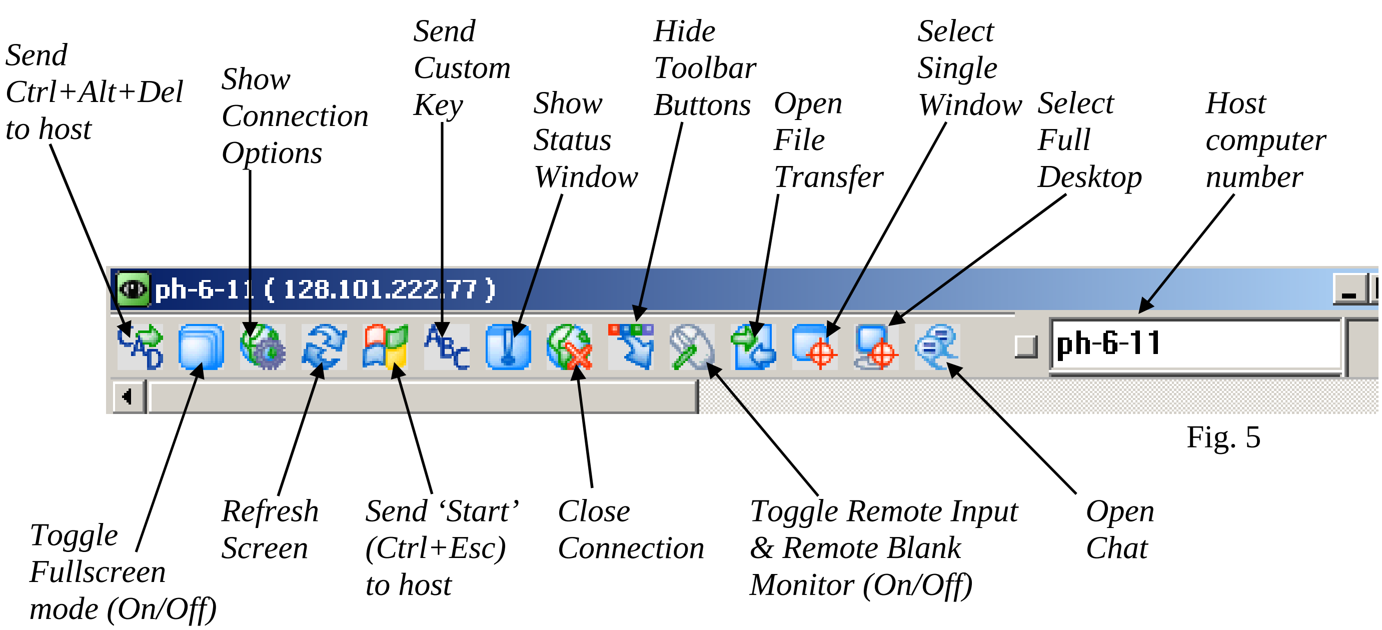
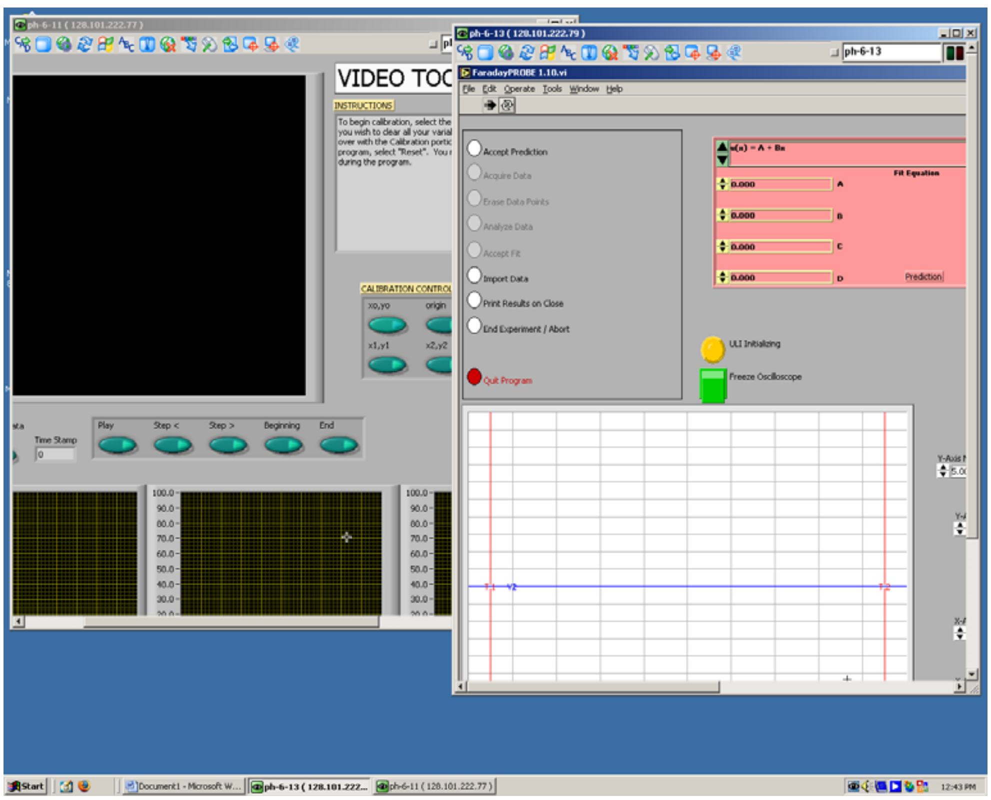


Fig. 5

Selected Descriptions for Toolbar Buttons:

- ***Send Ctrl+Alt+Del to host*** will bring up the physics logout window on the student's computer.
- ***Send 'Start' (Ctrl+Esc) to host*** will depress the start button on the student's computer, giving you the power to access programs, etc. from the host computer.
- ***Show Connection Options*** will display the same pop-up window that is available from the ***Options*** button of the initial ***Connection*** window (Figure 3).
    - There are three options for the *Mouse Cursor*: Track remote cursor locally, Let remote server deal with mouse cursor, and Don't show remote cursor.
    - The first two options appear to be a shared-control option between the student and instructor computers, with slight differences between what is seen on each screen.
- ***Toggle Remote Input & Remote Blank Monitor (On/Off)*** gives total control to the instructor by disabling the student's computer mouse.
- ***Select Single Window*** gives you the option to select and view one window that is open on a student's screen, providing multiple windows are opened at the same time. When this toolbar button is depressed, a crosshair appears and you can use this to click on the window to be viewed. Any remaining windows are "blacked out". To return to the fullscreen view, click the ***Select Full Desktop*** toolbar button.



It is possible to display multiple student screens on an instructor desktop, but you must reopen the Ultr@ VNC program each time and resize the windows (or only view one screen at a time).

Fig. 6

To exit Ultr@ VNC, click ***Close Connection***.

