Laboratory manual and Course Supplement

For

PH SC 108: Introduction to Physical Sciences

For Elementary, Early Childhood, and Special Education Majors

By

Dr. L. B. Krause, Clemson University

And

Mrs. Louisa Jane Fleming, Liberty High School

Fall Semester 2000 edition

Based on the original 1994 laboratory manual developed by Rick White and Renee Potts through a grant from the South Carolina Commission on Higher Education.

http://www.ces.clemson.edu/webct/admin_access_student.html
Use your regular Clemson login ID for both login and password. Then change your password to your regular CU password. Bookmark your MyWebCT page.
In this book you will find some relevant materials in your introductory physical science courses. Use it for reference for the lecture course and for lab. This edition is a DRAFT and I am sure there are errors in it. As with anything you read, read it critically, and any errors you find should be pointed out to your TA. There is a copy of this lab manual in a large binder in the lab (Brackett 424) in which you should note errors you find and changes you recommend.

Computers in Lab 424

We now have 4 iMac computers in lab. They are for your use when you are in lab, but are not available generally since the lab is locked except when a lab class is meeting. The iMacs have Microsoft Office programs and are able to read disks that originate on a PC machine. Your PC or a PC in a campus lab may not be able to read a disk that originates on a Macintosh computer.

You will use Excel for all of your graphs and data tables in PH SC lab. You will use Word to write your lab reports. It is acceptable to use other programs that you may have on your own computer to do these things, but your lab reports MUST be computer generated. Hand written reports and graphs will not be accepted.

These computers have been hooked up to the campus ISDN line which allows connection to the Internet. You will use the Internet to find material safety data sheets which you will include or reference in all labs that use chemicals.

The computers are equipped with two external drives. One drive is for 3.5" and superdisk floppies, and the other is a 100MB Zip drive. You are required to have a diskette (of either type) for your use. You will save any graphs or reports you do in lab onto your own diskette, rather than to the hard drive of the PH SC computer. Only one of these external drives can be connected to the computer at one time. If the one you need is not connected, unplug the other and plug in what you need. You do not need to restart the computer when you change drives.

If the computers "lock up" or do not work correctly, try quitting the application you are working on, and restarting it. Do NOT attempt to print a document again if it doesn't print the first time. It's already in the printing queue! Open the print monitor and trash documents you no longer want to print. You can "force quit" an application by pressing "option-command-Q" Restart the computer. If all else fails, you can turn off the power strip on the underside of the table, count to 10 or so, and turn it back on, then restart the computer. Most troubles with a Mac will fix themselves that way.

WebCT site:

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PH SC 108 Introduction to Physical Science

Professor: Dr. L. B. Krause
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656-7653
Email: krause@clemson.edu
Email @ home: breurkrause@earthlink.net

I do a lot of communication via email. Please check your email daily. If you use an address other than your Clemson student address, forward your campus email to the address you use. If you don’t know how to do that, see me.

‘official’ office hours: MWF 10:00-11:00 I will be found in my office at most times, M-F, from ~8:00 to ~4:00.
Anytime you find me is fair game for any questions, concerns, burning issues you may want to talk about. You may also email me and I will try to answer promptly.

Class meets: 220 Brackett Hall
Fall semester:
Section 1: 12:20-1:10 MWF
Section 2: 1:25-2:15 MWF

Spring Semester:
Section 1: 1:25-2:15 MWF

Second Summer: Class meets Brackett 322, 11:30-1:00, MtuWThF

Texts: required:
Chang, Raymond, Essential Chemistry, McGraw Hill

Additional texts and materials recommended:
A good dictionary
A calculator with a minimum of 4 functions, plus scientific notation, square and square root, log and ln.

Waiting policy: If I am more than 15 minutes late you may leave without penalty, unless the class has been instructed otherwise for some event.

Course web site: We will be using a WebCT web site for each of PH SC 107 and 108. The web site will have a course calendar of events, due dates of assignments, our syllabus, assignments, quizzes, projects, and many other things. Please check it frequently. Your grades will be posted periodically on the web site where only you will be able to see it. Lab grades will be included at the end of the semester only.

Study Group: You will be required to be part of a study group for this course. You are to form your own group, of not less than 3, nor more than 5 people. You should try to make your group of class members who are in the same lecture and lab sections you are in. This group will be responsible formally for graded group work and informally for interpersonal support of one another.

Language: Spelling, grammar and punctuation will “count” on every assignment you turn in to me or to your TA. Use a dictionary, English language handbook or reference as necessary, and a spell check on the computer on every assignment you do. If in doubt, look it up.

Mathematics: This course will require you to perform some mathematical calculations through simple algebra.

Quizzes: we will have several quizzes, some of which will be given online, in our WebCT web site. Although you will be permitted to use texts and notes for on line tests and quizzes, you are to do individual work. Getting

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help from or comparing answers with another student is cheating.

Tests: In the past all tests and exams have been given on line, and I expect to do the same this semester. Tests will not be cooperative, and no cheating in any form will be tolerated or condoned. Cheating will result in a zero on the test and possibly an F in the course, regardless of other grades. The computer does track your time on line, among other things, and evidence of cooperation on tests will result in a zero with the remaining tests and exams to be given in class, timed and supervised.

Grades:
midterm & final exam (20/20) 40%
Quizzes, Class work & Homework 25%
Project 10%
Lab 25%

Attendance Policy: Attendance in class is necessary to success in this and every course. If you must miss a class, it is your responsibility to get the notes from another student and to make up any work missed. Attendance will be taken in class, and more than 4 absences may lead to your being dropped from the course. This is NOT to be interpreted as allowed cuts. There are NO allowed cuts. Coming late to class or leaving early is inappropriate and distracting to your classmates and professor and should be avoided if at all possible.

Goals and objectives:
This two-semester sequence is intended to provide a basic level of competence in physical sciences, with enough understanding to interpret events in the world around you and in the news. Primarily for pre-service teachers, the emphasis is on understanding the material at a level that will allow you to teach it accurately and effectively to your future students.

If you have a difficulty with any of the policies outlined here, or any other aspect of the course, please see me. If you require special accommodation for any reason, please see me at your earliest opportunity.

Schedule of Topics and tests, Subject to change:

<table>
<thead>
<tr>
<th>Intro, administrivia, important stuff.</th>
<th>Expect a pretest</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chang</strong>: (Chapter.section )1.2-1.5 Earth, Wind, Fire and Water</td>
<td></td>
</tr>
<tr>
<td>2.1-2.7 Learning the language (atomic structure)</td>
<td></td>
</tr>
<tr>
<td>3.1-3.3,3.5, 3.7-3.9 Baking Cookies (stoichiometry)</td>
<td></td>
</tr>
<tr>
<td>4.1-6 Time to Party! (reactions)</td>
<td></td>
</tr>
<tr>
<td>5.1-5.6 It's a gas! (gas laws)</td>
<td></td>
</tr>
<tr>
<td>6.1-6.6 Hot stuff! (thermodynamics)</td>
<td></td>
</tr>
<tr>
<td>7.7-7.10,-8.1-8.3, 9.1-9.5 (don't panic!)</td>
<td></td>
</tr>
<tr>
<td>11.1-11.7 Let the force be with you.</td>
<td></td>
</tr>
<tr>
<td>12.1-12.6 concentrate!</td>
<td></td>
</tr>
<tr>
<td>Ch. 13, 14, 22 Organics, polymers, and nuclear.</td>
<td>Midterm = Chemistry Final</td>
</tr>
</tbody>
</table>

**Physics**: Ch. 1 Motion

| 2. Newton's laws, toys and rides | |
| 3. Energy and Conservation | |
| 4. Matter,5. Temperature and Heat | |
| 6. Waves and Sound, 7,8: Electricity & magnetism | |
| 9-12: Optics-Relativity | Issues Projects due |

Physics and Cumulative Final Exam

There is, in reality, no way we will be able to get through everything in the syllabus. We will do as much as we can.

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Lecture Notes and Reference Materials
Chang: 1.2-1.7

1) Classification of matter
   a) Definition of matter
   b) Chemistry- study of matter and changes it undergoes
   c) Solid, liquid and gas
   d) Substances
      i) Definite or constant composition
      ii) distinct properties
      iii) water, silver, ethanol, salt, carbon dioxide
   e) Mixtures
      i) combination of 2 or more substances which retain their distinct identities
      ii) created and separated by physical means
      iii) heterogeneous
         (a) salt and sand
         (b) composition is not uniform
      iv) homogeneous
         (a) uniform composition
         (b) sweet tea- solution
   f) Elements
      i) cannot be divided into simpler substances by chemical means (so far 118)
         (a) 83 are naturally occurring on earth
   g) Compounds
      i) two or more elements chemically combined in fixed proportions

2) Physical and chemical properties of matter
   a) Physical properties- can be measured and observed without changing the composition or identity of the substance.
   b) Chemical properties- can be observed by carrying out a chemical change
   c) Physical change
   d) Chemical change
   e) Intensive properties- do not depend on how much of the substance
   f) Extensive properties- depends on or describes how much of the substance

3) Mass and weight (Chang 1.4)
4) Volume
5) Density
6) Temperature
   a) Celsius, Fahrenheit and Kelvin
      i) Translations
7) Scientific notation (Chang 1.5)
   a) Addition and subtraction
   b) Multiplication and division
8) Significant figures (Chang pg 15)
9) Accuracy and Precision
1) Atomic structure: mass, location, charge
   a) Protons
   b) Neutrons
   c) Electrons
   d) Atomic number
   e) Mass number- atomic mass
   f) ions
   g) Isotopes
   h) Charge
   i) radioactivity

2) Periodic Table

3) Molecules
   a) Ionic compounds
   b) Molecular compounds
   c) Formulas
      i) Molecular formulae
      ii) Empirical formulae
      iii) Structural formulae
   d) Naming compounds
   e) Acids and bases

Chang 3

1) Stoichiometry
   a) Avagadro's number
   b) Moles
   c) Formula mass
   d) Percent composition
   e) Chemical equations
      i) Notation of physical state
      ii) Balancing equations
   f) Chemical reactions

2) Amounts of reactants and products
   a) Ladders
   b) Limiting reagents
   c) Theoretical and percent yield
Chang 4
3) Properties of aqueous solutions 
   a) Solution 
   b) Solute 
   c) Solvent
4) Electrolytes /non electrolytes 
   a) Pure water does not conduct. Most water is far from pure. 
   b) Ionic compounds are electrolytes 
      i) Conduct electricity 
   c) Molecular compounds are non electrolytes

<table>
<thead>
<tr>
<th>Strong electrolytes</th>
<th>Weak electrolytes</th>
<th>Non electrolytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>CH₃COOH</td>
<td>(NH₃)₂CO -urea</td>
</tr>
<tr>
<td>HNO₃</td>
<td>HF</td>
<td>CH₃H -methanol</td>
</tr>
<tr>
<td>HClO₄</td>
<td>HNO₂</td>
<td>C₂H₅OH -ethanol</td>
</tr>
<tr>
<td>H₂SO₄</td>
<td>NH₃</td>
<td>C₆H₁₂O₆ glucose</td>
</tr>
<tr>
<td>NaOH</td>
<td>H₂O</td>
<td>C₁₂H₂₂O₁₁ sucrose</td>
</tr>
<tr>
<td>Ba(OH)₂</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ionic compounds

5) Polar vs. non polar solvents 
   a) Hydration
6) Acids and Bases (pg 90) 
   a) Strong acid, (almost) all H⁺ ionizes, ionize completely 
   b) Weak acids ionize poorly, reach equilibrium
7) Precipitation reaction 
   a) Solubility: maximum amount of solute that will dissolve in a given quantity of solvent at a specific temperature. 
      i) Soluble 
      ii) Slightly soluble 
      iii) Insoluble 
   b) Rules on page 91
   c) Insoluble compound precipitates 
   d) If a reaction in solution has all soluble compounds, it does not occur. 
   e) If a reaction has an insoluble product, or a non electrolyte product, it will occur.

8) Molecular vs. ionic equations
9) Acid Base reactions 
   a) Neutralization 
   b) Acids: sour, litmus turns red, produces H₂ with Zn, Mg, or Fe, react with carbonates to produce CO₂, aqueous solutions conduct electricity. 
   c) Bases: bitter taste, slippery feel, litmus turns blue, aq. Sol'ns conduct electricity.
10) Oxidation-reduction reactions 
   a) Reducing agent: donates electrons 
   b) oxidizing agent: accepts electrons 
   c) oxidation numbers: counts gains and losses of electrons
11) Activity Series for metals :chart, pg. 103
12) Concentration and dilution of solutions. 
   a) Molarity: moles of solution/liter of solution (ladder calculation)
Chang 5

1) Characteristics of a gas
2) Gas Laws
   f) Standard temperature and pressure: zero degrees Celsius, 1 atmosphere.
   g) 1 torr = 1 mm Hg. 760 torr = 760 m Hg = 1 atm.
   h) Boyle's Law
      \[ P_1 V_1 = P_2 V_2 \]
   i) Charles' law
      \[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \]
   j) Avagadro's law
      \[ V \propto n : 1 \text{ mole of any gas occupies a volume of } 22.4141 \text{ liters at STP} \]
   k) Ideal Gas law
      \[ PV = nRT \]
   l) Dalton's law of partial pressures
      \[ P = P_A P_B \]
   m) mole fractions
   n) Kinetic Molecular Theory

Chang 6

1) Energy in chemical Reactions: thermochemistry
   a) Radiant, thermal, chemical
   b) System & Surroundings
   c) Heat vs. temperature
2) Calorimetry
   a) Endothermic and exothermic reactions
   b) "Delta Q" calculations
3) enthalpy / entropy
4) First law of thermodynamics
   a) Energy can be converted from one form to another but cannot be created or destroyed.

Chang 7

1) Atomic structure
   a) Spdf: electron orbital notation (7.8)

Chang 8

1) Periodic characteristics of the elements

Chang 9

1) Covalent bonds
2) Electron dot notation

Chang 13, 14, 22: Organic, Polymer and Nuclear chemistry.
Chemical Equations

\[ \text{Al}_2\text{O}_3 \ (s) + \text{NaOH} \ (aq) + \text{H}_2\text{O} \ (l) \rightleftharpoons \text{NaAl(OH)}_4 \ (aq) \]

\[ \text{N}_2\text{O}_5 \ (g) + \text{H}_2\text{O} \ (l) \rightleftharpoons \text{HNO}_3 \ (aq) \]

\[ \text{P}_4\text{O}_{10} \ (s) + \text{H}_2\text{O} \ (l) \rightleftharpoons \text{H}_3\text{PO}_4 \ (aq) \]

\[ \text{NaH} \ (s) + \text{H}_2\text{O} \ (l) \rightleftharpoons \text{NaOH} \ (aq) + \text{H}_2 \ (g) \]

\[ \text{KClO}_3 \ (s) \rightleftharpoons \text{KCl} \ (s) + \text{O}_2 \ (g) \]

\[ \text{Cu} \ (s) + \text{AgNO}_3 \ (aq) \rightleftharpoons \text{Cu(NO}_3)_2 \ (aq) + \text{Ag} \ (s) \]

\[ \text{Zn} \ (s) + \text{CuSO}_4 \ (aq) \rightleftharpoons \text{ZnSO}_4 \ (aq) + \text{Cu} \ (s) \]

\[ \text{HCl} \ (aq) + \text{Mg} \ (s) \rightleftharpoons \text{MgCl}_2 \ (aq) + \text{H}_2 \ (g) \]

\[ \text{HCl} \ (aq) + \text{CaCO}_3 \ (s) \rightleftharpoons \text{CaCl}_2 \ (aq) + \text{H}_2\text{O} \ (l) + \text{CO}_2 \ (g) \]

\[ \text{K}_3\text{PO}_4 \ (s) + \text{Ca(NO}_3)_2 \ (aq) \rightleftharpoons \text{KNO}_3 \ (aq) + \text{Ca}_3(\text{PO}_4)_2 \ (s) \]
Which is most dense, gold, sand, or Indiana Jones?

Work in your study group to answer these questions.

1. Mass is (definition):

2. Mass is measured in (SI units):

3. Volume is (definition):

4. Volume is measured in (units):

5. Density is (definition):

6. Density is measured in (units):

7. The equation for calculating density is: \( D = \)

8. By rearrangement, determine the equations for calculating mass and volume:

   \[ M = \]

   \[ V = \]

9. Gold has a density of 19.3 g/mL. The statue appears to have a volume of about 1.5 L. What is its mass? Show your work.

10. The density of dry sand is 1.6 g/mL. If the volume of sand that Indy put on the pedestal to replace the statue is also 1.5 L, what is the mass of the sand? Show your work.

11. How many bags of sand would it take to equal the mass of the gold statue and keep Indy safe? Show your work.

12. How many pounds of sand would that be? (You may use the conversion table inside the front cover of your textbook.) Show your work.
Insert ladders page in place of this page.
Average speed or velocity = distance / time
\[ \bar{v} = \frac{d}{t} \]

Average acceleration = change in velocity / time
\[ \bar{a} = \frac{v_f - v_i}{t} \]

Average velocity = (final velocity + initial velocity) / 2
\[ \bar{v} = \frac{v_f + v_i}{2} \]

Distance = 1/2 (average acceleration)(time)²
\[ d = \frac{1}{2} \bar{a}t^2 \]

For free fall
\[ d = \frac{1}{2} gt^2 \]

Force
\[ F = ma \]

Weight
\[ w = mg \]

Momentum
\[ p = mv \]

Centripetal acceleration
\[ a_c = \frac{v^2}{r} \]

Centrifugal Force
\[ F = \frac{mv^2}{r} \]

Gravitational force
\[ F = G\frac{m_1 m_2}{d^2} \]

Constants:
Gravitational constant: \[ G=6.672\,59 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \]
Speed of light in a vacuum: \[ c= 2.997 \, 924 \, 58 \times 10^8 \text{ m/s} \]
Acceleration due to gravity (on earth): \[ g= 9.806 \, 65 \text{ m/s}^2 \]
PH SC 108
Introduction to Physical Science
Laboratory Syllabus

My TA: ______________________________
TA's office hours: ____________________

All PH SC Lab sections meet in 424 Brackett Hall

Texts: required:
• PH SC L-108 Lab Manual. Should be supplied on 3 hole-punched pages, which you are to keep in a ring binder and bring to every lab. You will also add regular notebook paper to the binder for your lab notes and work.
• Lab goggles, OSHA approved style, with full side protection.
• A calculator with a minimum of 4 functions, plus scientific notation, square and square root, log and ln

Waiting policy: If your instructor is more than 10 minutes late you may leave without penalty, unless the class has been instructed otherwise for some event.

Language: Spelling, grammar and punctuation will “count” on every assignment you turn in to your TA. Use a dictionary, English language handbook or reference as necessary, and a spell check on the computer on every assignment you do. If in doubt, look it up. All papers handed in must be computer generated. Hand written assignments will not be accepted, except completed lab manual pages.

Mathematics: This course will require you to perform some mathematical calculations through simple algebra.

Grades:
Lab Reports  40%
Notebook       35%
Participation and Technique 10%
Peer Evaluation     5%
Attendance            10%

Attendance Policy: Attendance in lab is just as necessary as attendance in lecture. If you miss a lab it is your responsibility to make up the work you missed at the TA's discretion and direction. You may be permitted to attend another lab section to do this. Attendance will be taken in lab and missed labs, late arrival or early escape will affect your grade.

Goals and objectives:
The lab portion of the course sequence is intended to develop competence in techniques and handling materials, a working knowledge of scientific methods and practices, and to assist in development of understanding of the concepts studied in lecture.

All other policies as detailed in the lecture syllabus also apply to the lab portion of the course. If you have a difficulty with any of the policies outlined here, or any other aspect of the course, please see me. If you require special accommodation for any reason, please see me at your earliest opportunity.

Notebooks and Lab reports:
Don't lose this. You will need it to put your lab reports together properly!
Some lab exercises will be graded on formal lab reports, and others will be graded on your lab notebook. Lab notes are to be kept in your binder with your lab manual, as designated by your TA. TA's will take up notebooks or portions of your notebooks periodically for grading.

Lab reports are to include, and will be graded upon, the following sections: Each section must be titled, i.e. "Introduction", "Materials and Equipment," etc. Lab reports are to be typed, computer printed, and all tables and graphs must be done on computer.

Introduction: includes the statement of the problem, question or hypothesis that is investigated in the exercise. It must be clearly stated and complete, and will be given up to 5 points.

Materials and Equipment: includes a complete listing of all materials and equipment used, and should also include reference materials as appropriate. Will be given up to 5 points.

Safety Concerns: Where chemicals are used, the MSDS should be read for guidelines for handling, and those that are appropriate to the procedure detailed here. Any additional cautions must be listed and explained as to why they are necessary. Particular attention should be given to any special concerns one might have in doing this procedure with small children. Will be given up to 5 points.

Experimental Procedure: The procedure you followed is to be written up in sufficient detail that someone who is unfamiliar with the course, and who does not have your lab manual could duplicate exactly what you did and get the same results. Include here all procedures you did, even those that didn't work out right. Must be complete and accurate, and will be given up to 25 points.

Data and Results: This section should have tables of data (measurements) as appropriate, lists of results of procedures, and any calculations. Tables and charts are to be done on a computer, in a spreadsheet program such as Excel. It must be complete and correct, and will be given up to 25 points.

Discussion: IN this section you are to explain your data and results, and demonstrate your understanding of the relevant concepts. You may also include any particular methods you might use, or modifications to the lab procedure in this course, to teach the concept to small children. It will be given up to 25 points.

Conclusion: Present in a single paragraph the answer to the question, problem or hypothesis posed in the Introduction. You data, results and discussion must support this conclusion. It will be given up to 10 points.

**Safety Rules!**

- Wear OSHA approved lab goggles whenever chemicals are present in the lab.
- Look up the MSDS for every chemical you use. Safety considerations from the MSDS must be included with your lab report.
- Never put edible materials in lab glassware or other lab containers. When doing labs that allow you to eat materials, use separate, disposable food containers. Be certain the table tops are thoroughly cleaned, and then do not put edible materials on the table without being in appropriate containers or on paper.
- Clean up your area thoroughly after each class.
- Do not wear headphones or other music devices in lab. They distract from what you are doing and may cause accidents.
- Be careful not to spill chemicals, and if you do, clean it up promptly. If you are unsure how to clean it up or if it is a chemical spill, ALWAYS ask your TA. Always be careful not to get any chemical on you or on your clothing.
- Do not try new reactions of your own design without first getting permission from your TA. TA's will not give permission for "skunkworks" if they are not sure of the reaction that will occur.
Microsoft Excel for Computer Phobics

Launch Excel: Put your mouse cursor on the small icon that looks like a jigsaw puzzle that is in the top right corner of the monitor. Press the button down and hold it to bring up the menu, and then drag down until Microsoft Excel is highlighted. Let up the mouse cursor and it will bring up the program called Excel. You will see a spreadsheet, which is a table of empty spaces. Once you have clicked the mouse cursor into a cell, you can type into that cell to enter numbers. This explanation covers a graph of temperature versus volume like you might do in a lab procedure. It was put together by a TA who cared about her students. I hope it helps.

1 - In the first column, type in the values for temperature. Just type in the numbers; don't include the units or anything else.

