A REVISION OF THE ELEMENTARY PHYSICAL SCIENCE 290 LABORATORY FORMS

by

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Senior Honors Project

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I recommend this thesis (project) for acceptance by the Honors Program of Ball State University for graduation with honors.

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STATEMENT OF INTENT

As a laboratory instructor for the Elementary Physical Science 290-390 sequence at Ball State University, I found that--though the material covered in the laboratory was interesting and useful for future elementary teachers--the theory and procedure forms used in carrying out the experiments were not geared to the needs of the students. Not only was the wording too technical, but often the procedures were not clearly outlined. Also, the data sheets provided within the experiments did not contain places for the suggested data to be written.

Because of these personal observations and the comments of my students, I decided to assume as an Honors Project the task of rewriting the laboratory handouts. I had four main goals in mind when composing and revising these forms:

1) to use language that is understandable and usable for elementary teachers;

2) to outline the procedure to be followed step-by-step and in detail;

3) to provide alternate ways of doing similar experiments using items and equipment found in any elementary classroom or the common household;

4) and, finally, to stress the major concepts being illustrated or discovered in the experiment.

It was the task of the Physics Department at Ball State University to accept and utilize, or reject, these forms. I hoped that my experience had been objective enough to allow me to write them in a manner suitable to future instructors. Unfortunately, I was engaged in student teaching during the "trial quarter" and so was unable to test the value of the forms first-hand.

During the Spring quarter of the 1970-71 school year, the Physics Department utilized the forms I had prepared for their Elementary Physical Science 290 laboratory program. Laboratory instructors were given copies of the forms in advance to aid them in preparing to teach the two-hour sessions; students were given the forms upon entering the laboratory.

At the end of the quarter, evaluation forms were given to both instructors and students. The results of those evaluations will be presented on the following pages. Both a statistical and verbal interpretation of the data are included.

The appendix at the end of the paper includes copies of the nine forms which I composed in the order in which they were used.

RESULTS OF STUDENTS' EVALUATIONS

A blank copy of the evaluation sheet included on the following page was given to all students who had taken Physical Science 290 during Spring quarter, 1970-71. The composite data shown on this sheet may be interpreted as follows:

a) the number in the upper left-hand corner of each square represents the total number of students who gave the respective experiments that ranking;

b) the number in the lower right-hand corner of each square represents the percentage of students who gave the respective experiments that ranking;

c) the number at the far right of each row represents the total number of students who ranked that particular experiment (Note: some students did not rank all nine experiments.);

d) the same interpretation as described in b and c above may be applied to the two numbers given in the question section at the bottom of the sheet, these numbers representing the negative responses to the questions.

The reader will note that the rankings are heavily distributed on the upper portion of the scale. In fact, the total percentages ranking the respective laboratories in either the "very good" or "good" ranges were as follows:

1.	Scientific Method	71.8%
2.	Velocity and Uniform Acceleration	78.8%
3.	Equilibrium of Forces	63.0%
4.	Simple Machines	64.6%
5.	Heat and Humidity	57.7%
6.	Archimedes' Principle	65.1%
7.	Wavelengths and Velocity of Sound	70.0%
8.	Convex Lens	71.1%
9.	Electric Currents and Circuits	58.5%

Although no specific data of this type is available on the previously-used lab forms, it appears to this author that these rankings are somewhat higher than a similar survey would have yielded for them.

19	15.3	70	56.5	33	26.6	2	1.6	0	0	124
36	28.1	65	50.7	25	19.5	1	0.8	1	0.8	128
21	16.6	58	46.4	39	31.2	7	5.6	0	0	125
25	22.8	46	41.8	35	31.8	4	3.6	0	0	110
8	6.5	64	51.2	43	34.4	9	7.2	1	0.8	125
20	16.9	58	48.2	33	28.0	4	3.4	3	2.5	118
33	26.0	56	44.0	29	22.8	8	6.3	1	0.8	127
42	32.8	49	38.3	32	25.0	7	5.5	2	1.6	128
30	23.4	45	35.1	29	22.7	17	13.3	8	6.2	128

25

19.5%

16

12.5%

7

5.5%

Regarding the questions at the bottom of the page, few comments were made in reference to specific experiments. The majority of comments which were made were concerning the experiment entitled "Electric Currents and Circuits". These comments indicated that this was the most difficult lab to follow and perform. The author suspects that the primary reason behind this difficulty is the fact that the vast majority of these students were girls (who seldom feel comfortable around electricity).