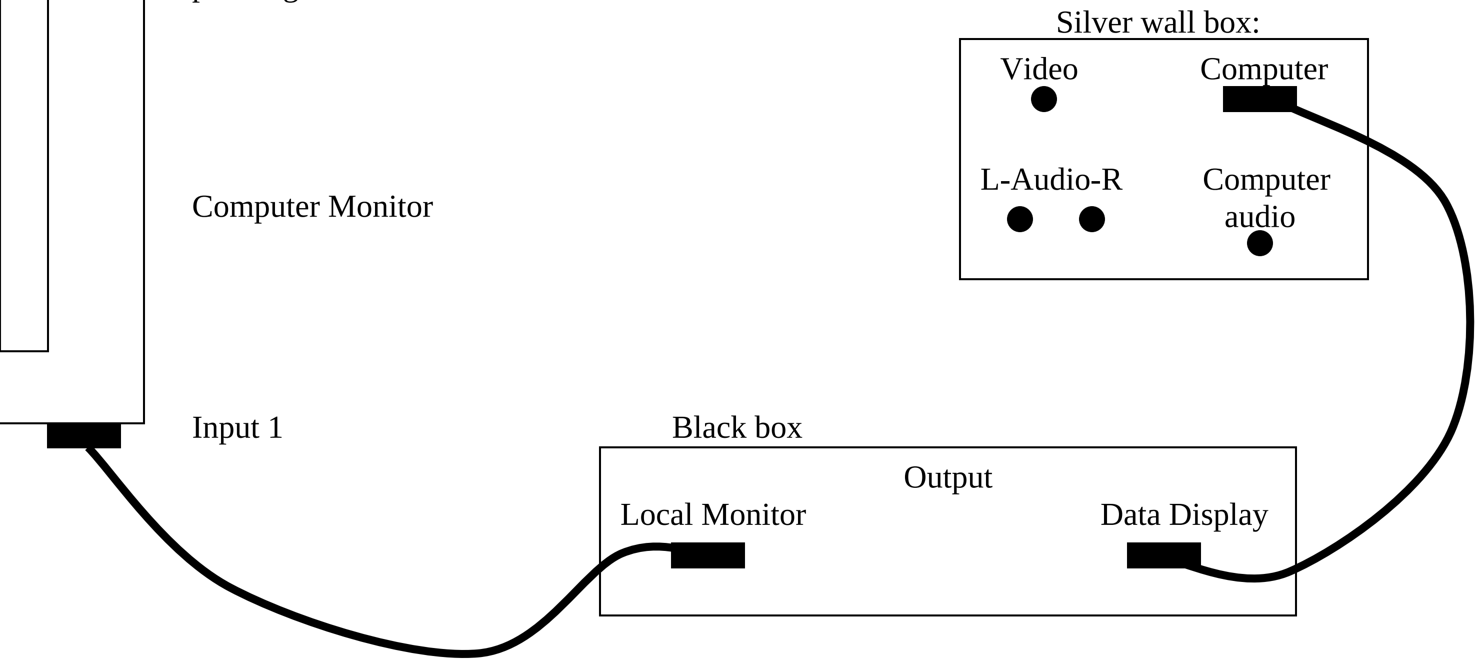
For more information, the software developers' website is:
http://www.ultravnc.com/

Digital Projector Reference:

Every lab room has a Panasonic® projector fixed to the ceiling with connections to a wall unit. This is useful to project documents or programs onto a pull-down screen for easy viewing by the entire class.

To project the instructor computer, log in using either a student ID and password or a TA username and password.   This computer should have a serial cable connected from *Input 1* of the monitor to *Local Monitor* of the black Output box, and another cable from *Data Display* of the black Output box to *Computer* of the silver wall unit.

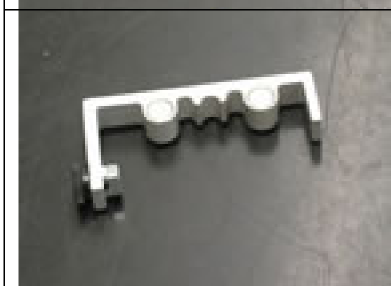
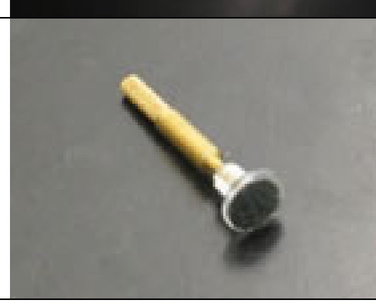
Turn on the Panasonic® projector by depressing the large *Power* button. You might need to use a meter stick to reach it. If the computer screen does not immediately display, cycle through the input by pressing the *RGB* button. Most will display on *RGB 1*. Turn off the projector by pressing *Power* twice.

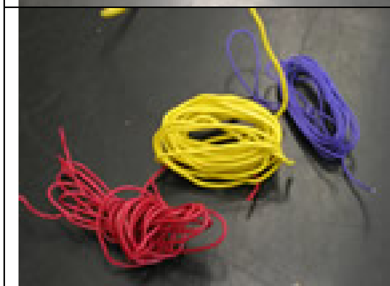
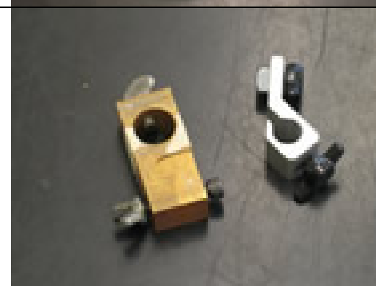
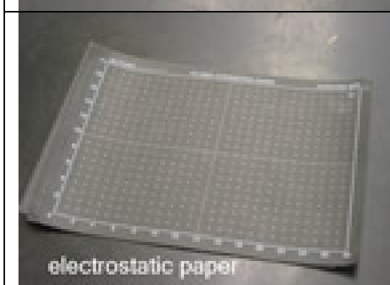
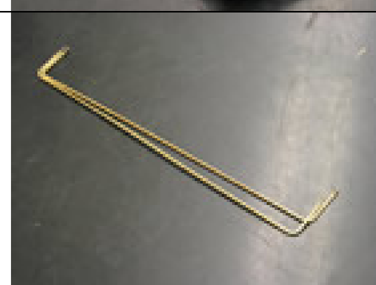
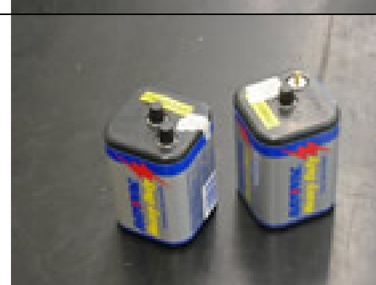


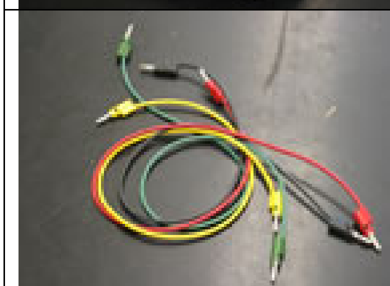
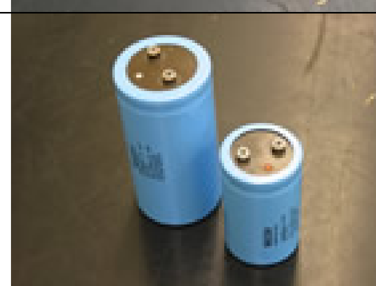
1102 Equipment Guide

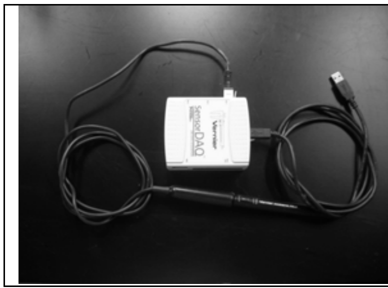
Remember to submit a lab problem report using the link on the desktop of the lab workstations for any problems with the lab equipment. Some equipment is noted as being commonly available in supply closets on the second floor. If you take equipment, you still need to submit a problem report. **Please encourage your students to keep all parts of equipment together. Mass sets should remain as sets and nuts and bolts should be securely tightened after use.** Common problems are noted for some equipment that might provide potentially quick fixes. Thanks for you help!

	**Metal Object Set**		**Hot Plate** **Remember to always turn off!**
	**Styrofoam cups**		**Digital Thermometer**
	**Electrical Equivalent of Heat Apparatus**		**Harmonic Springs** Make sure your students don't overstretch! Replacements in second floor closet #7
	**Rod**		**Table / Pulley Clamp** Replacements in second floor closet #7

	**Meter Stick**		**Wood Dowels**
	**Stopwatch** Replacements in second floor closet #8		**Cart** Replacements in second floor closet #8
	**Endstop** Replacements in second floor closet #8 Keep lock screw tight.		**Mass Hanger** Replacements in second floor closet #8
	**Mass Set** Keep mass sets together as sets. (1x200g, 1x100g, 2x50g, 2x20g, 2x10g & 2x5g)		**Tape and String** Replacements in second floor closet #8
	**Video Setup – firewire camera and cable.** Replacements in second floor closet #8		**Track** Tracks are left in the labrooms.
	**Mechanical Oscillator** Check the fuse		**Friction Accessory** Keep parts together. Replacements in second floor closet #8 in cup.