2 - in the second column, type in the values for volume. So now you should have values in 6 cells (or boxes), 3 in each column.

3 - now highlight all six cells using the mouse (hold down the mouse button and move it around so that all 6 cells turn black/highlighted).

4 - let the mouse button go when they are all highlighted and go to up to tool bar and click on the icon that looks like a magic wand (this is the chart wizard). If your arrow turns into a crossbar just click it and move on.

5 - now you will be creating the graph. This first menu is just verifying the cells you have selected, so just click "ok" or "next"

6 - the next menu asks you to select what type of graph you want. Select "XY Scatter" and click "next"

7 - the next menu asks you to select what type of scatter plot you want. Select the box that just has some dots on it (i.e. the dots are not connected, nor are there any other lines on the graph) and click "next"

8 - the next menu lets you view the graph to make sure it looks ok. So look at it and see if the data points are in the correct place. Click "next" if everything looks ok.

9 - the next menu lets you put a title on the graph and label the axis. Because you will only have one line on the graph, you really don't need a legend. So where it says "legend" click "no". If you are working on a newer version of excel, you may have to go to the file folder that says "legend" to do so. So now type in a title for the graph (i.e. chart 1:name) and label the axes (x & y-axis) and don't forget to put the units.

10 - ok, so you should be done creating the graph so click "next" or "ok". If you have a newer version of excel, the next menu will ask you where you want to put the plot. I suggest clicking next to where it says 'as a new sheet' and then "finish"

11 - now look at your plot. Does it look ok? We now want to insert a "best fit line" like we did in class. Click on the graph so that it is highlighted and then click on one of the points on the graph. The points should become highlighted. Then go up to the menu bar (at the top of the screen) and pull down the insert menu and then click "trendline".
12 - a menu will come up asking you to select what type of trendline. And what type do we pick? Well, "linear" of course! Then click on the "options" folder (it should be within this menu box) and click the box next to the phrase "display equation on chart" (there should now be a check mark next to this). Now click "ok"

13 - excel should insert a best fit line through the data points and also display the equation for that line. If this doesn't work please come see me.

So now you're done creating the graph. You can fiddle around formatting the graph by just double clicking on parts that you want to reformat. If you want to change the scale of the axes, just double click on the axes. If you want to change the title, double click on it and so on. Try messing around with it to make it look presentable.

I now want you to do an analysis of this data. Using the equation of the line that excels gives you; you can calculate the value for absolute zero based on your data. The equation that excel gives is a linear equation in the form:  

\[ y = m \cdot x + b \]

where

- \( y \) = y value (which is really volume)
- \( m \) = slope of the line
- \( x \) = x value (which is really temperature)
- \( b \) = y-intercept

If we set \( y \) equal to 0 (0 mL), then we can calculate the value for \( x \) because \( m \) and \( b \) have been given to you in the equation. So now, \( x = -\frac{b}{m} \) which is the value at absolute zero. We did this in class graphically by extrapolating the line on the graph (i.e. drawing the line so that it intersects the y-axis at 0 mL). Now you are calculating exactly what this number is based on your data points! This number probably won't be exactly -273 degrees Celsius, but that's ok. You just need to tell me why your value is not what it should be (i.e. explain your sources of error).

So in your data and results section, you should include one table (I just want the average values for each water type), the graph (with the line and equation on it), and sample calculations. You need to have 3 sample calculations:

1 - calculating the volume of the balloon (easy!)
2 - calculating the slope of the line (like we did in class)
3 - calculating the absolute zero value based on the equation from excel (from above)

Be sure to include the initial equation, plug in the numbers and give the answer...and don't forget UNITS.

In the discussion, be sure to fully discuss the relationship between temperature and volume, including the idea of kinetic energy. You may want to look at the last question in the lab manual and also in your textbook. Also, you may want to refer to graph when trying to explain your data and this relationship between temp and volume. Also, explain all the sources of error (and there were quite a few).

So this should definitely get you going on your graph and report. If you have any questions email your TA, or come to room 427 where the TA's do their office hours. Get started as soon as possible, so we can work out any problems before it's too late! Good luck.

Susan
STEAS: Students and Teachers Excited About Science
Service Learning Project

Service Learning differs from community service projects in that it specifically includes skills being learned in the courses currently in process. It gives the student hands on practice in the course content, strengthening the learning experience and meeting a community need at the same time.

You are to design and carry out a project that gets students and teachers in a local school excited about science. Kids are naturally interested in and curious about the world around them. Exploring that world and what makes it work is science. Capture that enthusiasm and bring it into the school experience for students and teachers to reawaken interest in science.

In your study group discuss what gets kids interested in science. What is it that kids like to do? List specific activities and then explore that list for connections with science activities and exploration.

For example, making and flying paper airplanes could lead to a whole study of how airplanes are able to fly and how different wing and fuselage designs might affect the efficiency of an aircraft. After the kids understand and experiment with the principles of flight, a pilot could come in and talk with the kids about how he controls the aircraft with the flaps and speed. The kids could then perhaps visit local airport see different types of planes and different jobs that are needed to make it happen.

Design a project that you could do over a semester's time with a group of elementary or middle school students. Remember your objective is to get those kids and their teacher excited about science. Plan on visiting your class about 4 times, with the first visit being for observation.

You will be given an opportunity to choose from possible classroom assignments, or you may make your own arrangements. In addition, you may choose to volunteer at the geology museum, guiding school groups on tours. Then follow through and do it!

While doing your project, keep a journal of your experiences. You might encourage your students to keep a journal also, or to write in YOUR journal. Keep one journal for them, and one for you. You may also want to take photographs of your students participating in their (your) project.

Reflect on your project. What did you accomplish? What did they accomplish? How do you feel about what you did? Put together a reflection of the whole project to share with your P SC class, including details of educational objectives and activities. You may do this in any media of your choosing. These reflections are to be handed in in any format of your choosing, (provided you fulfill the requirements) for your project grade at the end of the semester. The due date is the last day of classes before the final exam.

Alternative service learning projects may be offered on a semester by semester basis. These may include preparing curriculum packets by grade level for local "class trip" destinations. If you are aware of a need in the community for student assistance that might be a good service learning project for youself and classmates, please bring it to your lecture professor's attention.
Issues Project; Chemistry vs. Humanity

Assignment Objective: The student will demonstrate the ability to readily discern whether published material is intended to inform or to influence public opinion. The student will search beyond mainstream media to discover the background, facts and relevant data, to build a case on truth and reality. The student will form an opinion of position on an issue, and support that position with confirmed and documented reality.

1. You are to choose a controversial topic that involves chemistry. For examples and ideas for topics I suggest that you thumb through your text, search the Internet, daily newspapers, news or science magazines or programs, and publications from activist organizations such as the Sierra Club or Greenpeace. Narrow your topic choice. (E.g. instead of “pollution,” or even “air pollution,” choose a specific component of air pollution) Once you have an idea for a topic, see me for approval. Your topic must be approved by your professor.

2. Begin by compiling information from mainstream media, then find better sources. In addition to the mainstream media, you must use at least a minimum of three primary sources, one on each side of the issue, and one unbiased. (Be sure you know what a primary source is.)

3. Find the organizations or industry arguing on each side of the issue. Research the sources of their funding, and how they spend their resources. Find and report on their incentives. Accumulate the organizations’ literature and material on each side of the issue. (use the Internet, and contact the organizations directly for a primary source,. i.e. talk to a real person.)

4. Look for the differences in information presentation from the opposing sides. Sort out facts and data from emotionalism, and show examples of each.

Find sources of data presented and trace back to the original work for confirmation and elaboration. (Use the footnotes or endnotes of the articles) Look especially for what data or information from the original source is NOT included in the material. Does it present a conflicting interpretation or explanation?

5. Where does the mainstream media stand on the issue? Document and present examples of biased reporting. If an example is from broadcast, document the network, program, time and date and name of the individual reading the copy or discussing the issue.

6. What regulatory actions, if any, have been taken by federal, state or local governments? Find the limits set (if relevant) or rules imposed and factual bases used. Are the limits or rules supported by the evidence? In your opinion are the legal restrictions or limits reasonable based on cost and level of risk?

7. Find reality. Take a position. Present your opinion and position and support your conclusions with documentation to original sources.

8. You may work in small groups (no more than 4) in gathering information, but all writing and the project to be handed in must be individual and solely your own work. Duplication of work will be considered cheating and in violation of the university’s code. Cheating will get you a zero on the project.

9. Your project must include documentation in APA format of all sources. Materials in media other than your formal written report (videotape, multimedia software, poetry, musical composition, etc.) are welcome, however, sufficient information to meet the requirements itemized must be included in the form
of a formal written paper in APA format.

10. Projects must be handed in no later than one week before the end of classes for the semester. original data:

Grading rubric:

<table>
<thead>
<tr>
<th>Category</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate choice of topic:</td>
<td>5 pts</td>
</tr>
<tr>
<td>sources</td>
<td>25 pts</td>
</tr>
<tr>
<td>(5 pts. each primary source, 10 for all other sources)</td>
<td></td>
</tr>
<tr>
<td>information on organizations</td>
<td>20 pts</td>
</tr>
<tr>
<td>(10 pts. each side)</td>
<td></td>
</tr>
<tr>
<td>Identification of writing style (to influence opinion or to inform:)</td>
<td>10 pts</td>
</tr>
<tr>
<td>Original sources, comparison</td>
<td>15 pts</td>
</tr>
<tr>
<td>Examples of biases evident in information found:</td>
<td>10 pts</td>
</tr>
<tr>
<td>Regulatory limits relevant to issue and your commentary:</td>
<td>15 pts</td>
</tr>
<tr>
<td>Clear and reasonable statement of your position:</td>
<td>5 pts</td>
</tr>
<tr>
<td>Support of your position by relevant factual material:</td>
<td>15 pts</td>
</tr>
<tr>
<td>footnotes</td>
<td>5 pts</td>
</tr>
<tr>
<td>bibliography</td>
<td>5 pts</td>
</tr>
<tr>
<td>Appearance and presentation (not necessarily a live presentation in class) of your finished product:</td>
<td>10 pts</td>
</tr>
<tr>
<td>Meeting deadlines:</td>
<td>10 pts</td>
</tr>
<tr>
<td>final grade:</td>
<td>150 pts</td>
</tr>
</tbody>
</table>

During some semesters the Issues Project may be done as a group project, with in-class presentation in some form required. If you prefer this option, see your professor.
Process Skills and Cooperative Learning

**Background:** Cooperative learning is a style of learning that is ideal for use in the laboratory. Members of a cooperative group each have specific tasks that are all equally necessary for the group to function smoothly. All group members are responsible for leaving a clean work area for the next lab class.

**Terminology:** The value of a dependent variable will change as you change the value of the independent variable. The "dependent variable" therefore is "dependent" on the independent variable. The value of an independent variable doesn't change if you change another variable. Linear means the change occurs as a straight line, not as a curve, when plotted on a graph, provided the scales of the numbers are regular.

**Materials**

<table>
<thead>
<tr>
<th>Supply House</th>
<th>Grocery and/or Discount Store</th>
</tr>
</thead>
<tbody>
<tr>
<td>beakers</td>
<td>effervescent tablets</td>
</tr>
<tr>
<td>graduates</td>
<td>metric rulers</td>
</tr>
<tr>
<td>thermometers</td>
<td>stop watches</td>
</tr>
<tr>
<td>ice</td>
<td>coffee pot</td>
</tr>
</tbody>
</table>

**Objectives:**
After completion of this lab the student will be able to

1. identify the dependent, and independent variables.
2. graph the dependent vs. independent variables.
3. participate in cooperative learning groups.

**Problem:** Does the temperature of water affect how *vigorously* an effervescent tablet reacts?

**Hypothesis:** Temperature does not affect how vigorously an effervescent tablet reacts. (Your hypothesis is stated in "null" terms. i.e. that there is no affect.)

It is NEVER appropriate to make a guess and then try to prove your hypothesis. You state the null, and then do the work to figure out what happens. That way your work is unbiased.

Design an experiment to prove or disprove the hypothesis. Your lab report must explain how your procedure proved your conclusion.

**Make a data table in Excel.**

**Variables and graphing:** Graph data and answer the questions.

1. Our dependent variable is

2. Our independent variable is

3. Is the independent vs. dependent variable relationship linear?
Excel Lab

Objective
In this lab, you will enter data into columns in a spreadsheet, and use Excel to graph the data. Afterwards, you will copy the graph you have made and paste it into a Word document to use in your lab report.

If you have trouble with the computer, see the introductory class notes in this manual, and learn to use "help" on the machine. Part of the process is to learn to think and solve problems for yourself. When you are teaching, you will not have someone at your shoulder to solve all your problems.

Procedure
First let's collect some data. You may need to figure out how to get these numbers. That's part of the game. Determine the height in centimeters of each member of your lab group, then exchange information with other lab groups to get the data for the whole class. Enter these numbers in a column on the worksheet labeled "data" to do this, click on the tab at the bottom of the worksheet, and it will take you to the data worksheet. Then calculate the distance each group member is from home, in kilometers, and enter these data for each member of your group and the class. (This may include some estimating. If you are unsure, ask around "how many miles is it to É" or use a map, and convert from miles to kilometers.) Enter the distances in the column in the spreadsheet.

Select the areas of the spreadsheet that has the data (put your cursor in the top left cell, press the mouse button, hold it down and drag it to the bottom right cell of the data) and then click on the chart icon at the top of the screen. Follow the instructions. Try out different types of charts until you find some that you like. Save the chart to the sheet labeled charts. Do you see any correlation between these numbers? Would you expect to see any pattern in these data?

You can enter other data into columns and use it for charts also, whatever you like. Try making new sheets. Pull down the insert menu, click on worksheet. Label the new worksheet with your name by double clicking on the tab at the bottom and typing in what you want to call it. You can make a new worksheet for each member of your group, let each group member make their own chart. Label your charts appropriately.

You may play with colors and labels. Try changing formats, colors, grids, labels, etc.

Next open MS Word and start a new document. Type in your name and a title for the report. Write a short paragraph explaining what you have done in today's lab, and then insert your chart into the document by following the instructions in the pull down menus. This may take some playing until you find your way.

The purpose of today's lab is for you to have some time to explore Excel and Word, and have fun playing with different charts. In later labs you will need to plot data and write formal lab reports, which will use these skills.

Print your Word document and hand it in to your TA.
Internet Lab

Bring up the Internet and do a web search:
Double click on the Netscape icon on the desktop.
After the home page loads, click into the URL space at the top of the page.
This will bring up Google, one of the better search engines.

In the search box at the top, type in some topic you would like to search. (Perhaps your Issues Project topic.) Set the menu box for the number of results you would like it to show, choose the language you want, and click “search.”

You may narrow your search by adding qualifiers, additional words, into the search box with the original words, and search again.

Try putting “search engine” into the box and see if you can find others (besides my current personal favorite, Google) that you will be able to use. There are many, and most are fine. Make a list of the search engines you find, and some comments for your own use about how they are different from one another, and how the results of searches differ. (try yahoo, alta vista, excite, hotbot, etc.) You should not relay on just one search engine, as you may well miss some good stuff that way.

You may search around for awhile, getting used to how a search engine works. You will use Internet searches among other resources to research your issues topic in PH SC 108.

Now use a search engine to find Material Safety Data Sheets (a.k.a. MSDS). You will use these to determine the precautions necessary with materials you use in the chemistry part of PH SC 108.

When you have found several sources, look at a few, and choose which one you prefer. Bookmark it on your group’s iMac for your future use.
Mathematical Relationships and Graphing

Part A: Circles -- Relation of Circumference and Area to Radius

**Background:** The ability to determine how a change in the independent variable will affect the dependent variable is vital in the sciences. Graphs often make this relationship much easier to understand by visualizing exactly what occurs.

**Objectives:**
After completion of this lab the student will be able to
1. make a multi-line graph.
2. describe the relationship between circumference and area as a function of the radius of a circle.

**Materials**
<table>
<thead>
<tr>
<th>Grocery and/or Discount Store</th>
</tr>
</thead>
<tbody>
<tr>
<td>cans various sizes</td>
</tr>
<tr>
<td>marking pens</td>
</tr>
<tr>
<td>string</td>
</tr>
<tr>
<td>rulers</td>
</tr>
<tr>
<td>scissors</td>
</tr>
</tbody>
</table>

**Procedure:**
1. Get three different size cans and a string. Put 5 marks on the string at measures of one can's greatest expanse (diameter) creating a string ruler with marks 1 can diameter apart. (See picture)
2. Place the can on graph paper and draw its circular outline. Place the marked string on the circle you have drawn. Measure the circumference of the circle and record the number of marks in a chart (estimate to the nearest 1/10).
3. Repeat steps 1 and 2 for the other two cans. Use different colors for each set of marks.
4. Using a ruler, measure the length between the marks on the string and the total distance each string went around each circle on the graph paper. Record this data in a table.
5. Measure the area of each circle on the graph paper. Record this data in a table.
6. Using your data table, create a graph of circumference and area as a function of the radius of the circle.

**Graph:**
Make a data table in Excel.

**Analysis:**
1. What was the average number of times the marked string went around the circle? What is this number called?

2. Describe the lines on the graph. Why is each one shaped the way it is?

**Conclusion:**
1. Describe the relationship among the radius, circumference, and area of a circle.
Part B: Spheres -- Relation of Surface Area and Volume to Radius

Objectives:
After completion of this lab the student will be able to
1. make a multi-line graph.
2. describe the relationship between surface area and volume as a function of the radius of a sphere.

Procedure:
1. Get three different size balls. Measure the radius of each. Record this in a data table.
2. Devise a method to measure the surface area and volume of each sphere. Record in a data table.
3. Construct a graph showing the relationship of radius to surface area and volume of a sphere.

<table>
<thead>
<tr>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply House</strong></td>
</tr>
<tr>
<td>beakers</td>
</tr>
<tr>
<td><strong>Grocery and/or Discount Store</strong></td>
</tr>
<tr>
<td>balls various sizes</td>
</tr>
<tr>
<td>string</td>
</tr>
<tr>
<td>clay</td>
</tr>
</tbody>
</table>

Data Table & Graph:
Make a data table and graph in Excel

Analysis:
1. Describe the shapes of the lines on the graph.
2. Why are they shaped the way they are?
3. What is the simplest way to describe the size of a sphere?

Conclusions:
1. As the radius of a sphere increases, which increases faster -- the surface area or the volume?
2. Why?
3. What other shapes can you describe that have this same relationship?
4. Assume that you have ten small spheres that displace the same amount of water as one large sphere. How does the total surface area of the smaller spheres compare to the surface area of the larger sphere?
Metric Lab

Objective: the student will demonstrate familiarity with and understanding of everyday quantities in metric units.

Materials: meter stick, metric scale, 10 and 100 mL graduated cylinders, balances, objects and materials to be measured.

Safety concerns: You should not consume any materials that you are allergic to.

Procedures:

A. Length: Make the following measurements: (individual effort) Which objects are approximately 1 centimeter?

<table>
<thead>
<tr>
<th>Object:</th>
<th>Length in centimeters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of a paper clip</td>
<td></td>
</tr>
<tr>
<td>Width of a paper clip</td>
<td></td>
</tr>
<tr>
<td>Width of your thumb</td>
<td></td>
</tr>
<tr>
<td>Length of your thumb from tip to first knuckle.</td>
<td></td>
</tr>
<tr>
<td>Width of your pinky between tip and first knuckle.</td>
<td></td>
</tr>
<tr>
<td>Length of your pinky between tip and first knuckle.</td>
<td></td>
</tr>
</tbody>
</table>

Group: Obtain material #1 from instructor and measure out one meter of that material, (lay it out on a paper on the lab bench) and move your hands apart the meter's length. Make a mental note of how long a meter is. Each member of your lab group should do this, and then you may internalize the concept of one meter. (Share your meter of material among your group members.)

Make a mental note to remember the size of a centimeter and a meter.

5) Volume: (individual work on this part.)

4) Using the 100 mL graduated cylinder, measure out 50 mL of water. Pour this into a clean paper cup (each group member should do their own cup.) and mark the level of 50 mL on the outside of the paper cup. Pour out the water. Obtain material #2 from your instructor. Fill your cup to the 50 mL mark that you drew. Make a mental note of how much is 50 mL. Then you may internalize the concept of 50 mL.
5) Cut out the pattern and fold to make a cube as shown.
6) Tape four sides and the bottom together as a cube, fold the top down but do not tape it closed.
7) Measure the length of each side.

Cube measures _____ cm on each side. Volume of cube is: ______ (length times width times height)

Be sure the sides are well taped, creating an open box. Measure one mL of water in a small (10 mL or less) graduated cylinder. Pour the water into the paper box you have made. What do you observe?

1 mL = ____ cm³

Devise a method for finding the mass on one mL of water.

1 mL = ____ grams

Mass:
Obtain material #3 from your lab instructor.
Find the mass of one piece of the material in grams.
Find the mass of 6 pieces of the material in grams.
(You may internalize the concept of this mass.)

Weigh an empty 1 liter soda bottle.
Fill the bottle with water and calculate the mass (in grams) of the filled bottle based on what you have discovered so far in these procedures.
Hold the filled bottle in your hand to get the "feel" of the mass of one liter.
Measurement - Length and Volume

Background: Since scientists use many measurements for gathering data, practice with metric units is essential for the student. Length is the simplest property to measure and will be addressed first.

Objectives:
After completion of this lab the student will be able to
1. precisely measure length.
2. estimate length in metric units.
3. precisely measure volume.
4. estimate volume in metric units.

<table>
<thead>
<tr>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply House</strong></td>
</tr>
<tr>
<td>graduated beakers</td>
</tr>
<tr>
<td>graduates</td>
</tr>
<tr>
<td><strong>Pharmacy</strong></td>
</tr>
<tr>
<td>aspirin</td>
</tr>
<tr>
<td><strong>Grocery and/or Discount Store</strong></td>
</tr>
<tr>
<td>metric rulers</td>
</tr>
<tr>
<td>soda cans</td>
</tr>
<tr>
<td>marbles</td>
</tr>
<tr>
<td>sugar cubes</td>
</tr>
<tr>
<td>paper clips</td>
</tr>
<tr>
<td>coins</td>
</tr>
</tbody>
</table>

Metric Scavenger Hunt (Estimation)
A box of items is placed in front of each group. Find an object that your group feels meets the measurement given. Record the name of the item under "guess." Measure the item and place the result in the "measures" column. Come to agreement about the following list.

<table>
<thead>
<tr>
<th></th>
<th>Guess (object name)</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Object 1 cm across</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Object 2 cm across</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Object 3.5 cm across</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Object 25 cm long</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Object 20 cm long</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Object 15 cm long</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Object 5 cm long</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Object 10 cm long</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Object 7.5 cm long</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Object 8 cm wide</td>
<td></td>
</tr>
</tbody>
</table>
Measuring Volume

Procedure:
1. Obtain a sugar cube, a box, a marble, a soda can, and a rock.
2. Estimate the volume of each by comparing to a 10 ml graduated cylinder. Record in the data table.
3. Directly measure each item with a metric ruler and calculate the volume. Record in the data table.
4. Indirectly measure the volume of each by lowering into a graduated cylinder or graduated beaker. Record in the data table. NOTE: Beaker markings are neither accurate nor precise, but should be used only for rough estimates.