The question concerning the clarity of the procedure outlines indicated three major points:

1) the clarity depended to a large extent upon the skill of the laboratory instructor to present a complete, understandable introduction to the experiment;

2) the vocabulary could have been simplified even further;

3) often the labs were increased in difficulty because they did not coordinate with the regular class lectures.

The first and third of these points were not the direct result of the outlines given in the laboratory forms; rather, they are problems facing any instructor who wishes to conduct an organized, coherent class. However, it must be realized that the lecture time for the Physical Science 290 classes is limited to two hours per week, which presents a severe handicap to the instructor. Oftentimes, the laboratory must suffice to both introduce and conclude the discussion of the concept it involves, putting a heavy burden on the laboratory instructor as well. Hence, this situation is very nearly unavoidable.

The second point, that of the technicality of the vocabulary, is also somewhat an unavoidable one simply because any field must have its own set of words to describe its concepts. However, as one student suggested, it might possibly be a good idea in the future to include vocabulary lists with each laboratory form in order to eliminate some of the confusion caused by simply not understanding terms.

The third question revealed that the majority (87.5%) of the students would have preferred to have the laboratory forms before entering the laboratory. They indicated that this would have allowed them to prepare and research the experiment in advance, thus reducing the amount of introduction which the instructor would have needed to present. Many students indicated that they would have preferred to spend more time in doing the experiment, and less time talking about it. Those who did not feel that the advance acquisition of the forms would be beneficial stated that they would most likely not read them anyway, or would lose them. Perhaps if they were included in a bound manual, part of this difficulty could be overcome.

The most pleasing results of the evaluations were those regarding the sections entitled "For the Elementary Classroom". Over ninety-four percent of the students indicated that these sections made the labs more relevant to them as future elementary teachers, and that they would keep them for future reference. Those who felt that these sections would not be useful were apparently planning to teach either at the kindergarten level or in a mentally-retarded class.

Several students indicated that these sections could be improved by elaborating the suggested experiments and constructions in more detail, or simply by including a larger number of suggestions. Still others suggested that an open class discussion be held so that they could obtain more ideas from other students, or that a bibliography of possible sources of similar experiments be included with each laboratory.

RESULTS OF INSTRUCTORS' EVALUATION

The instructors' evaluations did not prove to be particularly enlightening. The responses to the questions (included on the next page) were brief and general and didn't provide much insight into the effectiveness of the project.

Those who had taught the labs using the old forms found the new forms to be somewhat easier for the students to read and understand. However, they indicated that it was unlikely that many students took the time to read the forms anyway. They also indicated that the major improvements were in the data sheets. Those who had not taught the labs before found them to be "very good" in most cases and stated that they were easy to use in preparing to teach the labs. All of the instructors indicated that the students--especially those who took time to read the forms carefully--were able to follow the forms adequately.

Suggested improvements for the labs which were offered by the instructors were:

1) to change some of the values of masses and distances in the experiments to produce better results;

2) to eliminate some of the mathematics in the introduction to the laboratory on simple machines;

3) and to provide more explicit information as to <u>why</u> certain things are done in the lab.

[illegible]

[illegible] which you have taught this quarter [illegible] of improving their usefulness [illegible] Another purpose for this evaluation [illegible] Please answer the following questions as completely and honestly as possible.

1. If you have taught the labs before, do you feel that the new forms were an improvement over the old forms? In what ways were they, or were they not?

2. If you had not taught the labs before, what was your first impression of the format? Were they easy to use in preparing to teach the experiment? [illegible] they be improved?

3. How did your students seem to respond to the format? Did they seem totally lost and confused, or did they seem to be able to follow them and proceed on their own?

4. Please add any comments on the particular experiments and on the forms in general that may help us evaluate their usefulness and effectiveness. [illegible] the future of the project.

CONCLUSIONS

On the whole, I was very pleased with the results of this project. Not only did I feel that I was helping my department, but also that I was making Physical Science 290 a more relevant and interesting course for elementary majors. The students' evaluations exceeded my highest hopes in their approval of the forms, and their criticisms and suggestions were most constructive.