	**1.8 Meter Spring** Do not overstretch!		**Goggles** Students Must Use Goggles when using 1.8 meter springs!
	**Oscillating Wire**		**Rod / Wire Clamp**
	**Pulley** Replacements in second floor closet #8		**DMM – Digital Multi Meter** Replacements in second floor closet #8 Box marked Bad for broken units
	**Electrostatic Paper** Replacements in second floor closet #8		**Long Brass Rods – contacts for Electrostatic Paper** the labrooms.
	**Plastic Holders for Brass Rods**		**Batteries** Replacements in second floor closet #7
	**Pin Tip Probe**		**Alligator Clips** Replacements in second floor closet #8

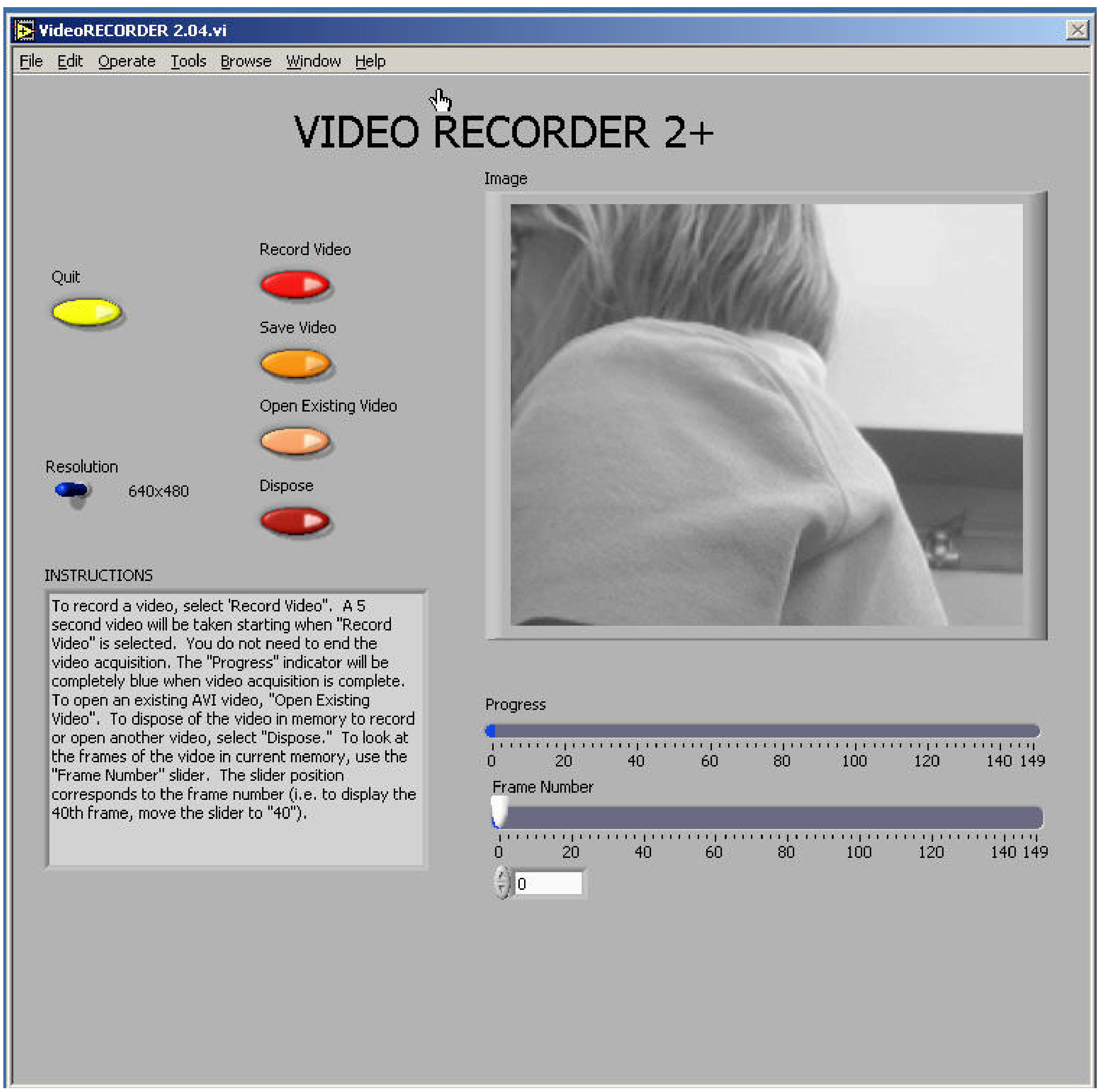
	**Wood Block**		**Brass Plates**
	**Cenco Power Supply (for CRT use only!!)** Check fuse		**CRT – Cathode Ray Tube** Check to see that bulb is seated in socket all the way.
	**Banana Cables** Replacements in second floor closet #8		**Light Bulbs** Replacements in second floor closet #8
	**Resistors** Replacements in second floor closet #8		**Capacitors** Replacements in second floor closet #8
	**Bar Magnets** Replacements in second floor closet #8		**Magnetic Field Projectual** If it is leaking, please submit a report ASAP.
	**Compass** Replacements in second floor closet #8		**18Volt 5Amp power supply** Make sure it is set to MASTER on the rear of the unit.

	**Lab Pro**		**Magnetic Field Sensor** Replacements in second floor closet #8

Software

MOTIONLAB -Video Analysis of Motion

Analyzing pictures (movies or videos) is a powerful tool for understanding how objects move. Like most forms of data, video is most easily analyzed using a computer and data acquisition software. This appendix will guide a person somewhat familiar with WindowsNT through the use of one such program: the video analysis application written in LabVIEW™. LabVIEW™ is a general-purpose data acquisition programming system. It is widely used in academic research and industry. We will also use LabVIEW™ to acquire data from other instruments throughout the year.



Using video to analyze motion is a two-step process. The first step is recording a video. This process uses the video software to record the images from the camera and compress the file. The second step is to analyze the video to get a kinematic description of the recorded motion.

(1) MAKING VIDEOS

After logging into the computer, open the video recording program by double clicking the icon on the desktop labeled *VideoRECORDER*. A window similar to the picture on the previous page should appear.

If the camera is working, you should see a "live" video image of whatever is in front of the camera. (See your instructor if your camera is not functioning and you are sure you turned it on.) By adjusting the lens on the video camera, you can alter both the magnification and the sharpness of the image until the picture quality is as good as possible.

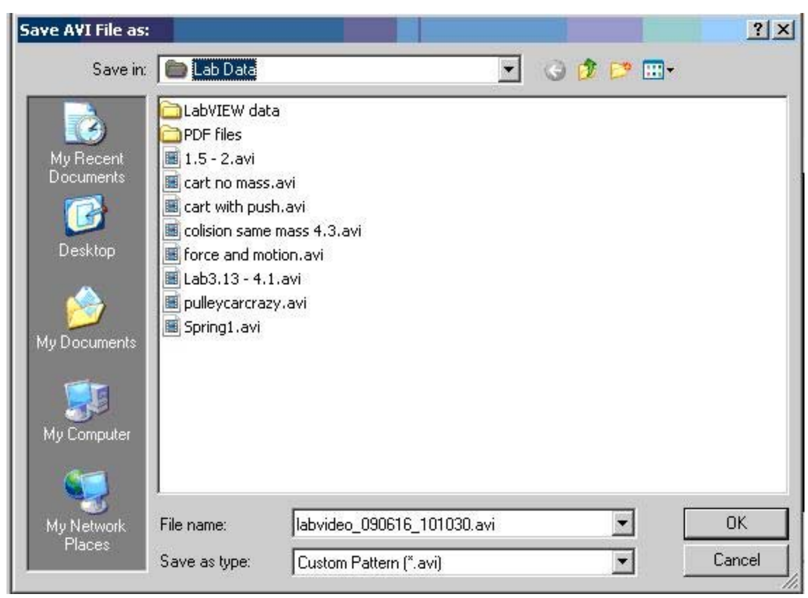
The controls are fairly self-explanatory; pressing the *Record Video* button begins the process of recording a 5-second video image. While the video is recording, the blue *Progress* bar beneath the video frame grows. Once you have finished recording, you can move through the video by dragging the *Frame Number* slider control. If you are not pleased with your video recording, delete it by pressing the *Dispose* button.

You may notice that the computer sometimes skips frames. You can identify the dropped frame by playing the video back frame by frame. If recorded motion does not appear smooth, or if the object skips irregularly, then frames are probably missing. If the computer is skipping frames, speak with your instructor.

While you are recording your video, you should try to estimate the kinematic variables you observe, such as the initial position, velocities, and acceleration. The time with the unit of second is shown in the *VideoRECORDER* window, in the box below the *Frame Number* slider. These values prove very useful for your prediction equations. Be sure to record your estimates in your journal.