Data Table:
Make a data table in excel.

Analysis:
1. Which items were easy to estimate? Why?

2. Which items were easier to measure directly? Why?

3. Which items were easier to measure indirectly? Why?

4. How would you measure the volume of a spoonful of sugar?
Measurement - Mass and Weight

Background: The difference between mass and weight is often not clear. This lab will provide you with the knowledge to make a clear distinction between the two.

Objectives:
After completion of this lab the student will be able to
1. construct and use a balance to measure mass.
2. compare mass and weight.
3. compare the homemade balance with a regular balance.
4. measure the density of a regularly or irregularly shaped object.
5. state the relationship between density and floating or sinking.

<table>
<thead>
<tr>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply House</td>
</tr>
<tr>
<td>balance</td>
</tr>
<tr>
<td>cubes</td>
</tr>
<tr>
<td>rubber stopper</td>
</tr>
<tr>
<td>Grocery and/or Discount Store</td>
</tr>
<tr>
<td>cardboard strips</td>
</tr>
<tr>
<td>rubber bands</td>
</tr>
<tr>
<td>soda cans</td>
</tr>
<tr>
<td>paper cups</td>
</tr>
<tr>
<td>metric ruler</td>
</tr>
<tr>
<td>string</td>
</tr>
<tr>
<td>paper clips</td>
</tr>
<tr>
<td>Pharmacy</td>
</tr>
<tr>
<td>eye dropper</td>
</tr>
<tr>
<td>aspirin</td>
</tr>
<tr>
<td>sugar cubes</td>
</tr>
<tr>
<td>rocks</td>
</tr>
<tr>
<td>beans</td>
</tr>
<tr>
<td>coins</td>
</tr>
<tr>
<td>washers</td>
</tr>
<tr>
<td>batteries</td>
</tr>
<tr>
<td>nails</td>
</tr>
</tbody>
</table>

*** Constructing a Balance

Procedure:
1. Secure two soda cans with a rubber band.
2. Put the tabs on the soda cans up and insert a nail and a cardboard strip so that the strip balances on the nail and is located between the tabs.
3. Use string to attach 2 paper cups at opposite ends of the hanger equidistant from the center hole. Secure with paper clips if needed.
4. Place a paper clip on the cardboard strip to balance the cups exactly.
5. Attach another string to a cup as above for comparison tests below.

*** Adapted from Operation Physics, Measurement, "Building a Cardboard Balance to Use in Measuring Mass," funded by NSF Grant # TEI-8751216, 1984.
Measuring Mass and Weight

Procedure:
1. Get a handful of “cubes” from the front desk.
2. Obtain an assortment of items including sugar cubes, washers, paper clips, aspirin, a battery, pennies, a rubber stopper, and 3 things you choose. List the items in order of the amount of matter present.
3. Place each item in one cup and place cubes in the other cup until the two are balanced.
4. Record the number of cubes needed to balance each item.
5. Using the same items and your 3rd cup, measure the weight recorded on a spring scale for each item. Record in the data table below or make a data table in excel.

Data Table:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th># of Cubes</th>
<th>Spring Wt</th>
<th>Item</th>
<th>Description</th>
<th># of Cubes</th>
<th>Spring Wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis:
1. Describe what is different about the properties you are measuring with the two devices.
2. Ask your instructor for a mass balance. Look at the mass balance and describe how your measuring device is similar.
3. Compare and contrast mass and weight.
4. Gravity varies with the location of an object nearer or farther from the surface of the earth. If you had to do an experiment on a mountain and it was critical to measure the amount of matter you used, which device -- the spring scale or the mass balance would you use? Why?
5. Which measurement would differ on Mars -- mass or weight. Why?
Lab 4  Measuring Density Directly

Procedure:

1. Measure the mass of a rubber stopper with your balance. _____
2. Measure the volume of a rubber stopper using a metric ruler. _____
3. Calculate the density of the rubber stopper by using
density = mass/volume  density is _________.
4. Predict whether your rubber stopper will float or sink.
5. Prediction ____________________.
6. Test your float/sink prediction in the container of water.
7. Results ________________________.
8. Repeat your test with a cork stopper.
9. Mass _____ Volume _____ Density _____
10. Prediction (floats or sinks) ________________.
11. Results ____________________.

General Lab Conclusions:
(mention density, floating, sinking,)
Vile Vials and Tillman Tower

**Background:** Some objects float and some objects sink, but very few objects stay put when they are placed under water. We will use a combination of objects -- some that float and some that sink in order to make an object that does neither. After constructing this object we will use it to indirectly measure the density of a liquid.

**Objectives:**
After completion of this lab the student will be able to
1. construct an object that neither floats nor sinks.
2. measure the density of a liquid indirectly.
3. measure the height of an object indirectly.

**Materials**

<table>
<thead>
<tr>
<th>Supply House</th>
<th>Grocery and/or Discount Store</th>
</tr>
</thead>
<tbody>
<tr>
<td>graduates</td>
<td>soda bottles</td>
</tr>
<tr>
<td>balances</td>
<td>BB’s</td>
</tr>
<tr>
<td>protractors</td>
<td>protractors</td>
</tr>
<tr>
<td>film vials</td>
<td>film vials</td>
</tr>
<tr>
<td>marbles</td>
<td>marbles</td>
</tr>
<tr>
<td></td>
<td>sand (fine grain)</td>
</tr>
<tr>
<td></td>
<td>washers</td>
</tr>
</tbody>
</table>

**Procedure 1: Vile Vials**
1. Fill a cutoff two liter plastic bottle 3/4 full of water.
2. Using only marbles, BB's and sand, fix the vial so that it neither floats or sinks when placed in the water bottle.
3. After your vial is fixed, find its mass with a balance.
4. Find the volume of the vial with a graduated cylinder.
5. Calculate the density of the vial (mass/volume).
6. Repeat the procedure with the "special" water.

![Diagram of experimental setup](image-url)
Vile Vials

**Data Table:** Attempts to make a Vile Vial stay put in water.
Make a data table in excel.

**Analysis:** Plain tap water
1. What is the density of the vial? Show work!

2. What is the density of the tap water?

3. How would you numerically characterize the density of any object that sinks?

4. How would you numerically characterize the density of any object that floats?

**Analysis:** Special water
1. What is the density of the vial? Show work!

2. What is the density of the special water?

3. What would happen if the special water and the tap water were carefully placed in one container?

4. Which water would be better for swimming a long distance?

**Tillman Tower**

**How tall is Tillman Hall?**

**Procedure:**
1. Assemble a sextant with a straw, tape, string, a weight, and a protractor as in the drawing.
2. Sight objects by looking through the straw with one eye closed. The angle that the taut string touches is the angle from your eye level to the object.
3. Practice sighting by looking at where the ceiling meets the wall. This angle will be small if you are far from the wall and get larger as you move toward the wall!
4. Measure the distance from you to the wall. You must practice pacing a few times along a known distance to figure your average pace.
5. Make a scale drawing of the resulting triangle.
Scale Drawing:
1. Choose a scale so that the distances measured will fit in the drawing area. Example: 1 meter = 1 cm.
2. Make a horizontal line across the drawing area.
3. At one end, use a protractor to measure and mark the angle you found while sighting the object. Draw a line up from this end at the desired angle.
4. Mark the distance along the horizontal line (you first drew) that represents the scaled distance from you to the object.
5. Draw a line straight up to intersect the angled line from this marked distance.
6. Measure this vertical line and convert (use your scale) to find the actual height of the object.
7. Add the distance from the ground to your eye to compensate for the fact that your eye was not at ground level when you sighted the object.

Data:
- Estimated height of Tillman Hall _______.
- Scale chosen ____________________.
- Distance to Tillman Hall ____________.
- Angle from eye to top of Tillman ______.
- Height of Tillman from drawing _______.
- Height of eye from ground level _______.
- Calculated height of Tillman Hall _____.

Drawing: Scale Drawing of Tillman Hall
Smorgasbord

**Background:** The Earth is habitable for many different life forms in part due to the abundance of water. We are essentially large collections of water with minor amounts of other elements and compounds. Water has several unique properties that are deserving of further attention. Air is a mixture of several gases. This mixture changes if air is involved in combustion.

**Objectives:**
After completion of this lab the student will be able to
1. determine how volume changes during a phase change of water.
2. determine whether combustion changes the composition of air.
3. describe surface tension.
4. make a primitive compass.
5. construct an object that floats exactly half in and half out of water.

<table>
<thead>
<tr>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply House</strong></td>
</tr>
<tr>
<td>graduated beakers</td>
</tr>
<tr>
<td>mass balances</td>
</tr>
<tr>
<td>masses</td>
</tr>
<tr>
<td><strong>Grocery and/or Discount Store</strong></td>
</tr>
<tr>
<td>ice</td>
</tr>
<tr>
<td>paper clips</td>
</tr>
<tr>
<td>needles</td>
</tr>
<tr>
<td>magnets</td>
</tr>
<tr>
<td>aluminum foil</td>
</tr>
<tr>
<td>metric ruler</td>
</tr>
<tr>
<td>paper towels</td>
</tr>
<tr>
<td>plastic wrap</td>
</tr>
<tr>
<td>various size boxes</td>
</tr>
<tr>
<td>plastic cups</td>
</tr>
</tbody>
</table>

---

**Add Paper Clips Slowly**

---

**Smorgasbord**
Part 1  Densities of Water and Ice During Phase Changes

Prediction:
How will the level of a glass full of ice/water change when the ice melts?
   Increase  Decrease  Stay the same

Procedure:
1.  Fill a container full of water/ice so that the water is at the rim and the ice is above it.
2.  Observe the level as the ice melts.

Results: (What happened and why?)

Part 2  Floating Boats

Prediction A:
What will the water level be inside an empty glass if you invert it into a tray of water?

Procedure A:
1.  Make a small boat out of aluminum foil and float it in a tray of water.
2.  Invert an empty glass over the boat and push the glass to the bottom.

Results A:

Prediction B:
What will happen if you repeat part 2A with lighted paper in the boat?

Procedure B:
Place a small amount of paper towel inside the boat from part 2A, light it, and immediately invert the glass as in part 2A.

Results B:
Lab 6 Part 3 Surface Tension

Prediction:
How many paper clips can you add to a full glass of water before the water spills over the rim?

Procedure:
1. Fill a glass to the rim with water.
2. Add paper clips to the center of the glass until the water spills over.

Results:

Part 4 The Floating Compass

Procedure:
1. Fill a glass with water.
2. Carefully place a magnetized needle on the surface of the water.
3. Move a magnet close to the needle and observe.

Results:

Part 5 Floating Boxes

Procedure:
1. Get a box, a balance, a ruler, masses, and a piece of plastic wrap big enough to cover your box completely.
2. Add enough mass to your box so that it will float exactly half in and half out of the water.
3. Cover your box with the plastic wrap and bring it to the sink in the front of the room to test.

Results:

Analysis:
1. A container is filled completely with water and then sealed and frozen. What will happen to the container? Why?

2. During combustion of a paper towel, oxygen combines with carbon to produce carbon dioxide (CO₂). What common evidence can you site that would help convince someone that the CO₂ left the air and entered the water?
Separation of Matter

**Background:** Matter can be classified as either a mixture or a pure substance. Mixtures are made of at least two different substances that are not chemically bonded and have variable compositions. A mixture is made when any two or more non-reactive substances are combined. Any mixture may be separated by physical means. Pure substances have definite chemical compositions and can not be separated by physical means. Compounds and elements are both pure substances.

**Objectives:**
After completion of this lab the student will be able to
1. devise methods to separate mixtures of matter.
2. separate a liquid mixture and a solid mixture.

**Materials**

<table>
<thead>
<tr>
<th>Supply House</th>
<th>Grocery and/or Discount Store</th>
</tr>
</thead>
<tbody>
<tr>
<td>beakers</td>
<td>iron filings</td>
</tr>
<tr>
<td>marking pens</td>
<td>salt</td>
</tr>
<tr>
<td>jars</td>
<td>sand</td>
</tr>
<tr>
<td>paper towels</td>
<td>paper</td>
</tr>
</tbody>
</table>

**Part 1 Paper Chromatography** (Separation of liquids)

**Procedure:**
1. Add about 2 cm of water to a coffee jar.
2. Cut two strips of paper towel about 3 cm wide. Get two test markers of the same "color" and place a line 1-2 cm from the bottom of each strip with the markers.
3. Insert the strips of paper towel into the jar so that the marked end just touches the top of the water and the other end is outside the jar. *The ink must not touch the water!*
4. Cover the jar with the lid and proceed to Part 2.
5. Record your observations after the ink has moved up the strip.
6. Label your chromatograms and save them for later!

**Part 2 Dirty Sand** (Separating a solid mixture)

**Procedure:**
1. Find the total mass of the given matter (provided by the instructor).
2. Devise a method to separate the matter into its parts and to account for all the matter.
3. Separate the matter and keep track of how much of each type you have found.
Separation of Matter

Part 1 Paper Chromatography

Analysis:
1. What did you observe? What type of matter separated during the chromatography experiment?

2. What property allowed for this separation to take place?

3. Compare the separation of your color markers to those of two other groups. How are they similar or different? What would account for the differences?

Part 2 Dirty Sand

<table>
<thead>
<tr>
<th>Sample</th>
<th>Property Used to Separate</th>
<th>Name of Matter</th>
<th>Amount of Matter (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample B4</td>
<td>------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample After</td>
<td>-----------------------</td>
<td>---------------</td>
<td>---------------------</td>
</tr>
</tbody>
</table>

Analysis:
1. How does the mass of the separated matter compare with the mass of the original sample?

2. What types of matter would not be separated by using the techniques from this lab?
Puzzle Powders

**Background:** Each kind of matter has its own unique set of characteristics, or properties, that help to identify it. Physical properties are those that can be measured and observed without changing the substance. Color, taste, odor, solubility, and melting points are examples of these. Chemical properties depend upon the substance’s ability to resist or undergo chemical changes. Matter can also be identified by the way that it changes when in contact with other substances. In a physical change, the appearance of matter changes, but its properties and makeup remain the same. The evaporation of water, melting of wax, dissolving of salt in water, and the breaking of glass are examples. Chemical changes involve the production of new kinds of matter that were not present before the change.

**Objectives:**
Upon completion of this lab you will be able to
1. identify chemical and physical properties of various solids.
2. classify observed changes as physical or chemical.
3. develop an identification key using physical and chemical properties and changes.
4. identify an unknown powder using its physical and chemical properties.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Supply House</th>
<th>Pharmacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>testing trays</td>
<td></td>
<td>iodine</td>
</tr>
<tr>
<td>hand lenses</td>
<td></td>
<td>eye droppers</td>
</tr>
<tr>
<td><strong>Grocery and/or Discount Store</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>baking soda</td>
<td></td>
<td>Plaster of Paris</td>
</tr>
<tr>
<td>powdered milk</td>
<td></td>
<td>sugar</td>
</tr>
<tr>
<td>salt</td>
<td></td>
<td>corn starch</td>
</tr>
<tr>
<td>paper towels</td>
<td></td>
<td>rulers</td>
</tr>
<tr>
<td>paper cups</td>
<td></td>
<td>straws</td>
</tr>
</tbody>
</table>

**Procedure:**
1. Get a small sample (1 gram) of each of the six known powders. Examine the powders and determine the physical properties of each. Record these in a data table.
2. Devise tests to determine the reactions of each of the powders. Tests may include, but are not limited to, solubility in water, reaction with acid, presence of starch, etc. Record and label each change as physical (P) or chemical (C) in your data table.
3. When you have determined the physical and chemical properties and changes of each powder, ask your instructor for an unknown powder. He/she will give you one of these powders without identifying it. *(That's your job!)*
4. Perform your identification tests on the unknown powder and, using your data table, identify the powder.
Puzzle Powders

Data Table:
Make a data table in Excel

Analysis:
1. How did your tests illustrate the differences between physical and chemical changes?

2. Why was it a good idea to conduct more than one identification test with each powder?

3. What powder did your instructor give you? How were you able to make this identification? (Be specific!)
Conservation of Matter

**Background:** If a chemical reaction occurs, new substances are produced when chemical bonds are either created or destroyed. Scientists have discovered exactly how this creation or destruction of bonds changes the amount of matter present.

**Objectives:**
After completion of this lab the student will be able to
1. describe the law of conservation of mass.
2. write a balanced equation for a chemical reaction.

**Procedure:**

**Part 1 Formation of a Precipitate**
1. Put 3 ml of NaOH (aq) into a test tube and place the tube into a beaker (to prevent it from spilling).
2. Put 3 ml of CuSO₄(aq) into a small graduated cylinder.
3. Place these items on a balance together and find and record the total mass (beaker, test tube, graduated cylinder and reactants).
4. Pour the NaOH into the CuSO₄ and place the tube back into the beaker.
5. Without removing anything from the balance, find the total mass of the products and the glassware and record in a chart.

**Part 2 Formation of a Gas**
1. Put 5 g of baking soda in a small cup.
2. Pour 10 ml of vinegar into a small beaker.
3. Place both items on the balance and record the total mass.
4. Slowly, pour the vinegar into the cup with the baking soda so that it does not bubble over.
5. Stir the reactants until the reaction is complete.
6. Find the total mass of the products with cup and beaker. Record.

**Part 3 Finding What Happened**
1. Place 5 g baking soda into a plastic bag.
2. Pour 10 ml of vinegar into a small cup.
3. Carefully, place the cup in the plastic bag and seal the bag.
4. Place the sealed system on the balance and record the total mass.
5. Spill the cup inside the bag and record the change in mass after the reaction is complete.
Conservation of Matter

Problem: Is the mass of the reactants in a chemical reaction equal to, greater than, or less than the mass of the products?

Hypothesis:

Part 1 Formation of a Precipitate

Observations:

**Data Table:**

<table>
<thead>
<tr>
<th></th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning Total</td>
<td></td>
</tr>
<tr>
<td>Ending Total</td>
<td></td>
</tr>
<tr>
<td>Difference (B-E)</td>
<td></td>
</tr>
</tbody>
</table>

Part 2 Formation of a Gas

Observations:

**Data Table:**

<table>
<thead>
<tr>
<th></th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning Total</td>
<td></td>
</tr>
<tr>
<td>Ending Total</td>
<td></td>
</tr>
<tr>
<td>Difference (B-E)</td>
<td></td>
</tr>
</tbody>
</table>

Part 3 Find What Happened

Observations:

**Data Table:**

<table>
<thead>
<tr>
<th></th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning Total</td>
<td></td>
</tr>
<tr>
<td>Ending Total</td>
<td></td>
</tr>
<tr>
<td>Difference (B-E)</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion: In which part did your findings depart from what you expected? Why?
Reaction Types

**Background:** Millions of chemical reactions can occur. Memorizing each reaction is one way to learn them, but learning a classification system and applying it to types of reactions is much easier and better. One way to classify reactions is to examine what happens to the reactants and how the products are formed. Using this criterion we classify reactions as either combination, decomposition, single replacement, or double replacement. Reactions may also be classified as endothermic, energy consuming reactions, or as exothermic, energy producing reactions.

**Caution:**
* Never look down into a test tube while heating. * Aim test tubes away from people while heating.

**Objectives:** After completion of this lab the student will be able to
1. classify reactions as one of four basic reaction types.
2. identify reactions as endothermic or exothermic.
3. write balanced equations for chemical reactions.

### Materials

<table>
<thead>
<tr>
<th>Supply House</th>
<th>Grocery and/or Discount Store</th>
</tr>
</thead>
<tbody>
<tr>
<td>sulfates, Fe &amp; Cu</td>
<td>NaOH &amp; KCl</td>
</tr>
<tr>
<td>steel tongs</td>
<td>candles</td>
</tr>
<tr>
<td>graduates</td>
<td>steel wool</td>
</tr>
<tr>
<td>beakers</td>
<td>steel washers</td>
</tr>
<tr>
<td>test tubes</td>
<td>pie pans</td>
</tr>
<tr>
<td>wood splints</td>
<td>baking soda</td>
</tr>
</tbody>
</table>

### Procedure A:
1. Pour 5 ml of copper (II) sulfate solution into a small beaker.
2. Place a steel washer in the copper sulfate.
3. Observe and determine the reaction.

### Procedure B:
1. Pour 5 ml of sodium hydroxide into a test tube.
2. Pour 5 ml of iron (II) sulfate into a graduated cylinder.
3. Pour the graduate contents into the sodium hydroxide.
4. Observe and determine the reaction.

### Procedure C:
1. Light a candle in a safe location.
2. Hold some steel wool (mostly iron) with a pair of tongs over the flame. *Do not* use plastic coated tongs!
3. Observe and determine the reaction.

### Procedure D:
1. Place 5 g baking soda into a test tube.
2. Light a candle in a safe location.
3. Heat the test tube over the candle.
4. Observe and determine the reaction.
Reaction Types

Procedure A

Observation:

Word Equation:

Balanced Equation:

Reaction Type:

Procedure B

Observation:

Word Equation:

Balanced Equation:

Reaction Type:

Procedure C

Observation:

Word Equation:

Balanced Equation:

Reaction Type:

Procedure D

Observation:

Word Equation:

Balanced Equation:

Reaction Type:
Reaction Types

Reactions classified by energy transfer

Procedure E:
1. Pour 10 ml water in a flask. Record the temperature.
2. Mass 5 g of KCl and add to the flask.
3. Swirl the flask and record the temperature change.

Observations about energy flow:

Procedure F:
Caution: NaOH is caustic!

1. Place 10 ml of water in a flask.
2. Add 2 g of NaOH to the flask.
3. Swirl the flask and record the temperature change

Observations about energy flow:

Temperature Data Table

<table>
<thead>
<tr>
<th>Reaction</th>
<th>°C Begin</th>
<th>°C Ending</th>
<th>°C Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl + H₂O</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaOH + H₂O</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Reaction Types

Procedure E

Observation:

Word Equation:

Balanced Equation:

Reaction Type:

Procedure F

Observation:

Word Equation:

Balanced Equation:

Reaction Type:

Conclusions:
1. Describe the four types of reactions from parts A-D.

2. Describe how energy is exchanged in reactions E and F.
**Solubility NaCl vs. KNO₃**

**Background:** Solubility is the maximum amount of solute that can be dissolved in a solvent. In this experiment we express solubility in grams of solute per 100 grams of solvent. Your instructor will assign you a temperature of water to use. If your assigned temp is above the temperature of the water from the faucet, then get hot water from a coffee pot. If your assigned temp is lower than faucet temp, then chill with ice.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Supply House</th>
</tr>
</thead>
<tbody>
<tr>
<td>hot plates</td>
<td>balances</td>
</tr>
<tr>
<td>thermometers</td>
<td>beakers</td>
</tr>
<tr>
<td>graduates</td>
<td>test tubes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pharmacy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>potassium nitrate</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grocery and/or Discount Store</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>sodium chloride</td>
<td>aluminum pans</td>
</tr>
</tbody>
</table>

**Objectives:**
After completion of this lab the student will be able to
1. experiment to find the solubility of various salts.
2. make solubility curves.
3. interpret data on solubility curves.