However, the most beneficial result of this project was derived simply from the experience of writing it. As a future teacher, I believe that the opportunity to compose and utilize laboratories was extremely valuable in helping to plan my own teaching method, especially insofar as the laboratory situation is concerned. Even though I probably will not use precisely these forms at the secondary level, the basic concepts and needs of laboratory forms are now firmly implanted in my mind.

Education is my major concern for the future. Although my own schooling has been primarily in physics, my conscience forces me to turn the bulk of my attention to the human-practical aspects of it--not the purely theoretical. This project has offered me a most excellent opportunity to apply my philosophy, and I am thankful to have had a useful, constructive chance to implement it.

A P P E N D I X

[illegible]

[illegible] Lab[illegible] Exercise No. 1
THE SCIENTIFIC METHOD

The purpose of this experiment [illegible] scientific investigation [illegible] illustrate the [illegible] relationships.

Scientific method [illegible]
I. Define [illegible] problem.
II. [illegible] and analyze [illegible] set of hypotheses [illegible] solution of the problem.
III. [illegible] to test [illegible] necessary equipment.
IV. Perform the experiment.
V. Draw conclusions.
VI. [illegible] further problem.

In your [illegible] of the steps of the "scientific method" [illegible]

I. [illegible] swing [illegible] affect the period?

II. [illegible] can be [illegible] that the [illegible] complete [illegible] determine [illegible]

(1) ______________________

(2) ______________________

(3) ______________________

Note the following definitions:

__Length__ = the distance from the point of support to the [illegible]

__Period__ = the time of one complete swing of the pendulum.

__Amplitude__ = the number of degrees the string makes [illegible] position, with the center position [illegible] maximum horizontal displacement from the center [illegible] protractor [illegible] amplitude [illegible] below.

In the following procedure [illegible] the period [illegible] 10 full vibrations or swings and then divide [illegible] 10 [illegible] average value for the period [illegible] on the [illegible]

[illegible]
(1) Determine the [illegible] period [illegible] Use a 30 inch [illegible] the protractor [illegible] you have an [illegible]

(B) Determine the effect of the mass on the period of the pendulum by changing to a light wooden ball. Use a 30 inch length and 10° amplitude.

(C) Determine the effect of the length upon the period of the pendulum. Use the heavy mass, select your own amplitude, and use the lengths on the data sheet.

We have now found (hopefully) that the period (T) is a function of (depends on) the length. This relationship may be effectively studied by the use of graphs. Following your instructor's directions, and using the space provided on your data sheet, plot:

(1) Period versus length
(2) Period squared versus length

The period of a simple pendulum may be calculated from the simple approximate formula:

$$T \approx \sqrt{\frac{L}{10}}$$

if the length L is in inches. Make these calculations for each of the lengths you used and enter the results in the [illegible] on the data sheet.

V. Draw your conclusions

What factor alone did affect the time it takes for a pendulum to complete one swing?

How did this factor affect the period? [illegible] increased, did the period increase [illegible]?

Were you able to [illegible] the shape of the [illegible] in this lab.

FOR THE ELEMENTARY CLASSROOM

Try hanging some object — an eraser or a ball, for example — from a light fixture or some simple improvised stand. (Be sure it is within easy reach of your students.) Let the object hang there and cause it to swing, but don't mention it until one of your students asks about it. Hopefully, some curious youngster will ask what it's for, or what you're going to do with it. You then simply say, "We're going to have a contest to see who can make it swing the fastest." Have the students suggest ways of making it swing faster. Then test their suggestions by actually timing (with the second hand of a watch or a clock) the swings to see which is right. You can actually use much the same method of discovery that we used in this lab.

Lab Exercise No. [illegible]   Name ____________________
SCIENTIFIC METHOD
Data Sheet

(A) EFFECT OF AMPLITUDE (30" length)

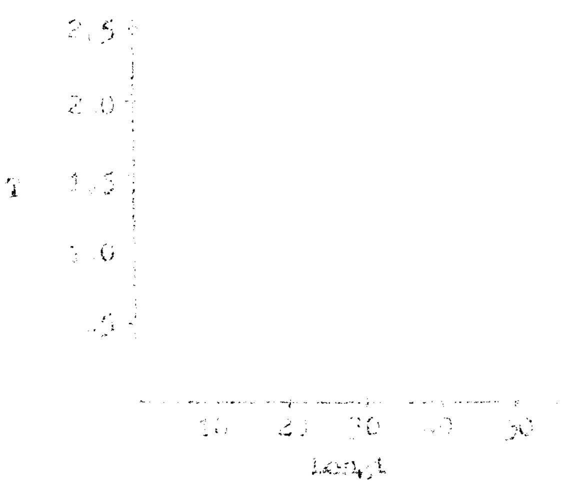
Amplitude	Time of 10 Periods (sec)	T, Period (sec)
5°		
10°		
[illegible]°		