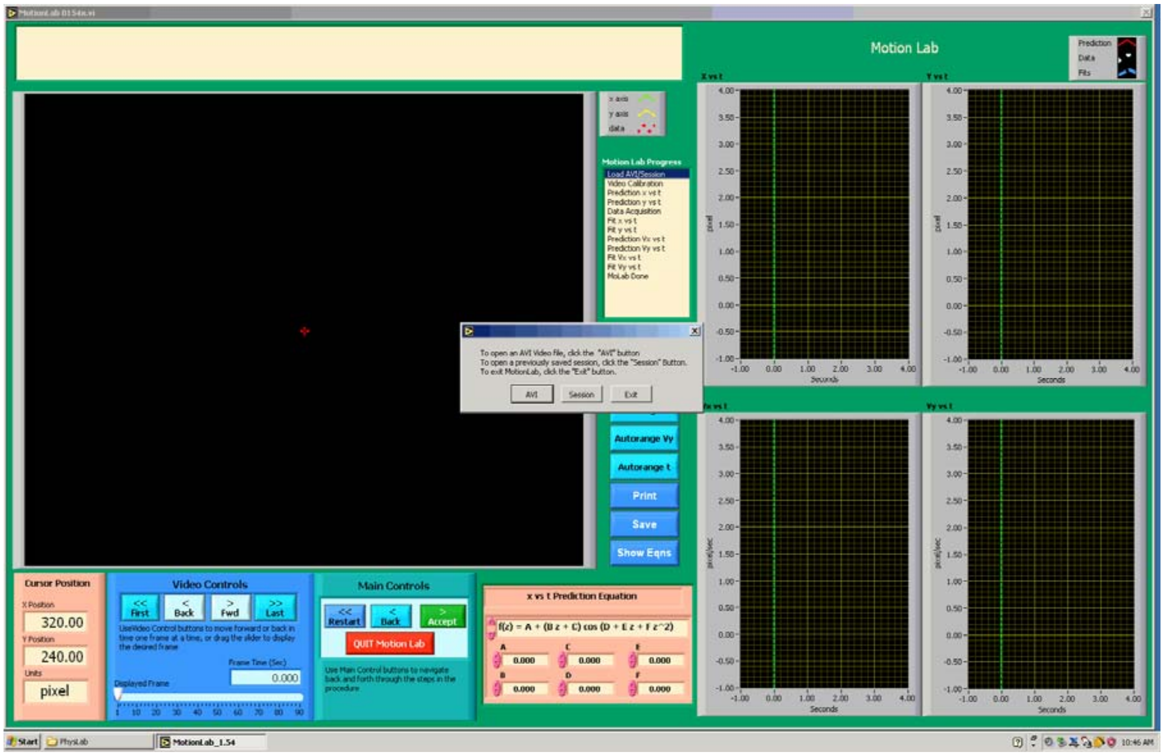
Once you have recorded a satisfactory video, save it by pressing the *Save Video* button. You will see a *Save* window, as shown on the next page.

To avoid cluttering the computer, you will only be able to save your video in the *Lab Data* folder located on the desktop. In the *File name* box, you should enter the location of the folder in which you wish to save your video followed by the name that you wish to give to your video. This name should be descriptive enough to be useful to you later.

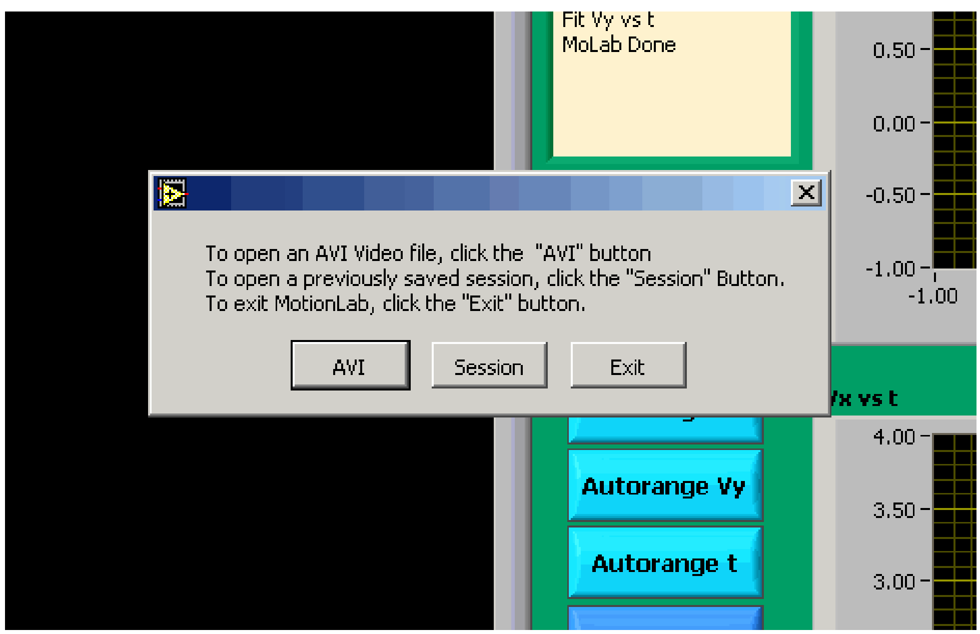


(2) Analysis Basics

Open the video analysis application by clicking the icon labeled *MotionLab* located in the PhysLab folder on the desktop. You should now take a moment to identify several elements of the program. As a whole the application looks complex, once it is broken down it is easy to use.

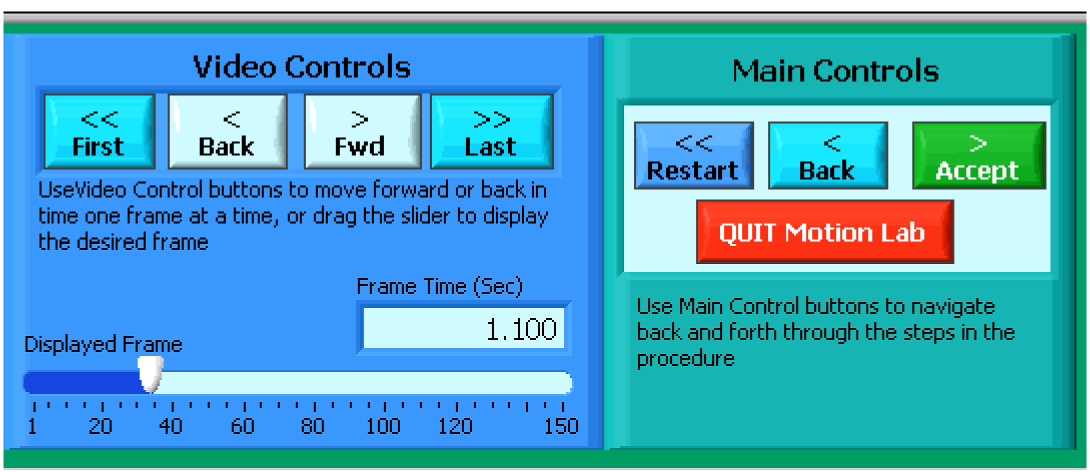


The application will prompt you to open a movie (or previously saved session) as shown below.