**Procedure A:**
1. Label two test tubes and two pie pans A and B.
2. Find the mass of the pie pans and record in a data table.
3. Fill a small beaker with water at your assigned temperature.
4. Add 5 ml of your water to each tube. Use a graduated cylinder. Place them in the beaker of water to help keep the temperature constant.
5. Add as much NaCl and KNO₃ to each tube as will dissolve. Add slowly, stirring constantly until particles of salt settle to the bottom.
6. Place the tubes upright in the beaker and let settling continue.
7. Pour the liquid only from tube A into pan A.
8. Repeat step 7 with tube B and pan B.
9. Heat the pans on a hot plate with low heat until the liquid has evaporated. Carefully remove the pans from the hot plate, cool and mass the pans. Record data. Calculate the solubility in g /100 g H₂O.
10. Gather the data from the other groups and graph the solubility (g /100 g H₂O) vs. temp for NaCl and KNO₃.

Make a data table in excel.
Solubility NaCl vs. KNO₃

Problem: Which salt is more soluble in warm water- NaCl or KNO₃?

Hypothesis:

Data Table: Make a data table in excel and graph your data.

Calculated Solubilities: (show work)

Analysis:
1. Why did some of the salt settle to the bottom of each tube?
2. Was one salt more soluble? Which?
3. At what temperature was the solubility of the two salts the same?
Acids, Bases, and Indicators

Background: Everywhere around us, in the air, water, soil, and in our food and drinks, are acids and bases. Indicators, substances that change color in a predictable way, are used to indicate the presence of these acids and bases. Indicators can be isolated from natural materials, such as the leaves or roots of plants, or they can be prepared through chemical reactions.

Objectives:
After completion of this lab the student will be able to:
1. identify the properties of acids and bases.
2. interpret reactions of various indicators.

The pH scale, the shorthand way of describing how acidic or basic a solution is, is typically shown to run from 0 to 14.
Caution: Materials with pH values at the extremes of the scale are dangerous to skin and clothing.

0---------------- ------------------------------7--------------------------------------14
very acidic                                                neutral                               very basic

Procedure 1: Properties of Acids and Bases
1. Pour some hydrochloric acid (Acid) and some sodium hydroxide (Base) into two containers.
2. Feel Test: Place a few drops of one solution between your thumb and forefinger and rub the fingers together. How does the solution feel? Wash your fingers and repeat with the other solution. Record your observations in a data table.
3. Taste Test: Vinegar is an example of an acid and soap is an example of a base. Record the general taste of these two substances in your data table. Do not taste the HCl or the NaOH.
4. Reactions with metals: Put about 2 ml acid into one test tube and 2 ml base into the other. Add a piece of Zn to each test tube. Record the reactions in your data table. Repeat with Mg.
5. Reactions with carbonates: Put about 2 ml acid in one test tube and 2 ml base in the other. Add a pinch of sodium bicarbonate to each. Observe and record the reactions. Repeat with calcium carbonate chips.

Procedure 2:
1. Litmus Papers: Place one drop of acid on one end of a piece of litmus paper and one drop of base on the other end. Observe the colors. Record your observations.
2. Reactions- Phenolphthalein and bromothymol blue indicators: Place some acid in each of two clean test tubes. Add 3 drops of phenolphthalein to one and 3 drops of bromothymol blue to the other. Do any color changes occur? Repeat the test in clean containers using base. Record your observations for both tests.
3. Reaction with Blueberry Juice: Put about 1 - 2 ml of blueberry juice to each of 7 clean test tubes. With the test tubes in a row, start at the left and add 1 ml of lemon juice to the first container. Continue with one ml of vinegar in the next container, then add 1% boric acid, distilled water, 1% baking soda, 1% borax, and 1% lye to containers three through seven respectively. Gently shake the containers and observe the colors. Record in your table.

Make a data table in excel for each procedure.
Analysis:
1. Examine the formulas of acids and bases. What element is common to all acids?
   What polyatomic ion is common to all bases?

2. Using the properties in the table, form an operational definition of an acid and a base.

3. What reason can you give for the fact that tea turns a lighter color when lemon juice is added?
Preparing Solutions

Background: We all mix solutions such as salt water to soothe a sore throat, vinegar and water for cleaning windows, coffee to drink, laundry starch for pressing shirts, and antifreeze for our car. Solutions are described by their concentration, the relative amounts of solute and solvent present. Solutions may be prepared by salinity, parts per million or billion, percent by weight or volume, and by molarity. Solutions, such as rain or ocean water, exist in nature and are described by these same means.

Objectives:
After completion of this lab the student will be able to
1. prepare a salt solution using percent by weight.
2. prepare a vinegar solution using percent by volume and percent by weight.
3. prepare a basic solution by using molarity.

<table>
<thead>
<tr>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply House</td>
</tr>
<tr>
<td>beakers</td>
</tr>
<tr>
<td>mass balances</td>
</tr>
<tr>
<td>Grocery and/or Discount Store</td>
</tr>
<tr>
<td>baking soda</td>
</tr>
<tr>
<td>NaOH</td>
</tr>
</tbody>
</table>

Procedure Part 1: Preparing a salt solution.
1. Place a 250 ml graduated beaker on a mass balance and record its mass.
2. Put 3-10 g of NaCl into the graduated beaker. Record the amount.
3. Add distilled water to the beaker in the amount of 100 g - the amount of salt added.
4. Record the new mass of the system.

Procedure Part 2: Preparing a vinegar solution.
1. Pour between 5-10 ml of vinegar in a 25 ml graduated cylinder. Record the amount.
2. Fill the cylinder to the 25 ml line with distilled water. Record the amount of water.
3. Place a 25 ml graduated cylinder on a balance and record the mass.
4. Pour the amount of grams of lemon juice into the cylinder as you had poured in ml. For example: if you used 5 ml in step #1, then use 5 grams.
5. Add water until a total of 25 g of lemon juice/water is in the cylinder.

Procedure Part 3: Preparing a basic solution by molarity.
1. Calculate the formula weight for either NaOH or baking soda, NaHCO₃. Record.
2. Use a mass balance to carefully obtain 1/10 of this weight in grams.
3. Add this solid to a graduated beaker and add distilled water to the 100 ml level.

Note: The instructor will want to save some representative solutions for the next lab period. Do not discard these solutions unless told to do so.

Data Table:
Make data tables in excel.
Analysis Part 1:
1. Calculate the density of the salt water solution.

2. Calculate the salinity of the salt water solution.

Analysis Part 2:
1. Calculate the percent by volume of the first vinegar and water solution.

2. Calculate the percent by weight of the second vinegar and water solution.

3. Glassware is known to expand when the temperature rises. Which of these two methods, percent by volume or percent by weight would be more accurately reproduced under varying temperature conditions?

Analysis Part 3:
1. A 1 molar solution, 1M, has exactly 1 mole of solute dissolved in 1 liter of solution. Calculate the molarity of the NaOH or NaHCO₃ solution.

2. Calculate the molarity of the saltwater solution, and the two vinegar solutions.
Comparing Solutions

Background: An acid is a substance that in aqueous solution produces hydronium ions (H$_3$O$^+$) and a conjugate base. A base in aqueous solution produces hydroxide ions (OH$^-$) and possibly a conjugate acid. Two factors affect the total amount of hydronium or hydroxide ions in solution, the strength and the concentration of the acid or base. Strength is the ability of the acid or base to form H$_3$O$^+$ or OH$^-$ ions, or ionize, and all acids and bases are not equally strong. Some acids and bases ionize 100% in dilute solutions, but many others ionize only a small percentage of the total amount put in solution. The percent of ionization is a way to characterize an acid or base as strong or weak. The total amount of the acid or base put into solution, the concentration, also affects the amount of ions present and the behavior of the solution. When an acid and a base of equal strengths and equal concentrations are combined in equal amounts, a neutral solution forms. When an acid and a base of different strengths or concentrations are combined the resulting solution is not neutral. Acids and bases are compared against each other by slowly adding one solution (acid or base) to a known amount of the other in the presence of an acid-base indicator. The indicator will change color in a given pH range and at this point the relative amounts of acid and base are equal. This method is known as a titration.

Objectives:
After completion of this lab the student will be able to
1. experiment to find relative strengths of various acids and bases using the titration method.
2. identify the salt formed in an acid/base reaction.

Procedure 1: Titration of Vinegar vs. NaOH

1. Add 10 drops of a vinegar solution to a test tube. Check the pH. Record in a data table.
2. Add 25 drops of an NaOH solution to a beaker and check and record the pH.
3. Add 2 drops of phenolphthalein to your acid.
4. Add NaOH to the vinegar with an eyedropper while stirring the solution until a color change occurs.
5. Record the pH of the solution after the color change.
6. Record the amount (drops) of NaOH used.
7. Repeat the procedure testing vinegar against a baking soda solution and an HCl solution against both the baking soda and the NaOH solutions. Record data in the table.
Comparing Solutions

Procedure 1: Titrate Vinegar and NaOH
Data Table: Vinegar vs. NaOH

<table>
<thead>
<tr>
<th>Solution</th>
<th>Amount</th>
<th>pH</th>
<th>Molarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinegar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaOH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinegar + NaOH</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Write the chemical reaction for the above titration.

Repeat procedure 1 with (1) a vinegar solution and a baking soda solution and (2) HCl and NaOH.

Procedure 2: Titrate Vinegar and Baking Soda
Data Table: Vinegar vs. Baking Soda Solution

<table>
<thead>
<tr>
<th>Solution</th>
<th>Amount</th>
<th>pH</th>
<th>Molarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinegar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baking Soda Sol.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinegar + B.S. Sol.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Write the chemical reaction for the above titration.

Procedure 3: Titrate HCl and NaOH
Data Table: HCl vs. NaOH

<table>
<thead>
<tr>
<th>Solution</th>
<th>Amount</th>
<th>pH</th>
<th>Molarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaOH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCl + NaOH</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Write the chemical reaction for the above titration.
Comparing Solutions

Analysis:
1. Which basic solution was stronger, the baking soda or the NaOH?
   How did you reach this conclusion?

2. Which acidic solution was stronger, the vinegar or the HCl?
   How did you reach this conclusion?

3. If you were to mix equal amounts of the HCl solution and the baking soda solution, would the resulting solution be acidic or basic?
   Explain your reasoning.

4. How would the volumes used in the titration of vinegar and NaOH be different if the NaOH was more dilute?

5. If NaOH and HCl of equal concentrations were combined until a neutral solution was produced, what would the ratio of the volumes be?

6. Name the products in each of the titrations you have completed. Is there a pattern here?
Welcome to the fascinating world of non-Newtonian fluids! These slimes, oozes, globs and the rest all have a high viscosity, which means that they have a resistance to flow dependent on the velocity of flow and a proportionate resistance to shearing forces. If something acts on them with a small amount of force (if you stir them slowly, or let you fingers slowly sink into them) they won't offer as much resistance as they would if a greater force acted on them. If you punch a good stout oozie, it should resist about as much as a brick wall. They fight back. Non-Newtonian fluids are so called because they do not fit into one or another of Newton's laws of how true liquids behave (specifically, in how they react to shearing forces). Quicksand, many pastes and glues, gelatin, and ketchup are all Non-Newtonian fluids.

Elmer's Slime

One of the simplest of the slimes, and a favorite among schoolteachers. Not terribly toxic, but watch the kiddies so they don't eat it. It produces a lovely, white (unless you color it), opaque goo. It will dry out, so store it sealed and refrigerated (zip lock bags work well). It also has a limited shelf life, and may eventually develop mold (horrors!) It (usually) cleans up easily. If it dries on anything, try soaking in water. It is best not to set it on wood, fabric, or any other surface that does not clean up easily.

This is the quick and easy method.

Materials

Teaspoon (or metric measure)
Big jar or measuring cup (1 qt. or 1l)
Bowl - 2 quart (2l)
Measuring cup
Borax powder
4 ounce (120 ml) bottle of white glue (not school glue!)
Water (pref. distilled)
Food coloring (opt.)

Pour the glue into the jar. Fill the empty glue bottle with water, and add to the jar. Stir. You can add food coloring here if you want to be festive - a few drops will do. Pour one cup (240 ml) of distilled water into the bowl and add 1 teaspoon (5ml) of borax powder. Muddle well. Slowly add the glue mixture to the bowl, stirring as you do so. Place the thick slime that forms into your hand and knead until it feels dry. (There will be an excess of water remaining in the bowl.) It will be wet, stringy and messy at first, but the more you play with it, the better it mixes and the less sticky and firmer it becomes. Store your slime in a zip-lock in the fridge. That's it!

Artisan methods: design your slime

The thing that makes this particular slime work is the bonding of polyvinylacetate (PVAC) molecules by the Borax (sodium tetraborate). The molecules (polymers) are long to begin with, and they are tangled, which is why the glue is so viscous. Once the Borax links up some of the molecules, it becomes even more viscous. Not all of the molecules hook up, though. The more that do, the more viscous it becomes, until it reaches a point where it barely flows at all. The amount of attachment that occurs among the PVAC molecules depends in part on the concentration of Borax solution used. This is where we get the latitude for making different consistencies of slime.

All of these variations use the same simple ingredients: a solution of Elmer's glue, and a solution of Borax. The only variations are in the solution concentrations, and in the ratios that the solutions are mixed together.

Most basic recipes suggest a 4% Borax (in distilled water) solution for an average slime. This would be app. 1 teaspoon to half a cup (you've got it easy if you use metric!)
The glue to water ratio is almost always 1:1, though I have encountered 1:75. This really won't effect the viscosity, however, the amount of water that the slime retains does effect its "stickiness".

The typical glue to Borax solution ratio is 1:1. Ratios of 2:1 and 3:1 are often cited. I have seen them as high as 7:1, but usually the Borax solution was more concentrated. If you want to experiment with making different consistencies of slime, I would suggest two things. First, measure everything metrically, if possible. This makes it much simpler to keep track of concentrations and ratios. Second, start with basic solutions of 50% glue and 4% Borax, mixing them 1:1.

Experiment with increasing and decreasing the concentration of Borax solution, all else being the same. The more concentrated the Borax, the more viscous the outcome. You can actually produce something like a hard rubber ball if the concentration is correct. The lower the concentration, and the closer you approach a wet, sticky liquid. Keep notes so you can repeat the results that you like. If you can't quite get the consistency you want, vary the amount of water that goes into the mix.

Boric acid and borax method

This formula uses both boric acid and borax to produce a slime that seems drier and stiffer. Mix a solution of 100ml water (preferably distilled), 10ml rubbing alcohol, and 1 to 2ml boric acid powder. Mix well 20 - 30ml of this solution with approximately 50ml of white glue. Make a borax solution of 1 - 2ml borax to 100ml water. Add the borax solution a teaspoon or so at a time to the glue mixture. Stir continuously, adding borax solution until the desired consistency is reached. As with the other white glue slimes, kneading will make the slime drier and more viscous. If the slime feels too wet or sticky after kneading, knead in a little more of the borax solution.

Gel type glues

Over the past few years several brands of gel type glues have been introduced. Most of these make excellent slimes, and are able to be stretched into large, clear membranes. These slimes can be made to be very elastic and have a nice color and consistency. I have personally experimented with Elmer's School Glue Gel, but there are several similar products available from other manufacturers. Use the quick and easy method or the boric acid and borax method, above. If they are a little sticky when they are stored, they will tend to be stickier after a while. If this happens, see the following paragraph.

Slime overly sticky or runny?

If your white glue or gel glue based slime is too sticky or thin (runny), first try kneading it for a while. Working it in your hands will help to mix things up better, as well as remove some of the moisture. If it is still not quite right, mix 1 part borax with 10 parts water. Dunk the slime into this solution, remove and knead. The more you do this, the more "stout" the slime becomes.

PVA Slime

This is often referred to as "institutional" or "commercial" slime. This is the type that is generally found in toy stores. It is a little trickier to make, not quite as safe, and more difficult to get the main ingredient for (polyvinyl alcohol) than is the Elmer's slime. But it produces a superior slime. Longer lasting, more transparent, and with a visual and tactile appeal that is more, well, "slimy".

Assuming you can get hold of PVA, it is a fairly simple process to make slime. First, mix a 4% solution of PVA and water. 4 % would be 40 grams of PVA to 960 ml of distilled water (of course you can adjust and make more or less). Wear a mask and have plenty of ventilation when doing this! It helps to have a heated magnetic laboratory stirrer (don't use one of your good kitchen saucepans - it's best to use pyrex labware). Slowly, gradually, mix the PVA into the distilled
water. Heat it slowly, stirring the whole while, until the PVA goes into solution. This will take 15 minutes or more. Do not let it boil. Once cool, the solution can be stored in a stoppered bottle.

The 4% Borax solution is made by dissolving a gram of borax into 100 ml of distilled water. It should go into solution without heating. This can also be stored in a stoppered bottle.

Mix the two solutions in a glass or ceramic bowl. Do not use plastic. Start with the PVA solution, and stir in the coloring, if used, and borax solution. The standard ratio is 5 parts PVA solution to 1 part Borax solution. This works well, but ratios have been quoted bother slime makers as 6:1, 20:3, and as high as 200:15 (app. 13:1). The best bet is to start with the basic 4% solutions at 5:1, adjusting the ratio as necessary to get the consistency you want. Store in a sealed container. No need to refrigerate. Keep it clean and it should last indefinitely.

I read recently (and I apologize to the author, because I cannot find the page again to reference it) that the consistency of PVA slime depends also on the molecular weight of the PVA used.

Some archival art glues are actually a 5% PVA solution. It is almost certainly more expensive to purchase the glue than it would be to purchase the PVA, but, if you do happen to have a bottle around the house that you probably wouldn't use otherwise, it should work (check the ingredients!) PVA is also sold as a mold release agent for fiberglass molding, etc. Check with supply houses for molding, boat repair, or auto painting. Also, some soluble bags used in hospitals are made of PVA. If anyone knows how to make slime from these, I would like to hear about it.

Guar gum

This produces a good slime, but is tricky to make, and guar gum must be purchased from a chemical supplier.

The guar solution is made by adding a measure of guar gum to distilled water and stirring to dissolve. It will thicken more if you bring it to a simmer for a few minutes. Skim off the scum that forms on top and allow to cool.

The Borax solution should be 4%, as with the above slimes. Of all the slime recipes I have collected over the years, none vary so widely in concentrations and proportions as those involving guar gum. Typically, the guar is in 1% to 6% solution (though I have seen it up to 12%), and the ratios of guar to Borax solutions range from 10:1 up to 35:1. Start with a Borax solution of 4%, a guar gum solution of 5% and a mix ratio of 20:1 (guar to Borax). Experiment with the guar solution concentration as well as the ratio that the two concentrations are mixed together until you get the consistency you want.

To mix, pour the guar gum solution in a bowl (preferably glass; not plastic), add coloring if you so desire (a few of drops of food coloring works,) and then add the Borax solution. Stir. Guar gum slime improves with age, so let it sit a couple of days for it to be at its peak sliminess. If some happens to get in the carpet, try cleaning with a little vinegar, followed by water.

Cornstarch

Cornstarch makes a classic, sticky, messy slime. It is insanely simple to make. There are only 2 ingredients, dry cornstarch and water (food coloring optional). The lines are very thin between dry cornstarch, slime, and cloudy white starch water, so mix slowly and add the water only a little at a time. This stuff will make a mess, no matter how careful you are. Start with 2 parts cornstarch in a bowl (now is the time to add the food coloring). Slowly, add 1 part water, mixing with your hands (there really is no other way) to get all of the powder wet. Have another measure of water handy, and drop in a little at a time, mixing as you go. It will take much less water than you might think to change the consistency much, so add only a few drops at a time. You will know when it is the right amount, as the wet powder will stick together and suddenly start behaving very oddly. This slime has some of the weirdest properties. It will flow fairly quickly into the bottom of the
bowl, and your fingers will sink into it readily, but just try and punch it...

A strange variation I have not yet attempted is 1 part cornstarch to 1 part Elmer's glue.

**Electro-active cornstarch slime**

Mix 3/4 cup (175ml) of cornstarch with 2 cups (475ml) of vegetable oil. Put it into a tumbler in the refrigerator until it is chilled. Remove from the refrigerator, stir to mix (it will have separated), and let warm just enough so that it will flow. Find a block of Styrofoam, about 1 by 6 by 6 inches (25x150x150mm - not at all critical), and rub it on your hair (or a wool sweater, or a cat, etc.) to build up a static charge. Tip the container of slime. It should flow slowly. Place the charged Styrofoam just in front of it (an inch or so), in the path of the flow. The slime should stop flowing and seem to solidify. Wiggle the Styrofoam, and the slime will follow it somewhat, and pieces of it may even break off. Remove the Styrofoam, and the flow will resume.

**Metamucil "Flubber"**

You can create homemade "flubber" by using Metamucil. Place a teaspoon of the product into a shaker jar with 8-10 ounces of water. Shake vigorously for about 60 seconds, then pour the contents into a standard size cereal bowl. (Here's where it gets fun) Run at full power for 4-5 minutes... until the goo starts to "rise". It will look like bread-dough rising in a bowl, but much faster. When the bubbles are just about to overflow the bowl, turn off the microwave. Let it cool slightly and repeat the. The more times you repeat this process, the more "rubbery" the flubber gets.

After 5 or 6 runs, pour the goo onto a plate or cookie pan. With a spoon, stir the goo while it's cooling. (Be very careful, as this concoction will burn your fingers right down to the bone in a nanosecond, until some cooling has taken place.)

Once it's cooled, you have a "non-stick" Flubber. Take a knife and cut it into different-size pieces. You can shape it into all kinds of neat things... use our imagination.

If your first batch is "sticky" to the touch, you've used too much water. If prepared properly, it should feel cold and clammy to the touch, but should not stick to your fingers or anything else. If it does, try another batch with less water.

Flubber will keep for months if you store it in a baggy...it will last even longer if you refrigerate it.

---

submitted by Randy Krumland

**Various slimes**

**Methylcellulose**

Methylcellulose is what "movie" slime is made of. It is an organic thickener used in many of the foods we eat. Mixed with a little water and coloring and allowed to "set up", it makes one of the most beautiful of all the slimes (see "Ghostbusters"). Unfortunately, it is organically based and tends to stink/dry out fairly quickly. Not really recommended for home use. However, if you really feel compelled to make a batch, try some of the motion picture supply houses listed on the web.

**Baking soda and cornstarch**

A variation on the cornstarch recipie. Uses 1:1 baking soda to cornstarch instead of just the cornstarch. Supposedly makes a less sticky slime.

**Laundry starch**
Mix 1 part white glue (regular Elmer's; not school glue) with 1 part liquid laundry starch. Stir quite a bit, and let rest for 5-10 minutes. Knead the daylights out of it. It will take a while, but it will transform into a very nice ooze. If it is too sticky add a few drops more starch. Store covered.

Another variation: mix 1 part white glue with 1.5 parts starch. Proponents of this method prefer to let the solution sit for several hours, then pouring off the excess starch before kneading.

Green jelly ooze

This makes a nice jelly like ooze. First, you need to make some iron acetate. Do this by placing some steel wool in a jar, and adding enough white vinegar to cover it. Let this stand for five days to a week. Pour off some of the mixture into another. In yet another glass receptacle, add equal parts (a tablespoon or so) of this mixture and household ammonia. Use plain ammonia, not sudsy, and not scented. Instant weird green jelly ooze. Note: I haven't gotten this one to work correctly. If you know this slime, and I am leaving something out, please let me know.