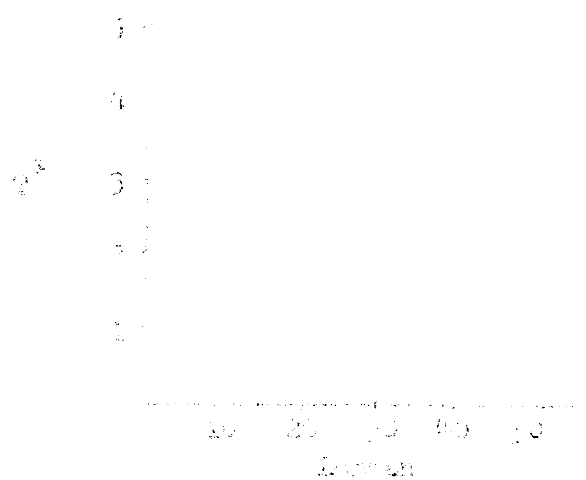
(B) EFFECT OF MASS (30" length)

Mass	Time of 10 periods (sec)	T, Period (sec)
Heavy		
Light		

(C) EFFECT OF LENGTH (small amplitude, heavy mass)

Length (inches)	Time of 10 Periods (sec)	T, Period (sec)	T^2, Period squared	Calculated Period $2\pi\sqrt{l/g}$
10				
20				
30				
40				
50				





CONCLUSIONS: [illegible]

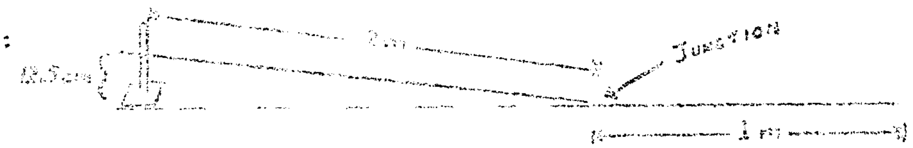
SCI 290 Lab. Exercise No. 2
VELOCITY AND UNIFORM ACCELERATION

References: WHITE, *Descriptive College Physics*, Chapter 2.

In this exercise we use Hot Wheels trucks rolling down slotted boards (on inclined plane) to produce accelerated motion. Times are measured with tenth-second lab timers. The general relations being studied are:

(1) $d = \bar{v}t$ (2) $v = at$ (3) $d = \frac{1}{2}at^2$ (4) $\bar{v} = \frac{v_o + v_f}{2}$

PROCEDURE:



Set up the track as explained by your lab instructor. You will need three lab benches to set up the apparatus. Support the upper end of the two-meter track section on a ringstand so that, at the 200 cm mark, the bottom of the board is 12.5 cm above the table top. Then place the shorter (one-meter) section of track at the lower end of the incline formed by the longer board so that the arrows align. Place a one-inch thick board under the junction of the two sections of track. Fasten the two boards together by wrapping doubled rubber bands around the screws located on either side of the junction. Run your thumb over the junction just inside the screws to see that the boards match smoothly. If they do not, adjust the screws on the longer board until the junction is smooth. NOTE: From this point on in the discussion, the lower board will be referred to as the horizontal section of track. However, it is not precisely horizontal, but slightly inclined to overcome the loss in velocity due to friction.

Place the truck on the incline 50 cm up from the bottom. First, determine the time required for it to travel down the incline (t). Next, still releasing the truck from 50 cm up the incline, determine the time required to travel one meter along the horizontal track (t_h). Measure the times carefully to obtain good results. Take each time measurement five times, record them in the space provided on the answer sheet, find the average time, and record the average in Table A.

Repeat the procedure above for finding t and t_h for distances of 100 cm, 150 cm, and 200 cm up the incline.