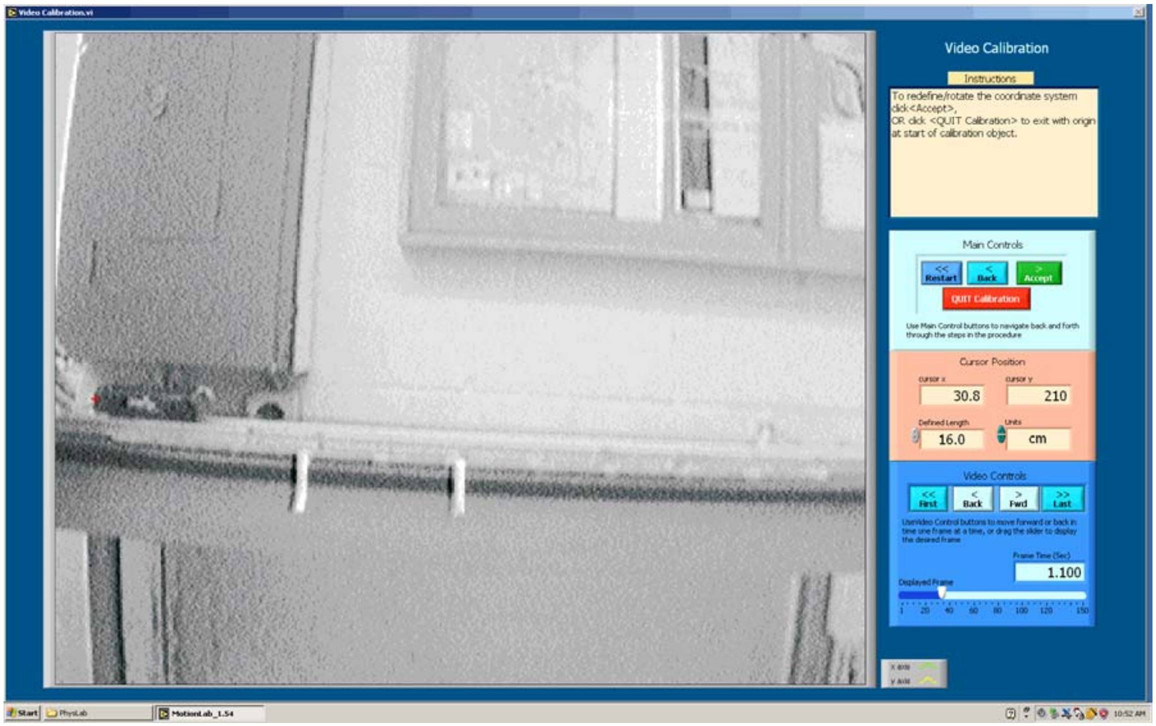


The upper left corner displays a dialog box with instructions for each step during your movie analysis. To the right of the video screen is a progress indicator. It will highlight which step you are currently performing.

Below the video display is the Video Controls for moving within your AVI movie. The slider bar indicating the displayed frame can also be used to move within the movie. Directly to the right of the Video Controls is the Main Controls. The Main Control box is your primary session control. Use the Main Control buttons to navigate back and forth through the steps shown in the progress box. The red Quit Motion Lab button closes the program.



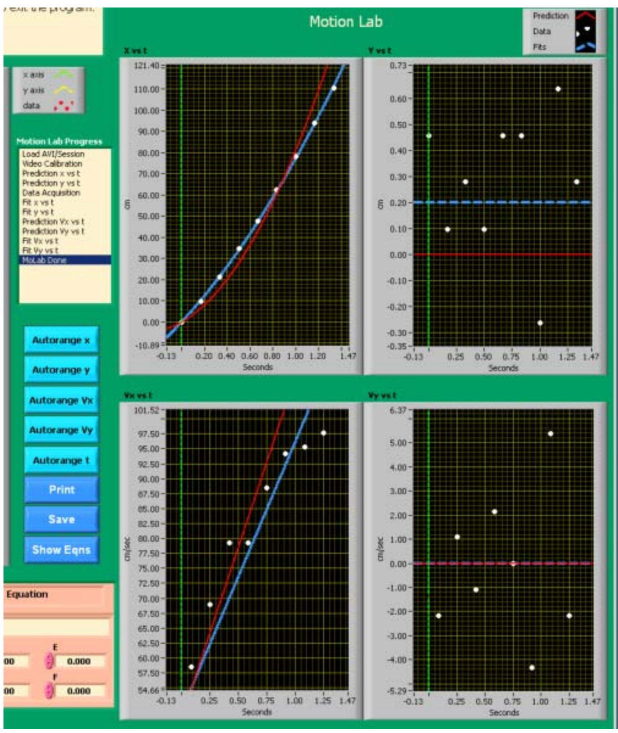
During the course of using MotionLab, bigger video screens pop up to allow you to calibrate your movie and take data as accurately as possible. The calibration screen is shown on the next page. The calibration screen has the instructions box to the right of the video with the Main Controls and Video Controls directly below. The calibration screen automatically opens once an AVI movie has been loaded.

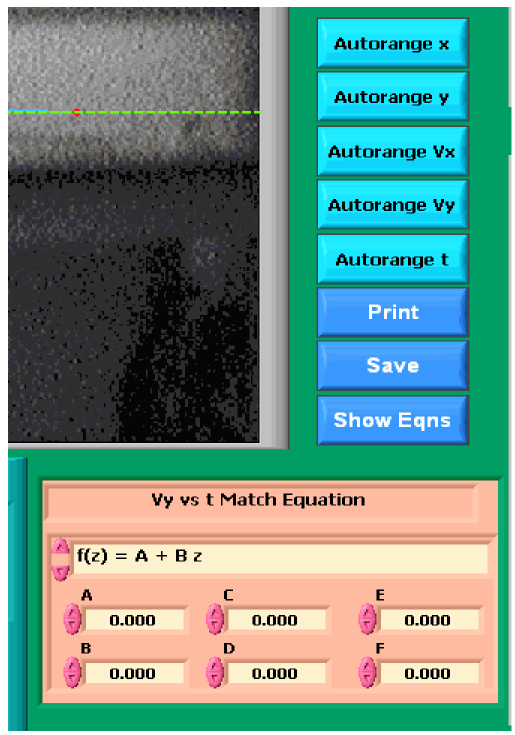


The data acquisition screen is shown below. To get to the data acquisition screen you need to first enter predictions (the progress indicator will display which step you are at.) More will be said about predictions in a bit. The data acquisition screen has the same instructions box and Video Controls, along with a Data Acquisition Control box. The Data Acquisition controls allow you to take and remove data points. The red Quit Data Acq button exits the data collection subroutine and returns to the main screen once your data has been collected. The red cursor will be moved around to take position data from each frame using your mouse.

Be careful not to quit without printing and saving your data! You will have to go back and analyze the data again if you fail to select *Print Results* before selecting *Quit*.

There are just a few more items to point out before getting into calibration, making predictions, taking data and matching your data in more detail. To the right the picture shows the equation box for entering predictions and matching data. Directly above this and below the progress indicator you have controls for setting the range of the graph data and controls for printing and saving. The graphs that display your collected data are shown on the next page. Your predictions are displayed with red lines, fits are displayed with blue lines.





CALIBRATION

While the computer is a very handy tool, it is not smart enough to identify objects or the sizes of those objects in the videos that you take and analyze. For this reason, you will need to enter this information into the computer. If you are not careful in the calibration process, your analysis will not make any sense.

After you open the video that you wish to analyze the calibration screen will open automatically. Advance the video to a frame where the first data point will be taken. The time stamp of this frame will be used as the initial time." To advance the video to where you want time t=0 to be, you need to use the video control buttons. This action is equivalent to starting a stopwatch.

Practice with each button until you are proficient with its use. When you are ready to continue with the calibration, locate the object you wish to use to calibrate the size of the video. The best object to use is the object whose motion you are analyzing, but sometimes this is not easy. If you cannot use the object whose motion you are analyzing, you must do your best to use an object that is in the plane of motion of your object being analyzed.

Follow the direction in the *Instructions* box and define the length of an object that you have measured for the computer. Once this is completed, input the scale length with proper units. Read the directions in the *Instructions* box carefully.

Lastly, decide if you want to rotate your coordinate axes. If you choose not to rotate the axes, the computer will use the first calibration point as the origin with positive x to the right and positive y up. If you choose to rotate your axis, follow the directions in the *Instructions* box carefully. Your chosen axes will appear on the screen once the process is complete. This option may also be used to reposition the origin of the coordinate system, should you require it.

Once you have completed this process, select Quit Calibration.

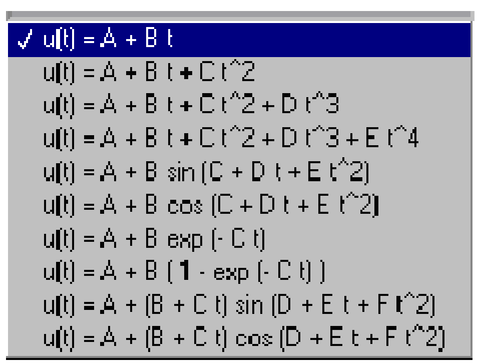
ANALYSIS PREDICTIONS

This video analysis relies on your graphical skills to interpret the data from the videos. Before doing your analysis, you should be familiar with both Appendix C: Graphing and Appendix B: Uncertainties.