Play dough

Not technically a slime, but it somehow seems to belong here all the same.

Non-hardening variety

Mix well

- 1 cup (250 ml) flour
- 1/2 cup (125 ml) salt
- 2 tsp. (10 ml) cream of tartar
- 1 cup (250 ml) water
- Few drops of food coloring

In a pan heat 2-tbsp. (10 ml) vegetable oil. Add the other ingredients, and cook 3 minutes. Stir constantly. Let the dough cool. Store in plastic wrap in the refrigerator.

Hardening variety

Mix well

- 1 cup (250 ml) flour
- 1/3 cup (83 ml) salt
- 6-8 tbsp. (30-40 ml) water
- Food coloring, if desired

Add the water gradually, using only enough to produce a workable consistency. To set, bake at 300° F until hard.

More recipes!

Here are a few other recipes that have been sent to me. I haven't tried them yet, so no guarantees!

"Just a quick FYI for your interest: many years ago I found out that one can make a substance somewhat like Silly Putty by simply mixing sodium silicate (which used to be available in drugstores (no longer, alas!) and which was also used to coat eggs - it sometimes was carried as 'egg preserver') with everyday rubbing alcohol. The two combine to form a jell-like substance that exhibits flow somewhat like putty. The ratios are not terribly critical."

- Submitted by Bert Koehler

"One of my students went home and tried to duplicate the slime, but didn't have borax so he
used Chlorox (liquid laundry bleach) instead. The result, which he brought in, was not slimy and much more like "Silly Putty". You might want to give it a try."

- Submitted by Cassandra L Whitsett

**Slime rules and safety**

- Slimes can wreak havoc with plumbing, so don't throw them down the drain.
- Always wear a mask when mixing PVA.
- Use distilled water for all solutions for best results.
- Keep slimes away from anything they could damage. They can dry into fabric, and any dyes they may have can stain. All slimes can potentially harm surfaces, especially wood.
- Supervise small children when playing with slimes so they do not ingest any.
- Some people are allergic to Borax powder. Wearing rubber gloves when mixing should help.
- Slimes using Borax solutions work best if you pour the Borax solution into the other solution, rather than the other way around. Coloring should be added before the Borax.
- Use metric measurements whenever possible. This will make it simpler to experiment with different concentrations and ratios.

If you want to know the ingredients to the king of all slimes, Silly Putty, check out [http://www.sirds.com/sillyputty/creations/ingredients.html](http://www.sirds.com/sillyputty/creations/ingredients.html). You won't be able to make it (unless you happen to be a chemist) but it should slake your curiosity.
PERCENT COMPOSITION

Experiment

When you make a new compound in the laboratory, you need to determine its formula. One of the first steps in doing this is to find the relative amounts of the elements in the compound. These relative amounts are expressed as the percent composition, the percent by mass of each element in the compound. The percent by mass of an element in a compound is the number of grams of the element divided by the grams of the compound, multiplied by 100.

\[
\% \text{ mass of element } E = \frac{\text{grams of element } E}{\text{grams of compound}} \times 100
\]

In this experiment, you will consider a post-1983 penny as your "compound." Since 1983, pennies have been made of a copper shell around a zinc interior. Prior to 1983, pennies were made completely of copper. By filing off the edge of the penny, the zinc interior will be exposed. When combined with hydrochloric acid, HCl, the zinc interior will react and dissolve, but the copper shell will remain. By knowing the mass of the penny before the reaction and the mass of the copper shell after the reaction, you can calculate the % copper in the copper penny "compound."

\[
\% \text{ Copper} = \frac{\text{Mass Cu shell}}{\text{Mass penny}} \times 100
\]

PROCEDURE:
1. File off the copper edge of a penny half way around the penny.
2. Determine the mass of the penny to the nearest .01 g. RECORD THE MASS.
3. Put the penny in a clean, dry 100 mL beaker.
4. Add 30 mL of 6.0M HCl. Allow the reaction to go to completion. Approx. overnight.
5. Using tongs, remove the copper shell from the acid. Rinse it at least 3 times with deionized water.
6. Insert a narrow strip of filter paper into the hollowed out portion to blot up the liquid inside.
7. Dry the coin. Determine its mass to the nearest .01 g. RECORD THE MASS.

DATA:

Mass of penny before reaction

Mass of copper shell after reaction

QUESTIONS AND CALCULATIONS:

Calculate the % copper in the penny.
Calculate your % error.

Calculate the % of element in the periodic table that are:

1. alkali metals

2. p block elements

A 36 gram sample of iron oxide contains 28 g Fe and 8 g O. What is the % Fe in the compound?

A 160 g sample of iron oxide contains 112 g Fe and 48 g O. What is the % Fe in the compound?

Are the samples the same iron oxide compound? Why?
BEER/SODA CAN OPENING: A PROPER METHOD

If you've ever shaken a can of soda before opening it with a can opener or popping the flip top, you know the mess that can occur when the soda sprays from the can. Some of the more experienced soda drinkers know of a technique that eliminates the mess:

Tap the sides of the soda can before opening it. Tapping the sides prevents the soda from spraying out.

Let's see what Boyle's law has to do with this. When you shake a can of soda, the tiny gas bubbles created by the shaking adhere to the sides and the bottom of the can.

What happens to the tiny gas bubbles adhering to the sides of the can when the can is opened? (Hint: Soda cans are sealed under pressure.)

When a can of soda is opened, the pressure inside the can is reduced. The pressure reduction causes the gas bubbles adhering to the inside wall to expand, pushing out the soda and making the aforementioned mess.

How does tapping the sides of the soda can eliminate this mess?

Tapping the sides of the soda can causes the tiny gas bubbles to rise to the top of the can where their expansion (when the can is opened) is noticed only by a rush of gas from the can (as opposed to a rush of soda).

Buy a six-pack this weekend and perform this experiment yourself.

IT'S GETTING COLDER (FREEZING POINT DEPRESSION)

PURPOSE

The purpose of this experiment is to demonstrate the effect of solutes on the freezing point of water.

DESCRIPTION

This experiment is suitable for a first-year course. It could also be included in a second-year course as part of a unit on colligative properties. The calculations require the use of the equation, \( T = (K_f) (m) (i) \). In the first part of the experiment, various solutes are added to water and the resultant freezing points of the solutions are determined. The value of \( i \), dissolved particles per formula unit, is calculated. In the second part, the molar mass of commercial antifreeze is determined.

TIME REQUIRED

Two 40 minute lab periods.

MATERIALS

Chemicals:
- ice C\(_{12}\)H\(_{22}\)O\(_{11}\) (sucrose)*
- NaCl
- commercial automotive antifreeze*

Equipment:
- test tubes
- thermometer
- 400-mL beaker*
- 100-mL graduated cylinder
- stirring rod

*See Modifications/Substitutions

HAZARDS

Since commercial antifreeze is primarily ethylene glycol, it is highly toxic and should not be ingested. The ice used in the experiment could become contaminated with antifreeze by accident; students should be warned not to eat the ice. Goggles must be worn throughout the experiment.

MODIFICATIONS/SUBSTITUTIONS

1. Table sugar may be substituted for reagent grade sucrose.
2. Table salt can be substituted for laboratory grade NaCl.
3. Since antifreeze is mostly ethylene glycol, the chemical reagent itself could be used.
4. A 10 ounce Styrofoam cup can be substituted for the 400-mL beaker.

PROCEDURE

Preparation of Ice Bath
1. Fill the large beaker 3/4 full with ice.
2. Cover the ice with 1/4 to 1/2 inches of table salt.
3. Stir this ice-salt mixture with a stirring rod and make sure the temperature drops to at least -10°C.

Determination of Freezing Points of Solutions:

1. Prepare a solution of NaCl by adding 5.8 grams of NaCl to 100 mL of water. Mix until all crystals dissolve.
2. Prepare a solution of sucrose by adding 34 grams of sucrose to 100 mL of water. Mix until all crystals dissolve.
3. Place a test tube that is 1/2 full of water in the ice bath.
4. Stir the water in the test tube gently with a thermometer while keeping track of the temperature.
5. When the first ice crystals appear on the inside wall of the test tube, record the temperature. This should be the freezing point of the liquid. (In this step water is the pure solvent).
6. Repeat steps 3-5 with the prepared NaCl and sucrose solutions.
7. Using the equation, $T = (K_f)(m)(i)$, determine the value of $i$, where $i$ is the number of particles produced per formula unit and $K_f$ for water = 1.86°C/m.

Molecular Mass Determination From Freezing Point Depression

1. Dissolve 6.2 grams of commercial antifreeze in 100 mL of water.
2. Freeze this solution in the same manner as in the previous experiment. Be sure to record the freezing point temperature.
3. Calculate the molecular mass of this solute based on the freezing point depression.
   Molecular mass of solute = $\left\{\frac{(K_f) \text{ (grams of solute)}}{(T) \text{ (kg of solvent)}} \right\}$

DISPOSAL

All solutions may be flushed down the drain with plenty of water.

DISCUSSION

Colligative properties of solutions depend upon the concentration of solute particles. The freezing points of water solutions are always lower than that of pure water. The change in freezing point caused by the presence of a solute dissolved in water can be calculated from the equation,

$$T = (K_f)(m)(i),$$

where $K_f$ is the molal freezing point depression constant (1.86°C/m for water), $m$ is the molality of the solution, and $i$ is the number of particles produced per formula unit.

Molality = moles of solute/kg solvent

Since colligative properties depend upon the number of particles in solution, a one molal solution of an electrolyte (NaCl), which dissociates in water, lowers the freezing point more than a one molal solution of
a non-electrolyte (sucrose). The freezing point of a one molal solution of NaCl is actually -3.37°C, only 1.81 times that of a non-electrolyte, not the -3.62°C that would be expected if NaCl were completely dissociated. This difference is believed to be due to the interionic attractions that prevent the ions from behaving as totally independent particles. The activity or effective concentration of the ions is less than would be indicated by the actual concentration. Some of the ions may exist as solvated units called an ion pairs. The more dilute the solution of an electrolyte, the more widely separated the ions, the less the interionic attractions, and the closer the effective concentration of the ions approaches the actual concentration.

TIPS

1. This activity is easily accomplished in two parts and can be completed on different days.
2. The freezing point depressions of the salt and sucrose solutions could serve as the starting points of a study of colligative properties.

REFERENCES


Submitted by Joe MacQuade, Gina Monks, Doug Rickard, Irene Walsh, and Joe Wilkins
Ice Cream: Freezing point depression lab

Materials needed:

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ice</td>
<td>(one each per student)</td>
</tr>
<tr>
<td>Salt (1 Tbsp. per student)</td>
<td>Zip-lock plastic bags, quart size</td>
</tr>
<tr>
<td>Milk (4 ounces per student)</td>
<td>Zip-lock plastic bags, gallon size</td>
</tr>
<tr>
<td>Vanilla (1/4 tsp. per student)</td>
<td>Plastic spoons</td>
</tr>
</tbody>
</table>

Safety note: clean up your lab area thoroughly before doing this lab. This is one of the very few labs in which you are permitted to eat your product. Take care that you don't use any lab glassware in measuring your materials, and that you don't put your plastic spoons down on the lab benchtop, which might be contaminated with chemicals. Ethylene glycol, which may have been used in a previous lab, is very toxic and should not be anywhere near food items.

Work in pairs.

Place a generous amount of ice in two large zip lock bags. Add 6 tablespoons of salt to ONE of the larger bags of ice. Knead and squeeze the bag with salt in it a little to mix the salt with the ice. Record the temperature of each.

Into each of two small zip lock bags, put 1/2 cup milk, 1/4 tsp vanilla, and 1 tablespoon sugar. Squeeze out all the air and seal the bags shut.

Place one of them in each of the larger bags of ice, taking care NOT to get salt into the small bag.

Knead the ice bags, (each partner takes one set) causing the inside bag to be kneaded also, by shifting side to side, and squeezing until the milk mixture becomes hard. What do you observe?

After about 8 minutes observe the appearance, and take temperature readings in the ice mixture in each bag. Record these temperatures.

You may eat your ice cream when it is ready. You will probably want to move the small bag in the big bag without salt into the one with salt and knead it to make it freeze.

Read through the Freezing Point Depression Lab, and then explain as you would to elementary age children, why the ice cream froze in one bag, and not in the other. When doing this activity with a group you may want to bring in other ingredients, such as chocolate syrup or fresh fruit to add, being careful to avoid anything to which your students might be allergic.
In the Classroom

Work in your lab group:

You are to prepare a lesson on some topic of chemistry suitable for an elementary class. List safety concerns, materials needed, preparation required, what the kids need to know and understand prior to the lesson, and your lesson objective. State what grade level the lesson is intended for in your materials, but do not reveal this information.

Look up the MSDS for any (chemical) materials you will use on the Internet. When you find a website that is a good source for Material Safety Data Sheets, bookmark it for future use. Make sure that you take all appropriate safety precautions.

Write out the instructions for the class, as you would give them. (your script, so you don't miss anything.) Include activities or sequences suitable for all 4 types of learners (as in "How We Learn and Why We Don't")

Closure: How will you measure whether your objective has been met?

Do the lesson for the lab next week. You will need to supply all materials not already in the lab. Members of other lab groups will be the students, Do not tell them what grade level you have intended it for. Do the whole lesson, and then a critique following.

Critique questions:

Were the instructions clear? (How could they be made clearer?)

What grade level(s) was it appropriate for?

Was it fun to do?

Did the activity get the content/concept across?

What could be added, what should be shortened or eliminated, to make the lesson concept clearer?

What additional safety concerns might be considered?

Were all 4 types of learners served? What could be added/changed to do this?
**Acceleration Due to Gravity**

**Background:** Dropped objects and projectiles fall toward the Earth and gain velocity as they fall. Wind resistance may significantly affect the fall by providing an upward force that increases with the increasing velocity of the fall. Sometimes, as is desired in the use of parachutes, the wind resistance may increase until it finally balances the downward pull of gravity, resulting in a terminal (maximum and non-accelerating) velocity that remains constant for the remainder of the fall. Small, dense objects, such as balls of clay or ball bearings, experience comparatively little wind resistance and may, therefore, accelerate throughout short falls without noticeable effect of wind resistance.

**Look it up:** To three places, what is the accepted value of the acceleration of gravity in Clemson, SC?

**Materials:** Meter stick or metric tape measure  
Ping-Pong ball and similarly-sized ball of clay  
Small, dense objects to drop, such as tightly packed wads of paper or clay balls  
Stopwatch

**Objectives:** To develop a set of safety rules for students to follow for this lab.  
To develop a procedure for minimizing timing error due to human response time.  
To measure the time required for an object to fall from given heights.  
To use acceleration and/or velocity equations to calculate the value of one requested unknown at a time.  
To compare the falls of objects of similar size and shape, but differing densities.

**Procedures, data presentation, questions:**

**Part 1:** 1) A major problem in timing the fall of objects over relatively short distances is that the reaction time of the person timing may represent a significant percentage of the total time recorded and may, therefore, account for large timing error. Within your group, discuss how you might minimize this error, then describe your procedure below.

2) **SAFETY** - During this lab, you will be using the stairwells and the atrium. You will also be dropping objects small enough to fit within the human eye socket to endanger the eyeball itself. What safety rules would you have your future students follow under such conditions? Describe the rules you develop below. Have them approved by the lab assistant before proceeding, and follow them for the rest of this lab.
Questions: 1) During this lab, you will drop clay balls or tightly wadded paper balls.
   a) Why is the small, tight, spherical shape of a ball preferred?

   b) Why not use steel ball-bearings or other dense and/or high-bouncing balls?

   c) Since multiple balls will be used, what factors will you control to keep your test “fair”, and how will you control these factors?

Part 2: 1) Follow the procedure you described earlier to minimize timing error, and follow all safety rules discussed and suggested.

   2) *** Prepare a data table for your results, including a title and headings.***

   3) Using the atrium stairwell, time the fall of your clay or paper ball over distances of 2.0 m, 3.0 m, and 4.0 m.

Part 3: 1) Remember that: \( \frac{v}{v_{avg}} = \frac{d}{t} \) \( \frac{v}{v_{avg}} = \frac{(v_i + v_f)/2}{v_f - v_i} \)

   2) *** Prepare a data table for calculation results, including a title and headings. Columns are needed to show initial velocity for each of the three heights and calculate average velocity, final velocity, and change in velocity for each. ***

   3) *** Prepare a graph of change in velocity versus height for the three heights, including title and correctly labeled axes. ***

Questions: 1) Calculate the slope of your graph, showing work below.

   2) Explain why this slope represents the acceleration of gravity and what the unit must be, based on the calculation.
3) How does the acceleration of gravity you determined in #1 compare to the accepted value you looked up? Calculate the relative error for your measurement.

4) What reasons could explain the relative error has the value you found?

**Part 4:**
1) One group member should go to the 4.0 m stairwell height and prepare to simultaneously drop the Ping-Pong ball and a similarly-sized ball of clay.

2) Other members should be in position to observe.

3) Following safety rules, simultaneously drop and observe several times.

**Questions:**
1) Describe what your group members observed as the Ping-Pong ball and clay ball fell simultaneously.

2) Why is wind resistance more obvious in its effect on low density objects?

**Part 5:**
1) You will time paper or clay balls falling from the fourth floor of the atrium, using the procedure and safety rules you developed earlier.

2) At least one group member will be going to the fourth floor balcony with at least three paper or clay balls. At least one group member will time from the floor of the atrium. Describe how any other group members will be utilized in the space below, and also describe the point from which the ball will be dropped (floor level, balcony rail height, etc.).

3) *** Prepare a data table and use it to present your results. ***

4) Remember that: \[ d = v_i \cdot t + \frac{(at^2)}{2} \]
5) Use the average of the times from step #3 and the accepted (looked up) value for “g” to calculate the height of the ball before dropping. Show work and answer below.

6) If the paper were thrown out horizontally from the balcony (or rolled off the edge at floor level) at an initial horizontal velocity of 0.5 m/s, how much time would it have to travel horizontally before it lands?

7) How far (horizontally) from a point directly below the balcony edge would it land?

8) Have one group member roll a ball across the floor of the balcony and off the edge as another drops a ball from the same height. Describe the result as seen by various observers. You may need to combine with another group to ensure adequate observers.

9) Why is the accepted value for “g” used in step #5, rather than the value you found earlier in the lab?
Magnetic Compasses and Motors

**Background:** The Earth has magnetism and the area in which this magnetism can be observed is called the Earth’s magnetic field. A magnet mounted or hung so it is free to move will align itself with the Earth’s magnetic field, if it is free of interference from other magnetic influences. Much information about the Earth’s magnetic field, as it is today and has been in the past, is available, but the cause(s) of the Earth’s magnetism is/are still debated. Magnets respond to the presence of magnetic elements, as well as to the presence of magnetic fields. Overlapping magnetic fields can interact to produce combination effects. An electric current causes magnetism, and controlling the current controls the magnetism. Magnetic fields, through their interacting forces, can do work such as causing motor parts to move.

**Look it up:**

1) To what Earth locations do the terms “geographic north pole” and “magnetic north pole” refer?

2) Describe how the terms “north-seeking pole” and “south-seeking pole” apply to magnets.

3) Give two examples of geological evidence that the Earth’s magnetic field has changed over time.

4) Compare compass readings to “true” (geographic) north for Clemson, SC.

5) What great advantage did the magnetic compass give early human sailors?

**Objectives:** To build a functioning compass.

To study the response of a compass to a magnet.

To investigate how magnets can cause rotary motion.

To investigate the response of a compass to iron or steel objects.

To investigate the response of a compass to the magnetism caused by an electric current.
To investigate the magnetism around a current-carrying wire.
To investigate the magnetism and poles of a coil of current-carrying wire.

Caution: Keep magnets at least 30 cm away from computers, cassettes, and computer disks at all times.

Materials: One D-cell with holder or one 6V lantern battery
One large steel bolt (3”X 1/4”)
One bulb and bulb socket for source selected from above
One purchased magnetic compass
Three plastic cups
Four identical, strong, flexible magnets, each with a hole in the center and unmarked poles
One additional magnet of any type, with unmarked poles
Three small paper clips
One straight pin 2.5 cm long
Two #16 rubber bands
Five small colored stickers
Two plastic drinking straws
One switch made of a bulb socket and a short, fat bolt
Four pieces of #22 wire, each 20 cm long (may be hook-up wire)
Three pieces of #22 coated hook-up wire 20 cm long
One piece of #22 coated hook-up wire 80 cm long
One piece of #22 coated hook-up wire 1.5 m long
One wire-stripper (may be shared with another group)

Procedures, data presentation, questions:

Part 1: 1) Obtain a Student Activity Book for the NSRC/STC Magnets and Motors kit.

2) Follow the directions on pages 13-16 for building and balancing a compass. Build two compasses.

3) Working with your compasses 0.5 m apart, test each compass. To test, release the compass several different times, having it pointing to a different part of the room before each release. Allow the compass to swing slowly to point north-south while checking and adjusting the balance.

Questions: 1) *** Draw a sketch that illustrates the alignment of your compasses within the lab room. ***

2) Compare the alignment of your compasses to that of the compasses of at least three other groups.
3) Use your colored sticker to mark the NORTH side of each of the four magnets in your compasses.

4) Compare the alignment of the compasses you built to the purchased compass you were given. If they do not agree, which is more likely correct and why?

5) Suggest two changes your future students could make, in the structure of the compass you built, that could be tested against the original for a science experiment or project.

**Part 2:**

1) Move your compasses together until they are almost within each other’s rotational area. Test the interaction between the like and opposite poles of the magnets as you bring the ends of your compasses together. Describe the interactions and the effects on the compasses in the space below.

2) Locate and mark the north pole of your fifth, unused, flexible magnet. Describe your procedure for doing so below.

3) Use your fifth magnet to make one of your compasses spin in a continuing spin. Describe how you did so below.

4) Bring your steel bolt near one end of your compass. Describe the result.

**Questions:**

1) How did the compass’ response to the steel bolt differ from its response to the fifth magnet?
2) Boy Scout and ROTC groups teach orienteering, which is traveling from point to point using a compass and a map as guides. Beginners are warned to stay away from large, metal objects, such as dumpsters and eighteen-wheelers, while using the compass. Explain why this is good advice.

**Note:** As you work on the parts that follow, turn off the switch whenever you are not using current. This will prolong the life of your battery.

**Part 3:**
1) Use a wire-stripper to remove about 1 cm of insulation from each end of your five hook-up wires (three 20 cm, one 80 cm, and one 1.5 m piece -- the 1.5 cm piece will not be used until later).

2) Turn to pages 23-24 of the *Motors and Magnets* Student Activity Book. Work through all six steps, using the purchased compass you were given for the compass.

3) Repeat steps 4-6, but this time have the compass under the wire with the needle pointing perpendicular to the direction of the wire.

**Questions:**
1) Describe how and why the switch you used works, sketching if you like.

2) Describe the results of steps 4-6, in which you start with the compass under the wire, with the needle pointing the same direction as the wire.

3) Describe the results of steps 4-6 when you altered the steps to start with the compass under the wire, with the needle pointing perpendicular to the direction of the wire.
4) When and why does the compass needle move in response to the current in the wire?

**Part 4:** 1) Turn to pages 28-30 of the *Magnet and Motors* Student Activity Book.

   2) Follow steps 3 and 4 to make and test a current-carrying coil.