CALCULATIONS:

Since we have no way of knowing how fast the truck is moving when it reaches the bottom of the incline, we must assume that the truck continues moving at that same velocity on the horizontal section of track. The measurement of the time t_h for one meter of horizontal track, then, determines the final velocity, v_f, at the bottom of the incline. Using the equation

$$v_f = \frac{d}{t_h} = \frac{100\ cm}{t_h}$$

compute v_f for each of the four distances up the incline using their respective values of t_h. Record the results in the last column of Table A on the data sheet.

SCI 290 Lab. Exercise No. 5

DENSITY, SPECIFIC GRAVITY, ARCHIMEDES' PRINCIPLE

One property common to all matter is density. In this laboratory, we will look at different methods of finding the densities of solids that float, solids that sink, and liquids.

Density is defined to be the mass of a substance per unit volume, or

$$D = \frac{M}{V}.$$

Hence, if we have an object whose density we wish to know, we need only find its mass and volume.

Specific Gravity is defined as the ratio of the mass of the given substance to the mass of an equal volume of a standard. For solids and liquids that standard is water; for gases, the standard is air. In the C.G.S. system, specific gravity and density are numerically equal to each other since the density of water is 1.0 grams/cm^3.

Archimedes' Principle states that a body floating or submerged in a liquid is buoyed up by a force equal to the weight of the liquid displaced. We will use this principle to determine the densities or specific gravities of an aluminum cylinder, a cork, and a liquid (methanol).

PROCEDURE

I. Solids That Sink - Aluminum Cylinder

A. Weigh the cylinder and record the value on the data sheet.
B. Suspend the cylinder below the balance as demonstrated by your instructor. Find and record the weight of the cylinder submerged in water.
C. Find the difference between values A and B. This is the buoyant force - or the weight of the displaced water. And, since water weighs 1 gram per cm^3, this is also the volume of the cylinder.
D. Calculate the density of the cylinder: $D = M/V$.
E. Check your results by finding the volume of the cylinder directly using the formula

$$V = \pi r^2 h.$$

In order to do this, you must measure the dimensions of the cylinder. ($\pi = 3.14$)
Calculate the density again using this value for the volume.

How do the two values of density you found compare?

II. Solids that Float - Cork

A. Weigh the cork and record the value.
B. Attach a sinker to the cork and suspend both below the balance. Weigh again with the cork in the air and the sinker submerged.
C. Weigh again with the cork and sinker both submerged.
D. Find the difference between B and C. This is again the buoyant force - hence we have the volume of the cork.
E. Calculate the density of the cork using the volume from part D and the mass from part A.

III. Liquids - Methanol

The most convenient method for determining the specific gravity of a liquid is to use a hydrometer, which also makes use of Archimedes' Principle. Your instructor will show you how to read the hydrometer for the liquid provided.

FOR THE ELEMENTARY CLASSROOM

To illustrate the concept of density, take two objects that are exactly the same size and look exactly the same on the exterior (like two hollow cubes or plastic balls). Leave on empty, but fill the other with something heavy like sand. Don't give your students any indication that there is anything different between the two objects. Then have a student hold out his hands - palms up. Drop the light one in his hands first - then the heavy one - and watch his reaction.

Lab Exercise No. 5
DENSITY
Data Sheet

Name ______________________________

I. ALUMINUM CYLINDER

A. Weight of cylinder, M ______________ gms

B. Weight of submerged cylinder ______________ gms

C. Difference of A and B, V ______________ cm^3

D. Density of cylinder $= \frac{M}{V}$ ______________ gm/cm^3

E. Radius of cylinder, r ______________ cm

Height of cylinder, h ______________ cm

Volume $= \pi r^2 h$ ______________ cm^3

Density $= \frac{M}{V}$ ______________ gm/cm^3

II. CORK

A. Weight of cork, M ______________ gms

B. Weight with cork in air, sinker submerged ______________ gms

C. Weight with both cork and sinker submerged ______________ gms

D. Difference of B and C, Volume of cork, V ______________ cm^3

E. Density of cork $= \frac{M}{V}$ ______________ gm/cm^3

III. LIQUID * METHANOL

Hydrometer Reading: Specific Gravity ______________

CONCLUSIONS:

SCI. 290 Lab Exercise No. 6
HEAT AND HUMIDITY

A. Heat of Fusion of Water

You should be familiar with the following definitions:

1. calorie: the quanity of heat required to raise the temperature of one gram of water 1 C°.
2. thermal capacity: The number of calories required to raise the temperature of one gram of a substance 1 C°.
3. specific heat: the ratio of the thermal capacity of a substance to the thermal capacity of water. Note: the specific heat would be a unitless number. Why?
4. Heat of fusion of water: the amount of heat energy required to melt one gram of ice without changing its temperature.