Before analyzing the data, enter your prediction of how you expect the data to behave. This pattern of making predictions before obtaining results is the only reliable way to take data. How else can you know if something has gone wrong? This happens so often that it is given a name (Murphy's Law). It is also a good way to make sure you have learned something, but only if you stop to think about the discrepancies or similarities between your prediction and the results.

In order to enter your prediction into the computer, you first need to decide on your coordinate axes, origin, and scale (units) for your motion. Record these in your lab journal.

Next you will need to select the generic equation, u(t), which describes the graph you expect for the motion along your x-axis seen in your video. You must choose the appropriate function that matches the predicted curve. The analysis program is equipped with several equations, which are accessible using the pull-down menu on the equation line. The available equations are shown to the right.



You can change the equation to one you would like to use by clicking on the arrows to the left of the equation

After selecting your generic equation, you next need to enter your best approximation for the parameters A and B and C and D where you need them.

If you took good notes of these values during the filming of your video, inputting these values should be straightforward. You will also need to decide on the units for these constants at this time.

Once you are satisfied that the equation you selected for your motion and the values of the constants are correct, click "*Accept*" in the *Main Controls*. Your prediction equation will then show up on the graph on the computer screen. If you wish to change your prediction simply repeat the above procedure. Repeat this procedure for the Y direction.

DATA COLLECTION

To collect data, you first need to identify a very specific point on the object whose motion you are analyzing. Next move the cursor over this point and click the green *ADD Data Point* button in Data Acquisition control box. The computer records this position and time. The computer will automatically advance the video to the next frame leaving a mark on the point you have just selected. Then move the cursor back to the same place on the object and click *ADD Data Point* button again. So long as you always use the same point on the object, you will get reliable data from your analysis. This process is not always so easy especially if the object is moving rapidly. The data will automatically appear on the graph on your computer screen each time you accept a data point. If you don't see the data on the graph, you will need to change the scale of the axes. If you are satisfied with your data, choose *Quit Data Acq* from the *controls*

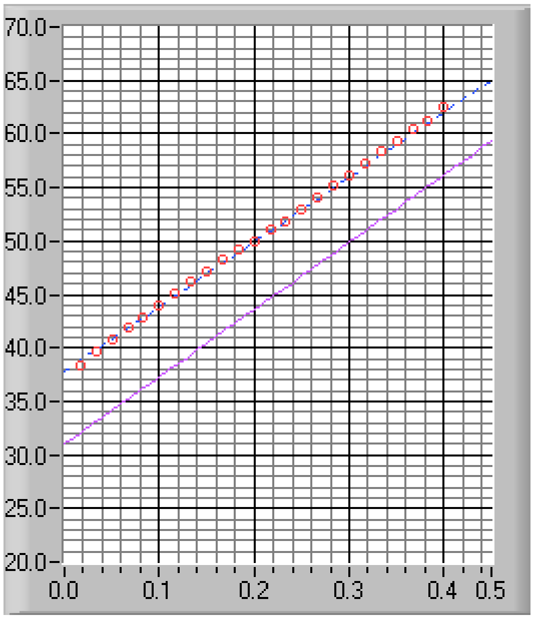
FITTING YOUR DATA

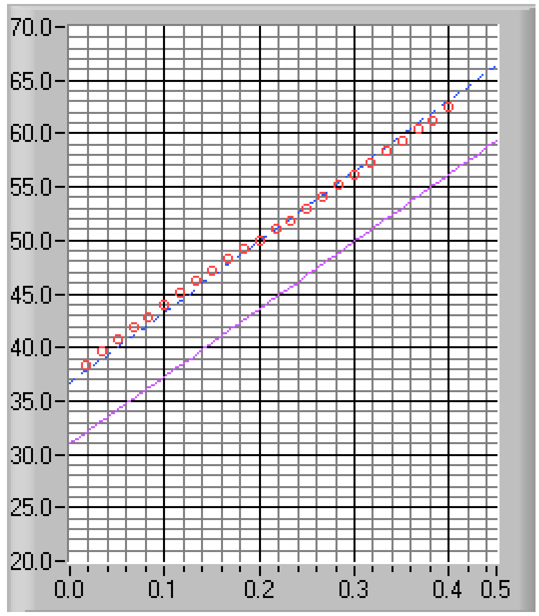
Deciding which equation best represents your data is the most important part of your data analysis. The actual mechanics of choosing the equation and constants is similar to what you did for your predictions.

First you must find your data on your graphs. Usually, you can find your full data set by using the Autorange buttons to the left of the graphs.

Secondly, after you find your data, you need to determine the best possible equation to describe this data. After you have decided on the appropriate equation, you need to determine the constants of this equation so that it best fits the data. Although this can be done by trial and error, it is much more efficient to think of how the behavior of the equation you have chosen depends on each parameter. Calculus can be a great help here.

Lastly, you need to estimate the uncertainty in your fit by deciding the range of other lines that *could* also fit your data. This method of estimating your uncertainty is described in Appendix C. Slightly changing the values for each constant in turn will allow you to do this quickly. For example, the X-motion plots below show both the predicted line (down) and two other lines that also fit the data (near the circles).





After you have found the uncertainties in your constants, return to your best-fit line and use it as your fit by selecting *Accept x- (or y-) fit* in the *Program Controls* panel.

LAST WORDS
These directions are not meant to be exhaustive. You will discover more features of the video analysis program as you use it. Be sure to record these features in your lab journal.

MAGNETLAB - MEASURING CONSTANT MAGNETIC FIELD

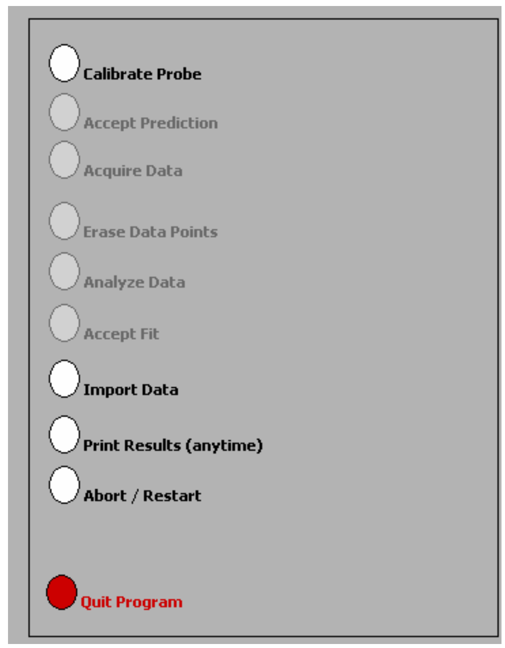
Application Basics

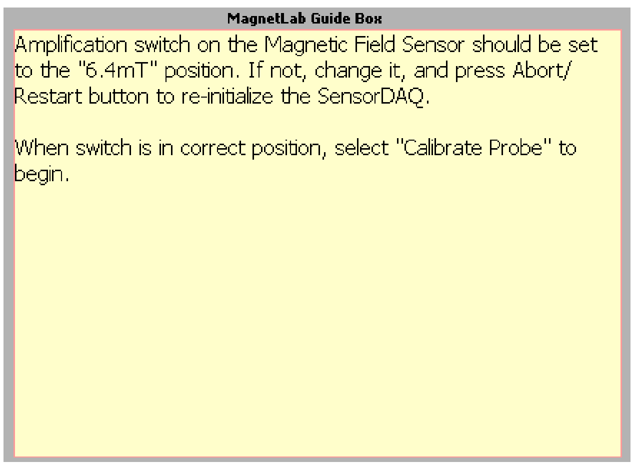
Before you begin, you should ensure that you have read the relevant sections of Appendix A to familiarize yourself with the equipment.

The software package that works in tandem with your magnetic field sensor is written in LabVIEW™. It allows you to measure and record magnetic field strength as a function of a number of different variables.

After logging into the computer, execute the application by double clicking the "MAGNETLAB" icon located in the PhysLab folder on the desktop.

Before you start using the program, you should take a moment to identify several key elements. The two most important of these are the Command Panel, shown to the right, and the Guide Box, shown below.