   3) Locate and identify the poles of your coil. See step 5 for help. Test to see if you can pick up paper clips with the poles.

   4) Reverse the direction of your current by reversing the battery in its holder (for the D-cell) or reversing the wires connected to it (6V lantern battery). Locate and identify the poles of the coil again.

   5) Follow step 7 to build a coil with a steel core. Locate the poles. Use the electromagnet you have build to pick up paper clips.

**Questions:**

1) How does the strength of the empty coil compare to the strength of the single wire, as measured by the reaction of the compass? Test each again, if needed.

2) What causes the difference you described in #1?

3) Draw a sketch of your coil and label the poles. Include the direction of the current in your sketch.
4) Describe the effect on the poles of reversing the current through the wire.

5) How does the strength of the electromagnet with the steel core (bolt) compare to the strength of the empty coil? Justify your answer.

6) List four or more changes your future students might make in the construction of this electromagnet that could be experimentally tested against the original for a science project.

**Part 5:**
1) Turn to page 43 of the *Magnets and Motors* Student Activity Book.
   2) Follow instruction steps 1-5 for making a motor.

**Questions:**
1) Describe the steps needed to keep the motor spinning.

2) List three changes your future students might make in the construction of this motor that could be tested experimentally for a science project.
Diagramming Forces

**Background:** Forces are pushes and pulls that act on objects. A force diagram represents forces. Forces are vector quantities which have magnitude and direction, and arrows known as vector arrows are used to represent forces in diagrams. The length of a vector arrow is drawn proportional to the size of the force it represents. The arrow starts from the object on which the force acts, and its direction shows the line along which the force acts (the force’s direction). By analyzing the combined effect of forces shown in a diagram, a student can determine whether the forces acting on the object are balanced or unbalanced.

**Look it up:**
1) If forces acting on an object are balanced, what type(s) of motion may the object experience?

2) If forces acting on an object are unbalanced, what type(s) of motion may the object experience?

**Materials:**
- Rubber band
- Books
- Bottle (a soft drink bottle, with top, will suffice)
- Ramp of flat cardboard and a support
- Large, soft sponge
- Meter stick
- String

**Procedure, Data Presentation, and Questions:**

**Note:** Obtain paper to use for your force diagrams. You will probably find graph paper easiest to use, as it will facilitate direction and arrow length determinations. The force diagrams will be attached to these pages as you normally attach your data tables and graphs. You will need enough paper for ten (10) force diagrams.

**Part 1:**
1) In the instructions that follow, you are given number values for force. Include the scale you use on your diagram, such as 1 cm = 10 N.

2) Draw a diagram with a vector arrow representing a 20 N force acting to pull an object to the right. Let a square box represent the object.

3) Draw a force diagram showing the object above (which weighs 50 N) sitting on a table as the 20 N force acts to move it across the table horizontally to the right. Include vector arrows for the force of gravity (weight), the force from the table supporting the object (normal force), and a 10 N force of friction resisting the 20 N pull.
4) Draw another force diagram as above, but let the force of friction be 20 N.

**Questions:**
1) Consider your force diagram for step #2. Describe the motion(s) of the object that would result. Justify your answer.

2) What two possibilities may exist for the object’s motion in step #3? Justify your answer.

**Part 2:**

1) In the force diagrams for this section, you will be showing forces acting on a bottle. You may use a square box to represent the bottle, if you desire. You will not have exact number values for your forces, but the relative length of the vector arrows you draw should give a valid comparison of magnitude.

2) For each of the following, draw a force diagram that includes all the forces acting on the bottle. You do not have to show objects other than the bottle in your diagram, but you may. You must include forces from these objects that act on the bottle, whether you show the objects or not. If your bottle is plastic, not glass, add water to it for additional weight.

Be sure your diagram makes it possible to evaluate each force’s direction and relative magnitude. Label each diagram with a letter that corresponds to the situation description, as given below:

a) Balance the bottle on the palm of a group member’s outstretched hand. Diagram.

b) Wrap a rubber band around the neck of the bottle. Suspend the bottle in the air by holding the rubber band. Diagram.

c) Place the extreme ends of your meter stick on books so the center of the stick is unsupported, as in the center span of a bridge. Fill the bottle with water and carefully place it in the center of the meter stick. Note the bending of the stick. Diagram.

d) Place the sponge on the table. Place the bottle on its side on the sponge. Push the bottle horizontally until the sponge is visibly affected. Diagram.

e) Attach a string to the bottle’s neck. Make the bottle move on the floor in a circle at constant speed. **Caution:** Be safe and keep the speed low. Diagram.

f) Prop the cardboard and its support to form a low ramp or incline. Place the bottle upright on the incline. If it will not stay as placed, adjust the incline. Diagram.

g) Place the bottle on its side on the ramp and observe to be sure it will freely roll down. If not, adjust the incline. Diagram the bottle at the point at which you release it, after placing it on the incline.

**Questions:**
1) What is true of the forces in all the situations in which the bottle is stationary? How is this shown in the diagrams?

2) What is true of the forces in “e”, in which the bottle moves at constant speed? How is this shown in the diagram?

3) What is true of the forces in “g”, in which the bottle accelerates down the incline? How is this shown in the diagram?

4) In “b”, “c”, and “d”, the rubber band, meter stick, and sponge were each affected as force was applied by the bottle. What name(s) do we give the type of force each applied to the bottle in response?

5) Which of Newton’s Laws of Motion describes the force the objects apply to the bottle as it applies a force to them?

6) If the sponge in “c” were removed to allow the bottle to rest on the table, what name(s) would we give the force that would resist the bottle’s motion as you pushed it horizontally?
Forces in Fluids

**Background:** Pressure is defined as force per unit area. Fluids (liquids and gases) exert pressure in all directions. This is most obvious when pressure causes dramatic effects, such as a pipe leak or floating an aircraft carrier, but is also present and observable when the effects are less obvious.

**Look it up:**
1) What is the standard value of atmospheric pressure and under what conditions does this value exist?

2) How does atmospheric pressure in Clemson today compare to standard atmospheric pressure? Give some factors that cause the two to differ.

3) State Bernoulli’s Principle.

**Objectives:**
To observe and describe the relationship between pressure exerted by a fluid on a point and the depth of the fluid at that point.
To analyze forces acting on an object experiencing Bernoulli’s Principle.
To fold, fly, and control the flight of a paper airplane.

**Materials:**
- Bottle or jar
- Two index cards
- Large Styrofoam cup
- Pan
- Scissors
- Tape
- Paper towels

**Procedures, Data Presentation, and Questions:**

**Part 1:**
1) Draw a line, from bottom to top, on the outside of your Styrofoam cup.

2) Use a pencil or pen to poke small holes, all the same diameter, every 2 - 3 cm along the line.

3) Place tape on the outside of the cup, covering the holes. Fill the cup with water and hold it about 30 cm over one edge of the pan, with the holes pointed toward the pan.

4) Quickly pull the tape to uncover all the holes at once and observe the streams of water that result. They should land in the pan. If necessary to confirm your observations, carefully dry the cup, retape the holes, then repeat.
Questions:
1) Compare and contrast the water flow from the various holes in the cup.

2) At which level is water pressure the greatest? How do you know?

3) State the relationship between depth of water and pressure exerted by the water at that depth.

Part 2: 1) Fill the pan three-fourths full of water.

2) Invert the bottle and lower it (mouth down) into the pan of water. Describe the results.

3) Fill the bottle completely with water, and place an index card over the mouth of the bottle. If the mouth is very small compared to the index card, cut the card in half. While holding the card in place over the bottle mouth, invert the bottle over the pan. Carefully remove your hand, leaving the card. Describe the results.

4) Repeat step #3, but lower the bottle into the pan so the pan’s water level is above the mouth of the bottle. Slide the card sideways off the mouth of the bottle while continuing to hold the mouth under water. Describe the results.

Questions: 1) Explain the results of step #2 in terms of forces.

2) Explain the results of step #3 in terms of forces.

3) Explain the results of step #4 in terms of forces.
**Part 3:**

1) Hold a paper towel or sheet of paper by its two upper corners. Rotate your hands so the towel or paper forms a curve at its top above your hands.

2) Move the towel so the curve is in front of your face, just under your bottom lip. Blow air over the curve and observe. Describe the results.

3) Draw a line on each side of an index card. Each line should be parallel to a short edge and 1.0 cm from that edge.

4) Fold the card along each line so the 1.0 cm fold is perpendicular to the rest of the card. Set the card on the table so it sits like a little table itself. Blow under the card, moving it to the edge of the table if necessary. Describe the results.

**Questions:**

1) Does the movement of the paper you blew over indicate greater pressure above or below the paper? Explain.

2) Does the movement of the index card indicate greater pressure above or below the card? Explain.

3) Explain your observations of the two in terms of Bernoulli’s principle.

4) Airplane wings are typically straight on the bottom and curved on the top. Draw such a shape (a wing seen from the side) in the space below. Explain why air going over the wing speeds up as compared to nearby air that goes under the wing, and, based on this speed difference, explain why the plane experiences a lifting force when moving.
Part 4: 1) Make a paper airplane and fly some test flights.

2) Using scissors, cut flaps (ailerons) into the wings and a rudder into the tail.

3) Try various combinations of flaps up and down and rudder left and right. Describe how each should be set to send the plane (a) right, (b) left, (c) up, and (d) down.

Question: 1) How does air pressure on the plane vary as the control surfaces are moved, and how does this produce forces that control the plane’s movement?
Gravitational Force and Motion on Inclines

**Background:** Unbalanced forces cause the motion of objects to change. An object with only balanced forces acting will show no change in motion. Single forces may be studied by determining perpendicular component forces that would act together to produce the single force.

**Look it up:**
1) Define inertia.

2) Explain what is meant by the term free-fall.

3) Draw a labeled sketch to show the X and Y directions commonly used for components of the weight of objects on an inclined plane.

**Objectives:** To analyze observations of falling objects.
To divide a single force into perpendicular forces.
To describe and compare the forces acting on a pulled block of wood.

**Materials:**
- Wood block with cup hook or bent nail embedded
- Paper cup
- Half-sheet of standard paper, made by horizontally cutting a full sheet
- Protractor
- Ramp or incline made of a flat sheet of cardboard and something to support the cardboard, such as a piece of plywood or section of 1”X 6” board
- Spring scale
- Steel washer
- Textbook

**Procedures, Data Presentation, and Questions:**

**Part 1:**
1) Predict which will fall faster, your open half-sheet of paper or the steel washer.
   Justify your prediction below.

2) Drop the paper and washer, each held flat and parallel to the floor, from the
same height at the same time. Describe the results below, repeating the drop as needed to clarify observations and reach group agreement.

3) Drop the paper and washer, each held perpendicular to the floor (edge will face floor) from the same height at the same time. Describe the results below.

4) Place both the paper and the washer on top of a lab book so no part of either extends beyond the edge of the book. Predict which will fall faster if you drop the book while the objects are on top. Justify your answer below.

5) Drop the book as described. The bottom of the book should be parallel to the floor at the time of release. Describe the results.

6) Place the paper and washer back on the book’s top. Holding the book and keeping hands clear of the book top, swiftly pull the book to the side with a quick, strong force, moving the book parallel to the floor. Describe the results.

**Questions:**

1) Explain why your observations for #2 and #3 of part 1 differed as the orientation of the paper and washer differed.

2) Students sometimes believe there is a strong attraction between the book and the objects on top, explaining the observations in step #5. Using your results from #6, offer proof as to why there is no such attraction, limiting yourself to terms an elementary student can understand.

3) Explain why the paper and washer fell as they did in step #5.
4) Describe how inertia was demonstrated in step #6.

5) In what procedures of part 1 was free-fall demonstrated?

6) In what procedure(s) was /were unbalanced forces demonstrated and in what procedure(s) was /were balanced forces demonstrated?

**Part 2:** 1) Use your pencil or pen to make a hole in the bottom of your paper cup and another in the side near the bottom (2 or 3 cm up from the bottom).

2) Cover the holes with your fingers and fill the cup with water.

3) Hold the cup over a sink or trashcan and uncover the holes.

4) Once water begins to run freely from the cup, drop the cup. Record observations below.

**Questions:**
1) Why does the water flow from the cup when you uncover the holes?

2) Explain your observations of the water’s behavior when you drop the cup while the water is flowing.

3) Cartoon physics often differs from real-life. Comment on the cartoon characters who maneuver up and down in the air while falling -- what degree, if any, of truth is there in this behavior?
Part 3:  1) *** Prepare a data table with a title and headings. Have rows for angles of incline and columns for weight of the wood block, pulling force, sine of the angle times the weight, cosine of the angle times the weight, and movement. ***

2) Place the hook of your spring scale through the cup hook or bent nail in the wood.

3) Holding the scale, suspend the block in the air and determine the force reading. What is the force reading, and what name do we give this force?

Note: As you proceed with this part, you will be pulling the wood block across your cardboard with the spring scale. The scale must be kept parallel to the cardboard at all times when pulling. Each group member should watch to be sure pulling technique is correct, as it will be hard for the “puller” to tell.

4) Set the cardboard flat on the table or floor. Pull the wood block across the cardboard at a constant speed. You may have to repeat several times to be confident of your scale reading. Record the scale’s force reading for the pulling force on your table (first row, which should be labeled “zero degrees”). Release the block by removing the spring scale.

5) Give the block a gentle push to get it moving. In the movement column, note whether the block continues to slide on its own by writing “yes” or “no”.

6) Prop the cardboard and its support to form a 10 degree incline or ramp. Use the spring scale to pull the block up at a constant speed. Record the force. Release the block and note whether it moves (slides down) once given a gentle downward push.

7) Change the ramp to add 10 degrees to its incline and repeat #6 for the new angle.

8) Continue to change the incline in 10 degree increments until the ramp is at 80 degrees. Repeat your observations at each new angle and record results.

9) Complete your data table by calculating the sine of the incline angle times block weight and cosine of the angle by block weight for each angle.

Questions:
1) In step 4, what force was measured as you pulled the block horizontally at constant speed?

2) Why is it necessary to keep the spring scale parallel to the ramp at all times when
pulling the block and reading the scale?

3) In all pulls in which the ramp is at an incline, not horizontal or zero degrees, what combination of forces must the pull on the spring scale overcome to move the wood block up the incline?

4) Gravity tends to make the block slide down the incline once it is no longer horizontal. What other effect does gravity have on the block (that is, what else does it tend to make the block do)?

5) Identify the X (sine of angle times weight) and Y (cosine of the angle times weight) components of the weight in terms of what the block tends to do -- see question #4.

6) The component of gravity you identified in #5 always acts to slide the block down incline when the angle of the incline is greater than zero degrees. However, the block does not always slide when released and pushed. What counteracting force acts up the incline against this component of gravity and what is its size? Describe how the force was measured earlier in the lab.

7) The wood block should slide down the incline at constant speed when the force up the incline equals the force down the incline (balanced forces), although a slight push to start the motion may be needed.

   a) At what incline angle is the slide down at or near a constant speed after a push, according to your lab results?

   b) Compare the calculated component of gravity (force down the incline) to the upward force at the angle of constant speed slide, using your measured values.

8) At angles greater than that necessary for constant speed, does the block accelerate? Explain.
9) Why does the block sometimes have to be given a gentle push before it will slide down the incline?
Levers

**Background:** Machines can multiply force or distance, thereby making work easier or faster. They can change the direction of work being done. A measure of a machine’s ability to assist the user is called mechanical advantage. Levers are in a category known as simple machines. There are three ways to build levers, and we refer to these as the three classes of levers.

Machines may be evaluated by their efficiency, which tells how much of the energy or work put into the machine is used to do work by the machine (the accomplishment). Some of the input will always be needed to overcome friction, so this portion is described as “lost”, since it does not do the work we want from the machine.

**Look it up:** 1) What are the other simple machines?

2) What is the equation for work?

3) What does AMA stand for (as related to machines), what math equation is used to solve for AMA, and, in words, what does AMA measure?

4) What does IMA stand for (as related to machines), what math equation is used to solve for IMA, and, in words, what does IMA measure?

5) Give two equations that could be used to find the efficiency of a machine.

**Objectives:** To construct first, second, and third class levers.
To measure input and output (effort and resistance) force and distance for each class of lever.
To analyze force and distance relationships for each class of levers.

**Materials:** Balance
Board, 1.0 m long and wide enough to support the bottle described next (1x4 or 2x4 wood works well)
Large (at least 0.5 liter) bottle with cap
Fulcrum
Spring scale
Procedure, Data Presentation, and Questions:

Part: 1) Set your fulcrum on a table or lab counter, and place your board on it to form a see-saw type lever. This is a first class lever.

2) Adjust your lever so the center of the board is at the fulcrum, and turn it so the fulcrum is near the edge of the table or counter. Set the lever so about half the board extends over the edge of the table or counter.

3) Fill the bottle with water and cap it. Mass the filled, capped bottle and convert the mass to weight in newtons. The work you are to accomplish with the lever is to lift the bottle, so the bottle’s weight is called the output force or resistance.

4) ***Prepare a data table with title and headings. You will have columns for force (effort), input distance (D_{effort}), output force (resistance), output distance (D_{resistance}), and efficiency. You will need rows for trials on each of the three different classes of levers. ***

5) Enter the weight of the filled bottle on your data table. Set the filled bottle on the end of the lever supported by the table or counter. Measure the distance from the center of the fulcrum to the center of the bottle. Convert this distance to meters. Enter the weight of the bottle and this distance on your data table. This distance is the output distance.

6) You will be lifting the bottle by using your spring scale to pull down on the end of the board extending over the edge. This can best done by fitting a string loop over the board and hooking the spring scale through the loop.

7) Place your string loop across the 45.0 cm mark, attach the spring scale so it hangs below the board, and pull down to lift the bottle, noting the reading on the scale in newtons and entering it in the data table as input force (effort). Convert the 45.0 cm to meters and enter it in the data table as distance input (D_{effort}).

8) Now perform trials with the sting loop across the 30.0 cm mark, then the 15.0 cm mark. Make readings, conversions, and complete the data table as before.

9) Select one of the efficiency equations for your use now. In the space below, show all the steps needed to calculate the lever’s efficiency for the first, 45.0 cm trial. Place the answer in the efficiency column of row one of the data table.
10) Calculate the lever’s efficiency for the other trials and enter on the data table.

**Questions:**

1) Levers often have high efficiency, and students may obtain impossible efficiencies of 100% or more. Describe possible problems and errors that might lead to such high efficiencies.

2) Although this lab did not instruct you to zero your balance and spring scale, you needed to do so. Your future students may forget to zero without a reminder. Why is it essential that these instruments be zeroed?

3) State the relationship between the input distance and the input force (effort) exerted by the scale to lift the bottle.

4) Identify the independent, dependent, and controlled variables for part 1.

**Part 2:** 1) Move your fulcrum from the center to a location much closer to the bottle.
Set the string loop at 45.0 cm and pull the spring scale down, as before, to lift the bottle. Record the scale reading, in newtons, below.

**Questions:**
1) How did the force recorded by the spring scale compare to the force at 45 cm in part 1?

2) How did the force recorded by the spring scale compare to the weight of the bottle?

3) Did the relationship between input force (effort) and input distance that you described before apply here? Justify your answer.

4) Describe the arrangement of resistance, effort, and fulcrum in each of the first class lever trials you have conducted. This arrangement is characteristic of first class levers.

5) Name, draw, or describe five tools, toys, other items, or body parts that act as first class levers.

**Part 3:**
1) Rearrange your lever parts to change it from first class to second class. Move the filled bottle (resistance) to the center of the board, and move the fulcrum under a spot 10.0 cm from the end that previously held the bottle.

2) *** Prepare a titled data table with the same column and row headings as before, but omit the efficiency column. ***

3) Use the same marks before for your string loop for the scale, which will be pulled up this time. Measure or calculate the distance from the fulcrum to the bottle \(D_{\text{resistance}}\) and from the fulcrum to each of the three marks used before \(D_{\text{efforts}}\). Convert these values to meters and enter on the data table.

4) Using your spring scale to pull up on the board, lift the bottle with the scale at the 45.0 cm mark, then the 30.0 cm mark, then the 15.0 cm mark. Note the scale readings in newtons and fill in the data table as you work.

**Questions:**
1) How did the spring scale readings at each mark compare to the readings taken with the
first class lever?

2) Have any of your trials so far shown work multiplied by a lever? Justify your answer and show a set of example work calculations.

3) Describe the arrangement of resistance, effort, and fulcrum for these second class levers.

4) Name, draw, or describe five tools, toys, other items, or body parts that act as second class levers.

**Part 4:**

1) Convert your second class lever to third class. Move the entire lever onto the table or counter. Set the fulcrum as before (10.0 cm from one end), slide your string loop over the board, and center the filled bottle over a point 10.0 cm from the end opposite the fulcrum.

2) Mark your board 15.0 cm on the other side of the center from your previous three marks. You will now have a center mark and marks 15.0 cm on either side of the center.

3) Prepare another titled table as for the second class lever, again omitting the efficiency column.

4) Your trials this time will involve lifting the bottle by putting the string loop at the center of the board and at the 15.0 cm marks on either side of the center. Use the spring scale to pull up to lift the bottle. For each of the three scale locations, record the scale readings in newtons, and record the input (effort) and output (resistance) distances to the fulcrum in meters.

5) Conduct the trials and complete the data table.

**Questions:**

1) How did these scale readings compare to those taken for the first and second class levers?
2) Was work multiplied by this lever? Justify your answer.

3) The input (effort) and output (resistance) distances for levers are actually arcs along which the effort and resistance forces move. Why was it valid to use the easier-to-measure straight-line distances instead?

4) Name, draw, or describe five tools, toys, other items, or body parts that act as third class levers.

5) Consider a catapult, such as was used to hurl objects over castle walls. Sketch one below; label the fulcrum, effort, and resistance, and effort; and identify the class of this lever.

6) Describe the arrangement of resistance, effort, and fulcrum for third class levers.

7) What aspects of the part 1 experimental set-up were controlled variables?
Magnets and Magnetic Materials

**Background:** Magnets can pull on some substances and can pull and push on each other, all without touching. Two or more magnets can affect the same region. Magnetic force varies with the inverse square of distance ($1/d^2$) from the magnet. All magnets have regions of greatest magnetic strength, called poles.

**Look it up:** All magnets contain one or more of three elements. What are these three elements?

**Materials:** Flexible magnets and other materials for this lab may be found in the NSRC/STC Magnets and Motors kit. Except where otherwise specified, each of the test materials needed is small or only a small piece will be needed.

Magnets: Four strong flexible magnets, identical in size and shape.
- One strong, metal, bar magnet
- One strong, metal, horseshoe magnet

Test items and testing materials:
- Two or three small aluminum items, such as foil, wire, or screen pieces
- Two or three brass items, such as a screw, paper fastener, or washer
- Copper wire
- Cork (natural)
- Paper clip, uncoated
- Pencil refill for mechanical pencil
- Two plastic cups, same size
- Nickel coin
- Recording tape, audio and video/audio, may cut from an old cassette
- Rubber band
- Silver wire or other small silver object, such as a piece of jewelry
- Steel nail
- Twenty-five steel washers, size USS #10
- String
- Tape, masking or clear
- Thread, nylon or cotton
- Tissue paper
- Twist-tie for plastic bag
- Toothpick, wooden
- Wooden tongue depressor (preferred) or popsicle-type craft stick

**Caution** - Keep magnets at least 30 cm away from computers, audio or video cassettes, and computer discs.

**Objectives** - Classify objects as magnetic, weakly magnetic, or non-magnetic. Observe characteristics that distinguish a magnet from magnetic materials.
Procedures, Data Presentation, and Questions

Part 1: 1) **Develop a data table, including a title and column headings, that will allow you to list each of your test items, along with your prediction as to results of testing with a magnet, your reasons for your prediction, and test results for each item.**

2) Predict whether each item you have been given will be strongly magnetic, weakly magnetic, or non-magnetic. Enter each prediction on your data table next to the item name.