In this experiment, we take a known amount of water at a known temperature and add a known amount of ice. The resulting temperature is then measured when the ice has all melted. From the law of conservation of energy, we can then set up the following heat balance equation and calculate the heat of fusion, F:

Heat Energy GAINED by ice = Heat Energy LOST by water and cup

$$M_i \cdot F + M_i c_w (T_f - 0) = M_w c_w (T_i - T_f) + M_c c_c (T_i - T_f)$$

PROCEDURE:

Weigh the calorimeter cup and stirrer and find out what metal it is made of. If the specific heat is not written on its side, ask your instructor for the value. Record the weight and specific heat in the data table. Add about 200 grams of water to the cup. Insert the thermometer CAREFULLY into the cork of the calorimeter and then place it in position in the calorimeter. Record the initial water temperature, T_i, in the data table. While stirring the water, add 6 - 10 ice cubes to the water, drying each one before placing it in the cup. Record the final temperature of the water, T_f, when the ice has completely melted. BE SURE YOU ARE USING THE CENTIGRADE SCALE ON THE THERMOMETER! Weigh the cup and water and determine the total amount of ice, M_i, added. Now calculate the heat of fusion, F.

B. Relative Humidity and Dew Point

The amount of moisture in the air has a tremendous influence on the activities of man. Air which contains the maximum amount of water vapor possible is said to be saturated. Any increase in moisture above this level causes condensation. Since the capacity of the air to hold water vapor decreases sharply as the temperature drops, a lowering of the temperature will eventually produce saturation. The temperature at which the air becomes saturated is known as the dew point. The ratio of the actual water-vapor content of the air to its maximum capacity at the same temperature is called the relative humidity, and is usually expressed as a per cent. In this exercise we determine the dew point and use it to compute the relative humidity. The actual water vapor in the air is called the absolute humidity and is often expressed as grams of water vapor per cubic meter of air.

For a certain temperature: $\text{Relative Humidity} = \dfrac{\text{Actual water vapor content of air}}{\text{Maximum capacity}} \times 100\%$.

PROCEDURE:

Partly fill the inner calorimeter cup with cold water. Add small bits of ice with constant stirring until a thin film of moisture appears on the outside of the cup. Record the temperature at which this film of condensation first appears. Remove the ice from the container and allow it to warm. Note the temperature at which the film disappears.

Repeat the above procedure to obtain an average value.

The dew point is the average of the two temperatures.

Record the temperature of the room.

From the absolute-humidity table given below, find the weight of water vapor the air is capable of holding at the dew point and room temperatures you found.

The relative humidity is then found by dividing the weight of water vapor the air holds at the dew point by the amount it holds at room temperature. Find this value for the relative humidity and express it as a per cent.

Absolute Humidity Table

Temperature in degrees Centigrade and

Absolute Humidity in Grams per Cubic Meter

Temp.	Humidity	Temp.	Humidity	Temp.	Humidity
0	4.84	12	10.59	24	21.54
1	5.18	13	11.25	25	22.80
2	5.54	14	11.96	26	24.11
3	5.92	15	12.71	27	25.49
4	6.33	16	13.50	28	26.93
5	6.76	17	14.34	29	28.45
6	7.22	18	15.22	30	30.05
7	7.70	19	16.14	31	31.70
8	8.21	20	17.12	32	33.45
9	8.76	21	18.14	33	35.27
10	9.33	22	19.22	34	37.18
11	9.93	23	20.35	35	39.18

FOR THE ELEMENTARY CLASSROOM:

Your students can find the dew point of your classroom just as we found it in the laboratory. Take a shiny tin food can with the label removed and fill it with slightly warm water. Add ice to the water until a mist forms on the side of the can. Measure the temperature at which this mist forms with any ordinary household thermometer (it's all right to use Farenheit degrees). This temperature is the dew point.

Be sure to point out to the students that this is the temperature at which dew would form on the ground (or fog or clouds in the air) for the amount of water vapor there is in the air on that particular day.