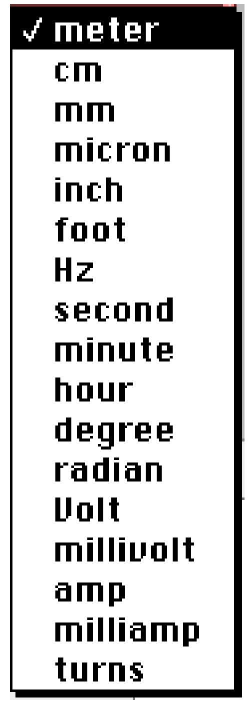
The Guide Box will give you directions and tasks to perform. It will also tell you when to select a command in the Command Panel. After selecting a command, it will "gray out" and the next command will become available.

You can also print and/or quit from the Command Panel or abort your analysis and try again.

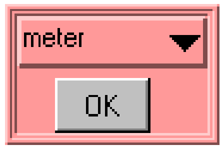
The primary data output you get is by generating pdf files of your results, so be careful not to quit without printing pdf files or exporting your data to be emailed amongst your lab group.

Calibration

The first command is to calibrate the Magnetic Field Sensor. Before selecting this command, you need to set the probe to the 6.4mT setting.

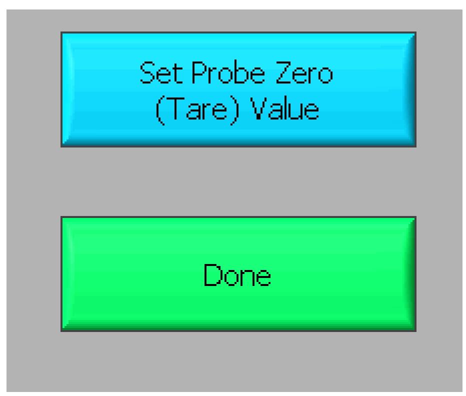


After selecting the "Calibrate Probe" command, you will be asked to do *two* tasks. Firstly, you will need to choose the quantity on the x-axis of your data graph. This is accomplished by moving the mouse cursor over to the word "meter" in the red-colored area (shown below) and then pressing the mouse button.



You should get a list of choices as shown to the right. By selecting any of these units, you will be making a choice about what you wish to measure. For example, if you choose to use "cm", you will make a graph of magnetic field strength as a function of distance (B vs. x). It is likely you will want to choose a small unit (cm's or mm's) to measure the distance in, since many magnetic fields are not very strong over long distances Selecting "degree" will make a plot of magnetic field strength as a function of angle (B vs. θ). Click "OK" when you are ready to proceed.

Secondly, you will need to eliminate the effect of the background magnetic fields. This process is called "zeroing the Hall probe" in the Guide Box. **Place the magnetic field sensor wand in the position you would like to take your measurement, but be sure that there are no magnets nearby.** Note that power supplies and computers generate magnetic fields, so it is a good idea to keep away from them! When you are ready, select the "Set Probe Zero" as shown below.



Then select the "Done" button. The calibration process is now complete.

Predictions

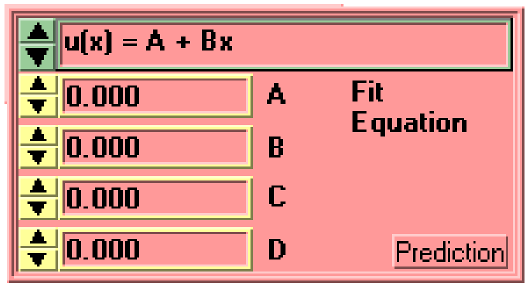
This type of analysis relies on your graphical skills to interpret the data. You should be familiar with both Appendix D: *Graphing,* and Appendix C: *Uncertainties.*

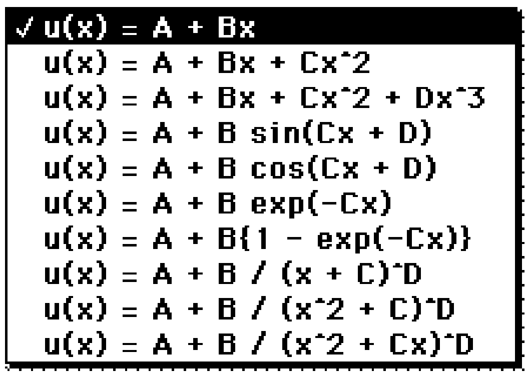
The first task is to enter your prediction of the mathematical function you expect to represent your data. Making a prediction before taking data is the best way to determine if anything is going wrong (remember Murphy's Law). It's also a good way to make sure you have learned something, but only if you stop to think about the discrepancies or similarities between your prediction and the results.

In order to enter your graphical prediction, you first need to decide on your coordinate axes and scale (units) for your measurements. *Record these in your lab journal*.

Next, you will need to select the generic equation, u(x), which describes the graph you expect for the data. Clicking the equation currently showing in the box will bring up a list of equations to choose from; see the diagrams to the right.

After selecting your generic equation, you next need to enter your best approximation for the parameters A, B, C, and/or D. These values should come directly from your prediction equation you did for class. As you enter these values, you should see the red line in the "Plot" box changing.





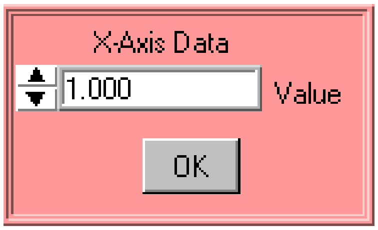
Once you have selected an equation and the values of the constants are entered, your prediction equation is shown on the graph on the computer screen. If you do not see the curve representing your prediction, change the scale of the graph axes or use the *AutoScale* feature (see Finding Data below). When you are satisfied, select the *Accept Prediction* option from the Command Panel. Once you have done this you cannot change your prediction except by starting over.

Exploration

After you have entered your prediction, you can explore the limitations of your magnetic field sensor before you take data. The value of the magnetic field strength is displayed directly under the Guide Box. When you are ready to take data, select *Acquire Data* from the Command Panel.

Data Acquisition

Collecting data requires that you enter the x-axis data each time the computer reads in a value for the magnetic field strength. You enter this data using the panel shown. For every x-axis data value you enter, the analysis program will record the magnetic field strength in gauss on the y-axis of the "Plot". Press "OK" to collect the next data point. Each data point should appear on the graph on the computer screen as you take it. If it doesn't, adjust the scales of your graph axes or use the *AutoScale* feature (see Finding Data below). If you are satisfied with your data, choose *Analyze Data* from the Command Panel.



Finding Data on the Graph

You can find your data on the graph by adjusting the scales of your X-axis and Y-axis plots manually. This scaling is accomplished by entering values into the legend of the graph. Click on the upper or lower legend value and enter a new value, then hit enter. If you cannot locate your data, you can select both "AutoScale Y-axis" and "AutoScale X-Axis" to let the program find the data for you. You can then adjust your axis scales to give you a convenient graph for analysis. Be careful, the AutoScale option will often set the scales in such a way that small fluctuations in the data are magnified into huge fluctuations.

Data Fits

Deciding which equation best fits your data is the most important part of using this analysis program. While the actual mechanics of choosing the equation and parameters is similar to what you did for your predictions, fitting data is somewhat more complicated.

By looking at the behavior of the data on the graph, determine the best possible function to describe this data. After you have decided on the appropriate equation, you need to determine the constants of this equation so that it best fits the data. Although this can be done by trial and error, it is much more efficient to think of how the behavior of the equation you have chosen depends on each parameter. Calculus can be a great help here. *This can be a time-consuming task, so be patient.*

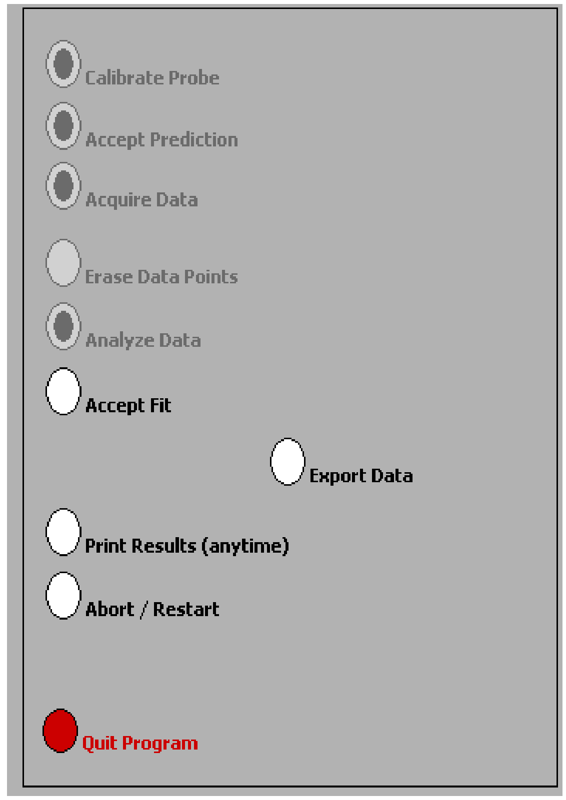
Now you need to estimate the uncertainty in your fit by deciding the range of other lines that *could* also fit your data. This method of estimating your uncertainty is described in Appendix D. Slightly changing the values for each constant in turn will allow you to do this quickly.