3) Test each of the items with one or more magnets to determine its classification. To determine the presence of weak magnetic properties, hang the item from a string with tape.

Questions:
1) Describe your testing procedures. Be sure to include the variables you controlled in order to keep your testing “fair”.

2) What evidence did you consider as you determined whether each material was magnetic?

3) Why would hanging a test item from thread make it easier to determine the presence of magnetic properties, especially for weakly magnetic materials?

Part 2: 1) Locate the poles on your magnets by testing them against each other.

2) Sketch each magnet and indicate the location of each pole.

Questions:
1) How can a magnet be differentiated from a piece of strongly magnetic material?

2) The shape of the horseshoe magnet was developed to most efficiently use the magnetic strength available in a bar of magnetized steel. Give one or more reasons why this
shape allows such efficient use of strength.

**Part 3:** 1) Build a testing platform by setting the two plastic cups upside down on the table. Set the tongue depressor across the two. Set one flexible magnet on top of the center of the tongue depressor. Open out the paper clip slightly and let the magnet’s attraction hold it so the open end points up as shown. See the *Magnets and Motors* Student Activity Book for an illustration.

2) By adding washers to the paper clip, determine the holding strength, in terms of washers, of one magnet.

3) ***Prepare a data table to display this information, including space for trials using more magnets.***

4) Add the strength of a second flexible magnet to the first by stacking it above the first, being sure the magnets attract one another as you do so. Test the as before, recording your results in your table.

5) Continue testing until all four magnets are stacked.

6) Graph your results of # washers versus # magnets.

7) Extrapolate from your graph to predict the strength of eight stacked magnets. Combine your magnets with those of another group to test your prediction.

8) Repeat prediction and test for twelve stacked magnets.

9) Use tape to force two magnets together against their repulsion. Test the strength of this pair.

**Questions:**

1) What was your prediction of the strength of eight stacked magnets? What was the measured strength?

2) What was your prediction of the strength of twelve stacked magnets? What was the measured strength?

3) Compare the measured strength of two magnets forced together to the strength of two stacked so they attract.
4) Can magnets act in the same region to produce combined additive effects? Justify your answer.

5) Can magnets interfere to weaken strength in a region? Justify your answer.

6) As distance from a magnet increases, the strength detected decreases by an inverse-square law.
   
a) Do any of the results of your testing in part 1 support this? Justify your answer.

   b) Do any of the results of your testing in part 3 support this? Justify your answer.

   c) Suggest another way in which you could test the inverse-square relationship between distance and strength for a magnet or magnet combination.
Speed, Velocity, and Acceleration

Background: Speed is defined as distance traveled per unit time. Most objects do not travel at constant speed, so average speed is usually used as an overall description of motion. Average speed is calculated by dividing total time by total distance.
Velocity is speed with direction and is, therefore, a vector quantity. Speed, a scalar quantity, is used when direction does not matter. For instance, we might say a given car will go a maximum speed of 110 miles/hour.
Velocity, on the other hand, is used when direction is important. For instance, a car attempting to elude the police might have a velocity of 85 miles/hour on Highway 123 toward Greenville.
Acceleration is the rate of change of velocity, not speed. Acceleration is negative, and may be called deceleration, when objects slow. Its value is positive when objects increase speed. Acceleration also happens when objects stay at constant speed, yet change direction.

Look it up: 1) What is the formula for acceleration?

2) What name is given to the acceleration turning objects undergo?

3) Newton’s Second Law of Motion relates the acceleration of a mass to applied force. State this law in words and by equation below.

Objectives: To measure distance and time for moving objects.
To use velocity and acceleration equations to perform calculations using lab data.
To use calculations and graphs to extend understanding of lab data.

Materials: Marble
Ramp or inclined plane - piece of grooved molding, a section of 1”X6” board, or similar surface to prop on a stool or books
Meter Stick
Stopwatch
Masking Tape
Procedures, Data Presentation, and Questions:

Part 1:

1) Locate an area where you can work. You may use the lab room or nearby hallways. You will need a clear area along the floor at least 6.0 m long.

2) Build a ramp for the marble to follow as it rolls to the floor. You may prop your ramp on a stool or books. The point from which the marble will start should be 10-30 cm from floor level (measured straight up, perpendicular from the floor).

3) Place a piece of tape on the floor at the base of the ramp and parallel to the ramp bottom. Label the strip 0 m. This tape can serve to keep the ramp from slipping, and it will also be your zero point for measurements along the floor and for measurements up the ramp.

4) Measure 2.0 m from the first tape and place another tape strip parallel to the first. Label this strip 2.0 m. Repeat this process twice more for tapes at 4.0 m and 6.0 m.

5) Do several trial runs by releasing the marble to travel down your ramp. Observe carefully. The marble should smoothly leave the ramp at the 0 m tape and travel along the floor for at least 5.0 m. Adjust as necessary to achieve this with no bouncing.

6) Practice timing the marble as it travels along the ramp and also as it travels from tape to tape along the floor. Strive to perfect your techniques for release and timing. If the marble appears to be traveling too fast for accuracy and precision, lower the ramp to slow it.

Note: Tape left on the floor for hours will bond to the wax, damaging the finish upon removal. Be sure to remove all tape as part of lab clean-up when done.

Questions:

1) Define accuracy and precision for the timing measurements you practiced in step #6.

2) At many ramp settings, the marble will hit the floor and begin bouncing at the foot of the ramp. Why should the apparatus be adjusted to have the marble smoothly leave the ramp without bouncing?

3) Your future students may not recognize that changing direction is acceleration, since it is a change in velocity. Tell how you will relate Newton’s Second Law to their own
experiences to convince them it is acceleration. Give your explanation in terms appropriate to the grade level you hope to teach and specify the grade level.

**Part 2:**

1) *** Prepare a data table with title and headings. Include columns for distance, time, and speed. You will be timing the marble’s travel along the ramp. ***

2) Mark the spot on the ramp from which you will release the marble. Check to be sure the ramp will not slip during your data gathering. If you believe it might slip, mark the bottom or side of the ramp at its point of support so that you can reset it, if you must.

3) Measuring along the top surface of the ramp, determine the distance from the marble release point, down the ramp, to the point of floor contact.

4) Release the marble and time its travel over the measured ramp distance for several trials, entering the data in the data table for correct significance.

5) Using distance and time, calculate the speed of the marble on the ramp for each trial and record to significance.

6) Calculate an overall average of the speeds in the space below.

**Questions:**

1) What level of significance did you choose for each of the columns of your data table? Justify the level of significance you chose for each.

2) How well did the results of the various trials agree? Discuss why you saw this level of agreement.
3) What was the initial (beginning) speed of the marble at the starting point for each trial?

4) a) What equation can be used to calculate the final speed of the marble as it comes in contact with the floor?

b) Use the equation to calculate the overall average final speed of the marble below.

**Part 3:**

1) *** Prepare a data table with title and headings. Use your previous trial numbers as the rows and have columns for final velocity, change in velocity, and acceleration. ***

2) Calculate to complete your table and enter values to correct significance.

3) Calculate your overall average acceleration in the space below.

**Questions:**

1) Compare your average acceleration to the accepted value for the acceleration of gravity. Explain why they differ.

2) How would changing the slope of the ramp affect the acceleration of the marble?

3) What table values other than acceleration would be affected by changing the slope of the ramp?

4) Imagine that you have done a similar lab with your future students. Name four aspects of the lab they might change and test against the original for a science project.
Part 4:

1) Your procedure should be the same in this part as for part 2, but your focus will be the marble’s travel across the floor after leaving the ramp.

2) *** Prepare a data table with trial numbers and the rows and column headings for three sets of time and speed pairs. Your sets will be labeled 0 - 2.0 m, 2.0 - 4.0 m, and 4.0 - 6.0 m. Include a row at the bottom for average values of time and speed for the trials you run. ***

3) Release your marble as before, timing its journey from 0 - 2.0 m. After your repeat trials, release the marble again, but time from 2.0 - 4.0 m for several trials. Repeat for timing from 4.0 - 6.0 m.

4) From distance and time measures, calculate the speed for each trial. Enter each in the table, then calculate the averages of the times and speeds.

5) *** Construct a graph of average overall speed versus mid-point distance (1.0 m, 3.0 m, 5.0 m) and extend the numbers on the x-axis to at least 50.0 m. ***

6) Draw the “best fit” line on your graph and extend it to extrapolate the distance at which the marble would stop. Give the distance below.

Questions:

1) Was the marble accelerating as it traveled across the floor? Justify your answer from your data.

2) What is your expectation of the original speed of the marble as it leaves the ramp and begins its travel across the floor? Why do you expect this value?

3) Describe the force(s) acting on the marble as it moves across the floor.

4) What is the shape of your graph?
**Sodium Chloride Concentration and Density**

**Background:** The density of water varies according to the kind and amount of solutes dissolved in it. Salt water is more dense than fresh. Objects that float on the surface of water have a density less than that of the water, and they float higher as the density difference increases. These floating objects are responding to the upward pressure of the water. The force exerted is called a buoyant force, which increases as water density increases. This same upward force offsets the weight of objects that sink in water, making them easier to lift and move.

**Look it up:**
1) What is the average density of sea water, and how does this density compare to that of fresh water?

2) How many grams of salt are dissolved in the average liter of sea water?

3) What is the average density of the Dead Sea?

**Materials:**
- 250 - 400 ml beaker or plastic cup
- 10 - 12 cm section of small diameter dowel rod
- Modeling clay or small washer with fast-drying, waterproof glue
- 100 ml graduated cylinder for measuring water
- A second 100 ml or larger graduated cylinder or similar tall, narrow container for the lab procedures
- 90 ml stock “mystery” sodium chloride solution
- Plastic spoon or stirring rod

**Procedures, Data Presentation, and Questions:**

**Part 1:**
1) Add a small amount of weight to the end of your dowel rod section by attaching modeling clay or gluing on a washer. The object is to make the rod float vertically, as opposed to falling on its side.

2) Fill your cylinder with 90 ml tap water.

3) Carefully lower your dowel rod, weighted end first, into the water in the cylinder. If it does not float vertically, adjust the weight so that it does.

4) Mark the dowel rod at the point where it intersects the surface of the water.

5) Replace the water with 90 ml distilled water. Float the dowel rod and check to see if it floats at the same level. If so, continue with tap water. If not, adjust the mark on the dowel rod for distilled water and use distilled water for the rest of the lab.
6) Mass 2.0 g of sodium chloride and place it in your beaker or cup. Carefully add 98.0 ml water and stir until the sodium chloride dissolves. (If you are using table salt for sodium chloride, be aware that there are small amounts of other salts present. Some of them will give a milky color to the solution; some will not dissolve well. You may not be able to get a visibly homogeneous solution, but you will still be able to get valid results from this lab.) What is the mass percent concentration of the sodium chloride in the salt water solution you just made, assuming the mass of any other salt present is negligible?

7) Take the dowel section from the cylinder, pour out the water, and add 90 ml of the sodium chloride solution (“salt water”) you just made. Mark the dowel at its intersection with the sodium chloride solution.

8) Repeat steps #6 and #7 with 4.0 g of sodium chloride and 96.0 ml of water. What is the mass percent of the sodium chloride in this new solution?

9) Continue to repeat steps #6 and #7 for the following combinations of sodium chloride and water:

- 6.0 g sodium chloride and 94.0 ml water
- 8.0 g sodium chloride and 92.0 ml water
- 10.0 g sodium chloride and 90.0 ml water

Questions:
1) Tap water contains dissolved solutes, including non-solid solutes. Why could we substitute it for distilled water if the dowel floats to the same level in each? What reason(s) might we have for wanting to substitute the tap water?

2) Why was it not necessary to mass the water used, even though you were preparing a mass percent solution? Include consideration of significant figures in your answer.

3) Why was it necessary to first be sure the dowel section would float vertically?

4) For this series of procedures, name the independent and dependent variables.
5) What aspects of the experiment were controlled by you to ensure a “fair test”, and what other aspects were controlled because of the experimental environment?

**Part 2:**

1) Write a procedure for preparing a 7.0 % by mass sodium chloride solution, using water as the solvent as you did in this experiment.

2) Following your procedure, prepare the solution and predict at what level the dowel will float. Write and justify your prediction below.

3) Pour 90 ml of your 7.0% solution into the cylinder and test your prediction. Record your observations below.

4) Empty your cylinder and obtain 90 ml of the prepared sodium chloride “mystery” solution.

5) Test the mystery solution with your dowel section. According to your previous markings, what is the mass percent concentration of the “mystery” sodium chloride solution? Justify your answer.

**Questions:**

1) Knowing that table salt, even plain table salt, contains impurities - other salts that may slightly affect the results of the experiment - why would you buy the table salt rather than obtaining sodium chloride from a chemical supply house? Answer from the perspective of doing this lab with your future classes.

2) Evaluate the results of your dowel measure of the 7% by mass sodium chloride solution. Were your expectations correct?
3) List two or more factors that could have caused the results of the above measure to be other than expected.

4) How might the measure have differed if a salt other than sodium chloride were used as the solute and why?

5) Most of your future students will have heard that it is very easy to float in the Dead Sea. Using terms they would understand, explain why this is true.

6) Did you rinse the cylinder between solutions? Why or why not? How might rinsing affect results? How might not rinsing affect results?

7) This lab could have been written referring to density, rather than sodium chloride concentration by mass. Describe a lab procedure or calculation you might do to determine the density of an 8.0% by mass sodium chloride solution.
**Pendulums**

**Background:** A pendulum consists of a mass that can swing back and forth along an arc. An ideal pendulum has all its mass in a dense, spherical bob that hangs from a “massless” string and experiences no friction. The length (l) of a pendulum is measured from its point of suspension to the center of its bob. The period (T) of a pendulum is the time required for it to move back and forth (one cycle) along its path.

**Look it up:** The motion of a pendulum approximates that of another category of motion. What is this other category, and what are its characteristics?

**Objectives:** To develop a technique for measuring the period of a pendulum that minimizes the effect(s) of reaction time. To design an experiment to determine the relationship between the period of a pendulum and its mass. To design an experiment to determine the relationship between the period of a pendulum and its length. To determine the height of the fourth floor balcony of the atrium indirectly, by use of a pendulum. To compare different methods of determining the height of the fourth floor balcony.

**Materials:** Balance  
Bottle with top  
Round metal rod  
Meter stick  
String  
Stopwatch

**Procedures, Data Presentation, and Questions:**

**Part 1:** 1) Use the bottle as your pendulum’s bob, adding enough water to allow it to swing freely from the string. Attach the string to the neck of the bottle and test, adjusting the attachment as needed. Note that the mass of the bob can be varied by varying the amount of water in the bottle.

2) Place your round metal rod on the table, allowing a few centimeters
3) Pull back the bob and release it. Practice releasing it as you try variations to determine the best way to achieve a smooth back-and-forth movement.

4) Try timing the period of the pendulum, attempting variations in order to find the best way to reduce the influence of human reaction time. Get the TA’s approval of your technique, then describe it below.

**Part 2:**

1) Design an experiment that will allow you to determine the relationship between the period of a pendulum and the mass of its bob.

2) *** Write the procedure for your experiment, with title, and attach. ***

3) *** Follow your procedures to conduct the experiment. Gather data and present it in a table you design. Graph your data. Attach the data table and the graph. ***

**Questions:**

1) Name the independent, dependent, and controlled variables for your experiment.

2) State in words or by equation the relationship between the period of a pendulum and the mass of the bob, based on your results.

3) From your observations, how great a role does friction play in your results? Justify your answer.

**Part 3:**

1) Design an experiment that will allow you to determine the relationship between the period of a pendulum and the length of the pendulum.
You may need more length than the height of the table will allow. You may use the stairwells or work off the second floor balcony of the atrium. Be aware of the safety hazards involved in hanging and swinging the pendulum, and respect the rights of others using the area.

2) *** Write the procedure for your experiment, add a title, and attach. ***

3) *** Run the experiment. Gather data and present it in a table you design. Graph your data. Attach your data table and the graph. ***

Questions:
1) Name the independent, dependent, and controlled variables for your experiment.

2) State in words or by equation the relationship between the period of a pendulum and the length of its bob, based on your results.

3) Suggest changes in your experimental design that would reduce energy loss due to friction.

Part 4: 1) Determine the height of the fourth floor atrium indirectly. Match the length of a pendulum to the height and measure the period of the pendulum.

2) Extrapolate the height (length of pendulum) from your part 3 graph, using the period you just measured. Write the coordinates of this point, with units, below.

3) Ask the instructor for the formula to use with pendulums. Substitute the period you use measured and solve for the height (length of pendulum).

4) Measure the height by measuring the length of the pendulum. What is this length?
Question: How well do your three ways of determining the height agree? Discuss.
Electric Circuits I

**Background:** Electricity flows easily through some materials, known as conductors. Simple resistive electric circuits may contain only one source of energy (such as one D-cell battery), one bulb, and hook-up wires. By varying the design of the circuit, the voltage available and the current flowing can be varied. Direct current flows only one way. The most common sources of direct current are dry cells and batteries.

**Look it up:**

1) Answering with only the basics, perhaps a sentence, tell what each of the following contributed to the use of electricity:
   - a) Benjamin Franklin –
   - b) Michael Faraday –
   - c) Joseph Henry –
   - d) Thomas Edison –
   - e) Samuel Morse –

2) Approximately how long has electricity been in wide use in America?

3) What is a short circuit? Why is it dangerous? Why does it quickly drain dry cells and batteries?

4) How do open and closed circuits differ?

5) What is a complete circuit?

6) How do conductors and insulators differ?
6) Find symbols commonly used in circuit diagrams for the following and sketch each:
   a) bulb  b) cell as energy source  c) wire

**Objectives:** To build simple electric circuits that work.
   To combine D-cells to increase voltage available.
   To draw circuit diagrams for the simple circuits built.
   To troubleshoot circuits by finding faults which make them inoperable.
   To differentiate conductors and insulators.

**Safety note:** The D-cells used as energy sources in this experiment will not produce harmful shocks. The voltage is too low to produce direct current large enough to be detected by dry skin. However, if a short circuit is left connected, the cell(s) and/or wires may get quite hot. Do not use rechargeable batteries for this lab, as they have been known to produce dangerously hot wires when short-circuited.

**Note:** Very warm or hot wires and/or D-cells are signs of short circuits. Quickly open circuits in which heating is noticed. Also suspect a short-circuit when a circuit appears correct, but the bulb won’t light. Do not overlook the possibility of other circuit faults, such as a burned-out bulb, however. As a general rule to preserve the life of your D-cells, limit the time in which your circuits are closed to your actual need of the working circuit.

**Materials:** Box or bag of test items made of various materials
   Four small bulbs with bulb holders
   One clear, household bulb designed for household current (share with another group)
   Several faulty circuits (shared by all groups)
   Three D-cells with D-cell battery holders
   Meter stick
   Small piece of fine sandpaper
   Seven pieces of hook-up wire 20 cm long
   One piece of hook-up wire 1.5 m long

**Procedures, Data Presentation, and Questions:**

**Part 1:**
1) Set out a small bulb (without holder), a D-cell, and a 20 cm piece of hook-up wire. Strip 1-1.5 cm insulation from each end of the wire.
2) Draw a sketch of your D-cell as seen from the side, showing its shape and labeling the ends (terminals) as positive or negative.

3) Using the one bulb, one D-cell, and one piece of wire, find and sketch four different arrangements of the three that will cause the bulb to light. Sketch below.

4) Draw sketches showing two ways the three items (bulb, D-cell, and wire) can be connected without having a complete circuit that will light the bulb.

**Questions:**
1) What specific areas on the bulb must wires touch for the bulb to light?

2) Is the bulb directional, or may current light it by passing through it in either direction?

3) What is the voltage of the D-cell?

**Part 2:** 1) Strip 1-1.5 cm insulation from each end of the 1.5 m piece of hook-up
2) Working with the group that is sharing your clear household bulb, set your meter sticks side-by-side with space between to hold D-cells.

3) Place a D-cell in the chute formed by the meter sticks. Using the two 1.5 m pieces of wire (one from each group), light a small bulb.

4) Place another D-cell end-to-end with the first. Sketch the two below.

5) Holding the two D-cells snugly together, use the pieces of wire at either end of the pair to connect them to the bulb. Does it light? If so, compare its brightness to the brightness using one D-cell.

6) Reverse one of the two D-cells and sketch the new arrangement.

7) Repeat #5, including answering the questions, for this new arrangement of two D-cells.

8) You have placed your D-cells in series, which results in an algebraic sum of their voltages once they are in a complete circuit. That is, the second D-cell either adds to the energy of the first or they mutually consume energy as they try to push current through each other.

9) Knowing that the clear household bulb was designed to operate at 120 volts, predict how many volts will be needed to visibly light it.
Also, how many D-cells must be placed additively in series to achieve this voltage?

10) Start with five D-cells in series between your meter sticks. Two or more members of the groups must hold the bulbs snugly in contact. Be sure the D-cells are arranged to add voltages.

11) With the wires, connect the batteries to the clear household bulb. Check to see if it lights, darkening the room, if possible.

12) Obtaining more D-cells and meter sticks from the TA as needed, add more D-cells, testing after each five. Continue until thirty D-cells in series have been tested. Report your observations for #12 and #13 below.

Questions:
1) How must D-cells be arranged for voltage to be added?

2) Does the clear household bulb appear to be constructed in the same way as the small bulb? Explain.

3) Name four common applications in which multiple cells or batteries are used to increase voltage

Part 3: 1) Strip 1-1.5 cm of insulation from your other pieces of wire.

2) Experiment with the Fahnestock clips on your bulb and battery holders to learn how to insert wires correctly. Pressing down on the moveable clip, push the wire completely through the loop. After the clip is released, the wire should show on each side of the loop and be held securely enough to resist a light pull.

3) Place a D-cell in a battery holder and a small bulb in the bulb holder. Do not overtighten the bulb, as you may break the glass or the seal between the glass and the metal base.
4) Use the circuit symbols from “Look it up” to draw the circuit below.

5) Open one side of the circuit at the bulb by removing the wire from the clip on that side. Place one end of a third 20 cm piece of wire in the clip instead. Touch the free ends of this wire and the wire you took from the clip. If the bulb fails to light, troubleshoot by looking for loose connections.

You have made a simple circuit tester. Try it out by touching your two free ends to either end of a fourth 20 cm piece of hook-up wire. The bulb lights to show the wire has no breaks in the insulation.

6) Go to the numbered non-working circuits set out for your use. Using the circuit tester and what you have learned so far, test the parts of each circuit until you determine the fault that keeps it from working. Return each to its original condition. In the space below, list the fault you find next to each circuit number.