After you have computed your uncertainties, return to your best-fit line and use it as your fit by selecting *Accept Fit* in the Command Panel.

Importing / Exporting Data

After you have selected *Analyze Data*, it is possible to save your data to the computer's hard drive. This feature can come in handy if you need to analyze your data at a later date or if you want to re-analyze your data after you have printed it out.

To save your data, simply select *Export Data* (as shown to the right) and follow the instructions in the windows. Your file should be saved in the **LabData** folder. To retrieve this file, restart *MagnetLab* from the desktop and select *Import Data.*



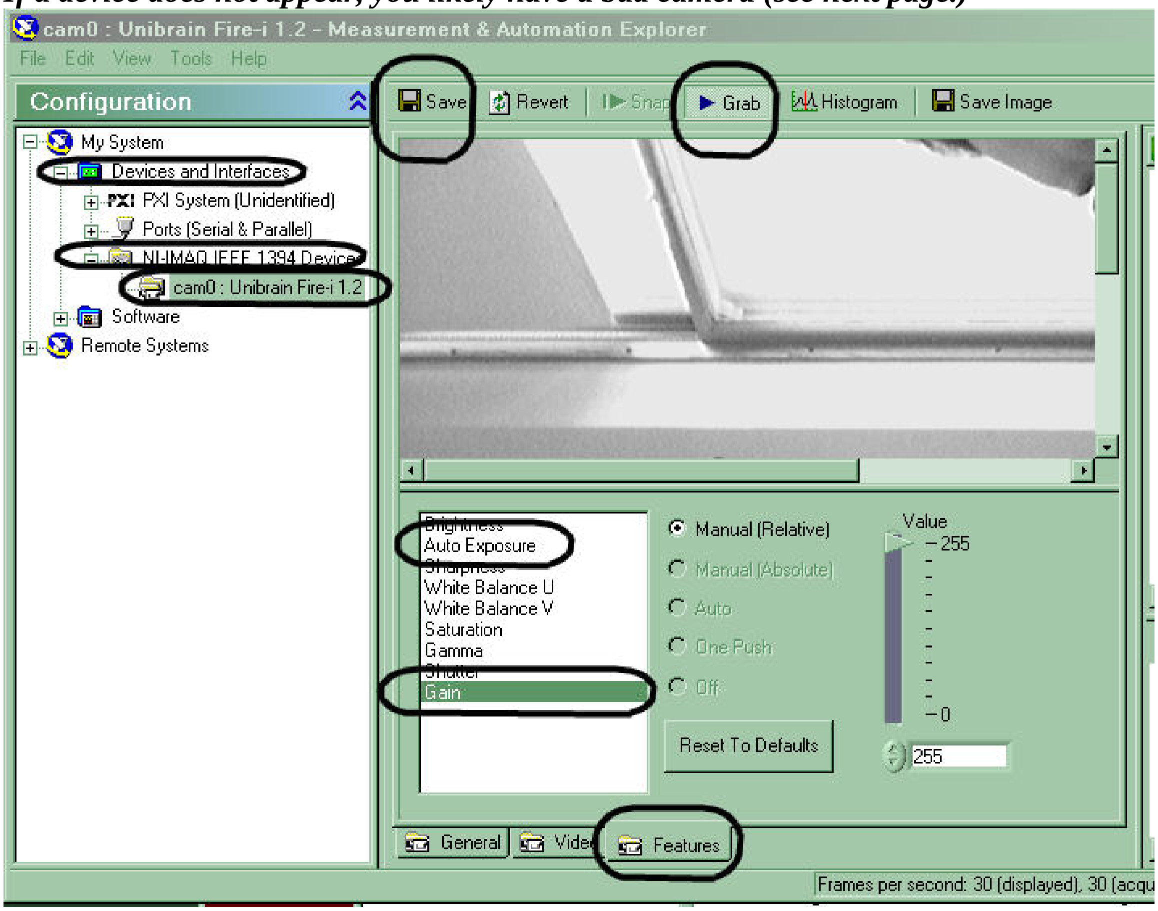
Last Words

These directions are not meant to be exhaustive. You will discover more features as you analyze more data. Be sure to record these features in your lab journal.

To install a camera:

1. Hook up new camera to firewire cable.
2. Launch the <u>“Measurement & Automation</u>” application (icon on desktop)
3. On the left-hand panel *(shown below)*, expand <u>“Devices and Interfaces”</u>
4. On the same panel, expand <u>“NI-IMAQ IEEE 1394 Devices”</u>

MAX has a generic camera setup initially; this needs to be switched to the Unibrain camera by right clicking on the device and selecting the NI-IMAQ driver using the menu. ***If a device does not appear, you likely have a bad camera (see next page.)***



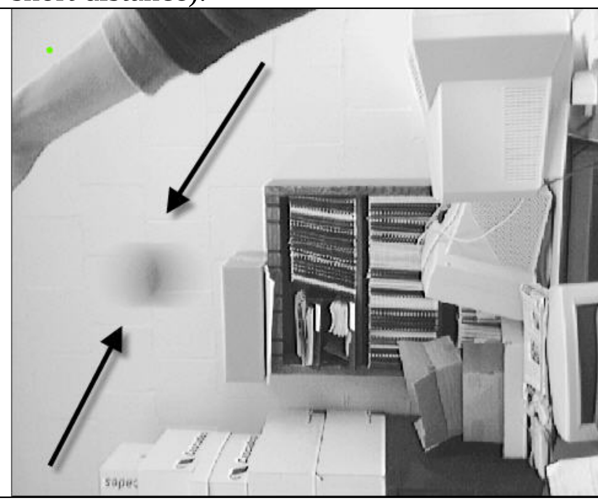
5. On the same panel, click the icon for the camera <u>(“Unibrain cam0:…”)</u>
6. Click <u>GRAB</u> *(along the top, shown above)* to see what the camera sees
7. Click the <u>Video</u> tab (*along the bottom, next to the circled features tab*)
8. Change Video Mode by selecting the last option in the pull down menu (640x480 Y (Mono8)(30fps))

To help your students get useful data from the video camera, it may be necessary for you to adjust additional camera settings. (These settings should be stable, but may change when a camera is unplugged from its computer.)

9. Click the <u>FEATURES</u> tab (*along the bottom, shown above*)

In the picture below, “gain” is selected, and is set to its maximum value of 255.

10. **Set <u>GAIN</u> to its MAXimum value (this may cause a “washed-out” image).**
11. **Set <u>AUTO EXPOSURE</u> to the MINimum value that shows a useful image (depending on camera and lighting, 180 or below may be possible).**
12. Click <u>SAVE</u> (*top left*) to save the settings.
13. <u>Exit</u> the “Measurement & Automation” application.

"Good" camera settings • short Exposure time • high amplification (Gain) Motionless objects may look grainy; objects in motion have well-defined edges (The ball below has fallen through the entire frame).	**"Bad" camera settings (factory default)** • long Exposure time • low amplification (Gain) Motionless objects look nice; motion causes blur (The blurred ball below has fallen only a short distance).
	

To check to see if a camera is bad:

1. Hook up camera to firewire cable.
2. Launch the "Measurement & Automation" application (icon on desktop)
3. On the left-hand panel, expand "Devices and Interfaces"
4. On the same panel, expand "NI-IMAQ IEEE 1394 Devices"

If a device (camera) does not appear, you have a bad camera, cable or firewire card. Check the cable, making sure the connectors are intact and not plugged by debris. Look at the firewire card in the back of the computer - try to use the port that looks best. If the camera still does not work, get a new camera and start over. If the new camera doesn't work, reboot the computer and try again, possibly with a third camera. You can also use the TA computer and see if the camera will work on that machine. Remember to submit an electronic lab problem report form about any unresolved problems and bad cameras.