Questions:
1) Why are circuit symbols preferred over more artistic sketches for diagramming electric circuits?

2) Describe how you tested the non-working circuits to see if the battery was drained.
3) Describe how you tested the non-working circuits to see if the bulb was burned-out.

4) Describe how you tested the non-working circuits for a loose connection or poorly-positioned D-cell or bulb contact.

**Part 4:**

1) Check your circuit tester from part 3 by touching the free ends of the wire. If the bulb fails to light, troubleshoot to find the fault and fix it.

2) *** Prepare a data table with title and headings. You will need columns for item tested, prediction, reasons for prediction, test 1, and test 2. ***

3) Remove a test item from your box or bag. Predict whether the bulb will light if you make it part of the circuit by touching the free ends of the tester to locations on the test item that are 1-2 cm apart. Enter the item and prediction on your data table.

4) Test the item as described above. Enter results on the data table under test 1.

5) If the bulb did not light, check to see if there is any coating or corrosion over the surface of the test item. If so, use the sandpaper to remove it, test again, and enter the results under test 2.

**Questions:**

1) Overall, were your predictions accurate? Explain.

2) In the space below, put two column headings: conductors and insulators.
List each test item under one or the other.

3) Why was it necessary to use the sandpaper and retest some items?

4) Could another device replace the bulb in your circuit tester? Explain.
Electric Circuits II

**Background:** Simple resistive circuits may be series, parallel, or a combination of the two. Varying the circuit design will vary the voltage and current in the parts of the circuit. Series and parallel circuits each have distinctive features.

**Look it up:**
1) In the circuit symbol for a cell, how are the positive and negative terminals shown?

2) In labs such as this, the energy used by hook-up wires is ignored. Why is this so?

3) Power companies talk about the “load” on their systems, and we can talk about the “load” in our lab circuits. What is the electrical meaning of “load”?

**Objectives:** To build series and parallel circuits.
To observe properties of series and parallel circuits.
To observe the effect of changing voltage on current flow, through observing the brightness of a bulb.

**Materials:** (All are included in the materials list for Electric Circuits I.)
Four small identical bulbs and bulb holders
Three D-cells and D-cell battery holders
Seven pieces of 20 cm hook-up wire

**Procedures, Data Presentation, and Questions:**

**Part 1:** 1) With a 20 cm piece of hook-up wire connect two D-cells in battery holders in series (voltages should add).

2) Connect two pieces of 20 cm hook-up wire to either side of a bulb in a bulb holder. Connect the free ends of the wires to the clips at either end of your D-cells in series. If the bulb does not light, troubleshoot.

3) Draw a circuit diagram of the circuit you built, using standard symbols for the parts.
4) Construct a circuit of one bulb, one D-cell in holder, and two wires. Compare the brightness of the two bulbs below.

5) Rebuild your first circuit by replacing one D-cell with a bulb in bulb holder. Compare the brightness of the two bulbs you now have in series with each other. Compare the brightness of these two bulbs to the bulbs in Step #2 and #4 (separate comparisons).

6) Draw a circuit diagram of the circuit from #5 below, using standard symbols.

7) Dismantle your circuits.

Questions:
1) All three of the circuits in part 1 share a pattern of current flow. This type of current flow is a property of series circuits. Describe the current flow that is similar for each of the three.

2) What is the voltage available to the bulb in Step #2? In step #4?

3) What is the relationship between available voltage and brightness of the bulbs?

4) In the step #5 circuit, energy is used by the first bulb, reducing the
voltage available to the second bulb. If the bulbs are identical, what voltage will be available for each?

5) Does the relationship you described in question #3 hold for step #5? Justify your answer.

Part 2: 1) Build a parallel circuit using one bulb and two D-cells, each in its holder. First, set the D-cells side-by-side, parallel to each other. Check to be sure the ends (terminals) are aligned in direction. Use two wires to connect the D-cells, positive to positive and negative to negative. Loosen one wire to open the circuit for now. Place the bulb in line with the D-cells, so that one D-cell is now in the middle, between the bulb and the other D-cell. Use two more wires to connect the two terminals of this middle D-cell to either side of the bulb.

2) Replace the wire you loosened earlier. If the bulb does not light, troubleshoot to find and fix the fault.

3) Loosen the bulb until there is no light. Tighten it (do not overtighten!).

4) Remove one D-cell from its holder. Describe your observations.

5) Replace the first D-cell and remove the second. Describe your observations.

6) Draw a circuit diagram of this circuit.

Questions:
1) Why did the bulb cease to light as you loosened it and light again as you tightened it? Justify your answer.

2) Study the pathway(s) for current in your circuit. Why was the bulb able to
light with only one D-cell at a time? (If it did not, troubleshoot and try again.)

3) Compare the brightness of the bulb to that of one bulb with one D-cell. If necessary, connect this circuit (part 1, step #4) again.

4) Based upon your earlier observations of the relationship between brightness and voltage, what voltage seems to be available to the bulb?

5) Any one unit of current passing through the bulb has energy from one battery or the other, but not both. Current flows in one direction in DC circuits. By how many pathways can current reach the bulb? Describe each.

6) What advantage(s) does the arrangement built in step #1 have over a circuit with one bulb and one D-cell?

**PART 3:**

1) Alter the circuit from part 2 to put one D-cell and two bulbs in parallel. To do so, remove the middle D-cell and holder from the circuit and replace with a bulb in a bulb holder. Troubleshoot if the two bulbs do not light.

2) Draw a circuit diagram of this circuit below.

3) Construct a series circuit with one D-cell and two bulbs (see your
diagram part 1, #6 for help). Troubleshoot, if necessary.

4) Loosen one lightbulb in the parallel circuit (step #1), observe. Replace it, then loosen the other, observe, and replace. Describe the results.

5) Repeat #4 for the series circuit (step #3). Describe results.

6) Compare the brightness of the bulbs in the parallel circuit to those in the series circuit.

**Questions:**

1) Describe how the pathway(s) for current in the parallel circuit (step #1) differ from the pathway(s) in the series circuit (step 3).

2) Remember that each unit of direct current flows in only one direction. How do your observations from loosening bulbs in steps #4 and #5 support this?

3) How do the relative brightnesses of the bulbs (see Step #6) support the idea that each unit of direct current flows only one way on one path?

4) From the brightness of the bulbs, how does the voltage available to each bulb in the parallel circuit compare to that available to each bulb in the series circuit?
Physics in the Park

**Background:** Many of the concepts we study in physics may be studied using typical playground equipment. Following safety rules and avoiding horseplay are essential in this setting.

**Objectives:** To recognize physics concepts in a playground setting. To analyze use of playground equipment using concepts from physics.

**Materials:** Soft ball or other soft object which will throw well
Medium or large toy car or acceleration cart
Paper, pencil or pen, and lab sheets
Spring scale
Meter sticks
Stopwatches

**Procedures, Data Presentation, and Questions:**

**Part 1:** The See-Saw, a First-Class Lever

1) *** Prepare a data table with columns for weight #1, distance #1, weight #2, distance #2, W1 X D1, and W2 X D2. You will need rows to run trials with at least three different pairs of people on the see-saw. One person of each pair will be #1; the other will be #2. ***

2) Have one person sit on each side of the see-saw. Adjust their positions until the see-saw is balanced. Note that you have set up a situation in which the force times distance on one side is equal to the force times distance on the other.

3) Measure the distance from the center of the fulcrum to each person’s center of mass. Record weights and distances in your data table.

4) Repeat for your other two pairs of students.

5) Complete your force times distance calculations.

**Questions:**

1) Compare the calculation results for the two people in each pair. If they were not equal, suggest some possible reasons for the inequality.

2) The see-saw can be analyzed in terms of work or torque. What is the efficiency of the see-saw if the two people are balanced?

**Part 2:** The Slide, an Inclined Plane or Ramp

1) Measure the vertical distance from the top of the slide to the bottom. Record below.
2) Measure the length of the slide’s incline. Record below.

3) Hang the toy car or acceleration cart from the spring scale and record its weight below in newtons.

4) Use the spring scale to pull the car up the slide’s incline at a constant speed. Be sure the scale is held parallel to the slide’s surface. Read and record the force in newtons.

5) In the space below, calculate the input work to pull the car up the slide from the bottom to the top. Use your measured force and distance values.

6) Your effort will accomplish lifting the weight of the car -- the resistance. Moving it up the slide’s slope will lift it the vertical height of the slide from top to bottom. Calculate this output work below.

7) In the space below, calculate the efficiency of the slide as an inclined plane, one of the simple machine categories.

Questions:

1) What two forces were overcome to pull the toy car up the incline at a constant speed?

2) If the car were accelerated up the incline, how would be spring scale reading change?

3) The efficiency of the incline is not 100%. Why is this expected and what happened to the “lost” percentage? If your value is 100% or more, what might have lead to this error?

Part 3: The Merry-Go-Round, a Wheel-and-Axle, but used to study frame of reference and angular momentum in this lab.
**Safety Note:** Keep the speed of the merry-go-round to a safe level. Students pushing should stay aware of the danger of falling and going under the platform or being struck by the merry-go-round or its riders. Riders should hold on tightly and be aware of the danger of falling. If a rider feels dizzy or sick, the trial should immediately be stopped to allow the rider to disembark. Students serving as spotters should be located around the merry-go-round to assist participants who need help.

1) Rotate the merry-go-round. Riding students (two or more) may be on or may get on after it is spinning. One rider should have a soft ball or other soft object to throw. Spotters may serve as observers from the ground.

2) While the merry-go-round rotates, the riders should toss the ball back and forth. Each should carefully observe the path of the ball. When the ball is dropped, it should be returned by one of the students not riding. Stop the merry-go-round.

3) Riders and ground observers should compare their observations. Give a summary of each groups’ observations below.

4) Group members should spin the merry-go-round empty. The timer should use the stopwatch to time three complete rotations. Record the time below.

5) While the merry-go-round spins, two group members should approach from opposite sides and carefully jump on the moving merry-go-round. The object is for the two to jump simultaneously and ride opposite one another. The timer should time three rotations with the two in place. Record time below.

6) The two riders should each move toward the middle of the merry-go-round. The timer should time three rotations with the two in this new position. Record the time below.

7) The two riders should return to their original positions and remain there while the timer times three more rotations. Record the time below.

**Questions:**
1) Describe how the frame of reference of the riders and spinners affects their perception of the thrown object’s path.

2) Compare the empty merry-go-round’s spinning speed to its speed with riders.

3) Explain how steps #4 - #7 illustrate the principle of conservation of momentum. Remember that momentum is a product of mass times velocity and that the effect of a mass for a spinning object increases as the distance from the axis of rotation increases.

Part 4: The Swing, a Pendulum

1) *** Prepare a data table with columns for weight and time and rows for each group member. ***

2) Select a height from which to start swinging. The height should be measured from the bottom edge of the swing to the ground. Group members will either brace themselves by their feet with the swing at this height or will be held there by another group member. Be sure that all group members will be able to reach this height. Record it below.

3) The first swinger should sit in the swing and step back or be pulled back until the bottom of the swing is at the selected height.

4) The swinger should start swinging by lifting his or her feel or by being released. When the swinger returns back to the original height, the timer should start the stopwatch and time three complete cycles (back and forth movements). The swinger should ride passively, with no pumping or external pushes.

5) Record the swinger’s weight and time in the data table.

6) Repeat steps #3 - #5 for each of the other group members.

Questions:
1) Since the original height is not used for any data analysis, why were you instructed to record it in step #2?
2) Did the weight of the swinger affect the time required for the three cycles? Justify your answer using lab data.

3) Why was it necessary for the swinger to ride passively?

4) Why was the swinger allowed to swing one cycle before timing started?

5) Which of the activities in this lab would you consider suitable for very young students, and which would you reserve for older students? Justify your answer.
The Temperature/Volume Relationship of a Gas

**Background:** Temperature is a measure of the average kinetic energy present in matter. It changes as the average kinetic energy changes. Different scales are used to measure temperature, and temperature values can be converted from one scale to another.

**Look it up:**
1) For each of the three commonly used temperature scales (Celsius, Fahrenheit, and Kelvin), find the date of the scale’s development, the fixed point(s), and the full name of the developer. In addition, compare the sizes of the degrees for the scales.

2) Define absolute zero.

**Materials:**
- Balloons
- Three 1000 ml graduated beakers
- Boiling water -- hot plates and beakers to prepare this, too
- Ice water -- beakers to prepare, too
- Two stirring rods
- One to three thermometers

**Procedure, Data Presentation, and Questions:**

**Part 1:** 1) *** Prepare a data table with title and headings. Column headings should be temperature (Celsius), total volume, and balloon volume. There should be rows for trials with cold water, tap water, and hot water, with additional rows for trial averages for each of the water
temperatures. ***

2) Add 400 ml tap water to one of your 1000 ml graduated beakers. Blow up a balloon, keeping it small enough to fit in the beaker and be submerged in the water. Test to be sure the size is correct, then remove the balloon and tie it closed.

3) Remove the balloon, set it aside, and adjust the tap water volume in the beaker back to 400 ml, if necessary.

4) Add 400 ml ice water (no ice) to the second of the graduated beakers.

5) Add 400 ml boiling water to the third container.

   **Note:** Use goggles in obtaining the boiling water and use standard safety procedures for handling the boiling water and its containers.

6) Place a thermometer in each of the beakers.

   **Note:** Repeat trials in this lab should be performed by repeating steps #2 - #6 so that each repeat gives one cold, tap, and hot water value. Each Trial should start with new water samples.

7) Read and record the cold (formerly ice) water temperature. Remove the thermometer. Submerge the balloon, using your stirring rods to submerge it and keep it submerged.

8) Note the new water level in the beaker. Watch until it stabilizes and record the volume under “total volume” in your data table.

9) Repeat steps #7 and #8 with the hot (formerly boiling) water, then the tap water.

10) Calculate the balloon volume for each trial and complete the trial averages for each column on the table for each of the three water temperatures.

11) *** Graph balloon volume versus temperature using your three rows of average values for the three temperatures of water. Use only the upper right one-third of your graph paper for the graph, if you do it by hand. ***

12) Extend your curve back to extrapolate the point of x-axis intercept. Number
your axes to include this point.

**Questions:**
1) Give at least two reasons why the stirring rods are appropriate tools for holding the balloon submerged.

2) Is the relationship between the volume and temperature of a gas linear? Cite evidence from your lab to justify your response.

3) What are the coordinates, including units, of the point at which your extrapolated curve intersects the x-axis?

4) Convert the Celsius temperature of the x-intercept to Kelvin.

5) According to your graph, how does the average kinetic energy of a gas relate to its volume?

6) In real life, as the temperature of a gas drops, molecules of the gas begin to condense to liquid. As compared to a few degrees of temperature drop, what effect does this change of phase have on the volume of the gas?

7) For this lab, identify the variable(s) that are independent and dependent.

8) What variables were controlled to keep this lab a “fair test”? 
Vibrating Strings and Sound

**Background:** Vibrating objects produce sounds. Many of these sounds can be heard by humans, but others are outside the human range. The size, including thickness and length, of vibrating objects is related to the frequency (pitch) of the sound produced, and the amount of displacement during vibration is related to the amplitude (loudness) of the sound. The loudness of sounds can be increased by causing additional surface, such as a bridge or sounding board, to vibrate.

**Look it up:**
1) What is the range of frequencies heard by the average human?

2) Name some animals that can hear infrasonic sounds that are below the frequencies humans can hear.

3) Name some animals that can hear ultrasonic sounds that are above the frequencies humans can hear.

4) Mankind has used harps to make music for a long time. When and where was their first known use?

**Objectives:** To observe the relationship of length of a string to its vibrating pitch.
To observe the relationship of tension of a string to its vibrating pitch.
To observe the relationship of thickness of a string to its vibrating pitch.
To observe the effect of a bridge on loudness of sound produced by strings.

**Materials:** With the exception of those asterisked, these items may be found in the NSRC/STC kit Sound. The nylon fishing line may be provided on the spool, with available meter sticks and scissors, for group members to measure and cut.

- One large uncoated paper clip
- Two unsharpened pencils
- One 60 cm piece of 8 lb nylon fishing line
- One wooden bridge for pegboard harp (2.5 x 15 x 0.65 cm)
- One candle and support (may be shared with rest of class)
- One plastic cup, 261 ml (9 oz), squat form
- Four eyebolts, 3.75 cm (1 ½ “) with 4 mm (3/16”) diameter
- One pegboard (15 x 45 x 0.6 cm), with holes 3/16” diameter
- Two unsharpened pencils
Five 60 cm pieces of 20 lb nylon fishing line
Two 100 cm pieces of 20 lb nylon fishing line
One 60 cm piece of 30 lb nylon fishing line
One 60 cm piece of 50 lb nylon fishing line
One 60 cm piece of 80 lb nylon fishing line
One steel washer, #10 (1/2” diameter)
Four wingnuts to fit the eyebolts

Procedures, Data Presentation, and Questions:

Part 1: 1) Tie the small washer to one end of a 100 cm piece of 20 lb nylon fishing line.

2) Open one loop of the paper clip. Heat the free (opened) end in the candle flame and use it to melt a hole in the center of the plastic cup.

3) Reaching into the cup, run the free end of the fishing line through the cup and out the bottom. Pull the string until the washer is inside the cup and snugly against the bottom.

4) Place the cup, open end down, on the floor, while holding the free end of the string. The person holding the string should sit down. Lightly hold the cup – a group member may do so, or the person holding the string may put a foot lightly on its top.

5) The string holder should wrap the loose end of the string around an unsharpened pencil, holding the string in place with a finger or thumb. The holder should then hold the pencil just above his/her ear, so that the string is near the ear.

6) Pluck the string varying the tension until an easily repeatable sound is produced. Maintain this tension.

7) Observe the string closely as it makes a sound after plucking. Hold the edge of a piece of paper lightly against it as it sounds.

8) Vary the length of the string by changing the amount wrapped around the pencil. Try to keep the tension the same. Pluck at each tension. Listen carefully and note observations below.
9) Keeping the tension and length of the string constant at a combination which produces an easy-to-hear sound, vary the size of the vibration (the displacement of the string during the pluck) by plucking more or less vigorously.

10) Dismantle the apparatus. Two group members should each take an unsharpened pencil and wrap around it one end of the second 100 cm piece of 20 lb fishing line. Each should hold the string in place with a finger or thumb, then move his/her pencil near his/her ear.

11) With one student plucking the fishing line, repeat steps #6 - #8 with this apparatus.

Questions:
1) Cite evidence that the string is vibrating as it produces sound.

2) Sometimes the string vibrates and no sound is produced. Explain.

3) What is the effect of changing string length on the sound produced?

4) Name the independent, dependent, and controlled variables for part 1, step #7.

5) What is the effect of varying the displacement of the string on the sound produced?
6) What aspects of the instrument made with the cup might your future students change to test against the original for a science project?

7) Consider yourself in a future classroom. How might you package or present the fishing line to make it easier to handle and to eliminate loose, flapping ends?

**Part 2:**

1) Using a 60 cm piece of 20 lb fishing line, assemble a pegboard harp as shown on page 45 of the Student Activity Book for the NSRC/STC kit Sound. Adjust the length of the string so it just produces an audible sound when plucked. One group member should pluck the string, turn the eyebolt to a new, tighter setting, and pluck again. Other group members should observe, paying special attention to the sound made by the string and how the sound changes. Continue until the full range of sounds that can be made by the string has been observed.

2) A second group member should replace the member manipulating the harp, and the first should become an observer. Repeat step #1.

**Questions:**

1) When the eyebolt was turned, how was the string affected?

2) When the eyebolt was turned, how was the pitch of the sound produced (when the string was plucked) affected?

3) Did turning the eyebolt produce a greater difference in length or tension of the string? Explain.

4) Describe observations of the group that did not involve the sense of hearing.
5) Suggest a way in which this part of the procedure could be altered to change only tension. Suggest an alteration that would change only length.

6) Why would it be desirable to change only one variable at a time?

7) State the relationship between string length and the pitch of sound produced.

8) The average human is most sensitive to sounds of high pitch. Such sounds, therefore, often seem louder than those of lower pitch, even when the actual amplitude (as measured by a machine) is the same. How did this characteristic of human hearing affect your group’s observations during the lab?

**Part 3:** 1) Following instructions on page 50 of the Student Activity Book for the Sound kit, assemble a four-stringed pegboard harp. Use four 60 cm pieces of 20 lb fishing line.

2) Tighten the four strings to the same tension. One technique is to tighten each string, by turning the eyebolt, just until there is no slack. Then, turn each of the eyebolts equally with the others. Increase the tensions until each makes an audible sound when plucked.

3) One group member should pluck the strings while others observe. A second should then pluck the strings while the first joins the observers.

4) After group members discuss observations and agree, describe the observations of the four strings below.
5) Tighten the eyebolts to change the tension on the strings. Strive to change them equally. Follow the plucking and observation process described in step #3.

**Questions:**
1) Describe the relationship between string length and sound produced.

2) Did altering the tension on the strings by turning the eyebolts produce the same effect on all four strings? Discuss.

3) How would you assemble a harp to include a string with extremely high pitch? To include one with extremely low pitch?

4) Why did step #2 call for all four strings to be set at the same tension?

**Part 4:** 1) Using the 60 cm pieces of 8 lb, 30 lb, 50 lb, and 80 lb fishing line one at a time, group members should listen to sounds made with the strings alone (not as part of the pegboard harp). One technique is for a group member to hold one end of a string in tightly in either hand, stretching it out near another member’s ear and snapping it quickly.

2) What steps did you take to ensure a “fair test” of the sounds made by the strings? What steps did you take to ensure that every group member participated evenly?
3) Describe how the strings differ in appearance and sounds made.

4) Assemble a four-stringed pegboard harp from the strings, setting the strings in sequence by thickness. The four should be of equal length and tension (refer back to part 3 for a technique that will result in equal tension).

5) Pluck the strings and listen as in the previous parts.

Questions:
1) What property of the strings was being studied in relation to the sound of the plucked strings in this lab? What was the relationship?

2) Name the independent, dependent, and controlled variables for the pegboard harp used in this part of the lab.

3) The sounds made by the four strings used in this section were studied two ways (steps #1-3 and steps #4-5). Did the results agree? Discuss.
4) *** Your future students might well be curious about the test strength of the nylon fishing line (8 lb, 20 lb, 30 lb, 50 lb, or 80 lb). Write a procedure these future students could follow to determine breaking strength of the five test strengths used. Include safety rules for the lab and questions for your students to answer. Be sure they evaluate how well the lab results compare to the given strengths as part of the lab. ***

**Part 5:**

1) Slide the wooden bridge under the four strings on your pegboard harp. Position it on edge like the bridge on a violin.

2) Experiment with the position of the bridge as well as adjusting the tension and length of the strings. Make observations as to whether the strings vibrate differently after the bridge is added. Experiment to see whether changing the point of plucking changes the way the strings vibrate.

3) *** Briefly summarize your method(s) of experimentation and results for each of the instructions in step #2. Illustrate with sketches, if you wish. ***

**Questions:**

1) What advantage(s) is/are gained by adding bridges to stringed instruments?

2) Name several stringed instruments and indicate whether they do or do not use a bridge. Be sure both categories are represented on your list.