DATA SHEET
Lab Exercise #6
HEAT AND HUMIDITY

NAME ______________________________

A. HEAT OF FUSION OF WATER

M_c = mass of inner calorimeter cup and stirrer	________
M_w = original mass of water in cup	________
M_i = mass of ice added	________
T_i = initial water temperature (C°)	________
T_f = Final water temperature (C°)	________
c_w = thermal capacity of water	1
c_c = thermal capacity of cup and stirrer	________
F = heat of fusion (calculated)	________

PERFORM YOUR CALCULATIONS FOR THE HEAT OF FUSION HERE:

$$F = \frac{M_w c_w (T_i - T_f) + M_c c_c (T_i - T_f) - M_i c_w (T_f - 0)}{M_i}$$

F =

B. RELATIVE HUMIDITY AND DEW POINT

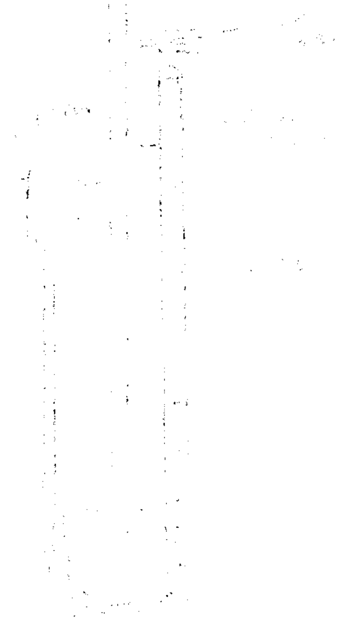
	Trial 1	Trial 2	Avg.
Temperature at which film appears, °C	____	____	____
Temperature at which film disappears, °C	____	____	____
Dew Point (average of above)			____

Temperature of Room, °C ________________

Absolute humidity of air at dew point in g/m^3 ________________

Absolute humidity of air at room temp. in g/m^3 ________________

Relative humidity expressed as a percent ________________



[illegible]

[illegible] 1, 2 and 3. [illegible]

[illegible]

[illegible] °C [illegible]

[illegible] [illegible]/sec

[illegible] [illegible]/sec

[illegible] Compare the [illegible] velocity [illegible] of the three [illegible] [illegible] difference [illegible]

[illegible]

[illegible] experiment [illegible] procedure for [illegible] frequency of [illegible] three frequencies [illegible]

[illegible] the velocity of [illegible]

Sci 290 Lab. Exercise No. 8

THE CONVEX LENS

Convex lenses are used today in a multitude of devices to form an image of a certain object. This is true if the lens is used as a magnifying, or reading glass, or if it is a part of a more complex assembly of lenses in such devices as telescopes, microscopes, cameras, or projectors. This study makes use of a "meter-stick optical bench" and concerns the nature and location of the images formed by a simple convex lens.

A. THE FOCAL LENGTH OF A LENS

A convex lens is mounted in a lens holder on a meter stick. A cardboard screen is placed similarly on the meter stick a few inches from the lens. If the assembly is pointed at a distant object such as the sun, another building, or tree, etc. and if the separation between the lens and the screen is varied, a position will be found where the image is very sharp and distinct. While standing near an outside window or door, carefully measure and record the distance between the lens and screen for which a sharp image of a distant object is obtained. Repeat this procedure for a second lens. For all practical purposes, the distance to the object may be considered as infinite, and the distance between the lens and the screen is then by definition the focal length of the lens. In the discussion which follows, this distance equal to the focal length is designated as "f".

Note the following definitions as they apply to the images formed:

1. real: formed by actual rays of light
2. virtual: appear to the eye to be formed by actual rays of light
3. erect: pointing in the same direction as the object
4. inverted: upside-down as compared to the object.

For a single lens, real images are always inverted; virtual images are always erect.

B. VIRTUAL IMAGES

For an object, print a small letter on the screen and look at it through the short-focus lens mounted on the meter stick, making sure the lens is less than one focal length away from the screen. Adjust the lens-to-object distance until a sharp image is observed with the eye. This image is virtual, i.e. it cannot be projected on a second screen. Carefully measure the object-to-lens distance and compare it to the focal length. Note also the nature of the image.

C. REAL IMAGES

(1) A small triangle or arrow painted on a lamp bulb is placed at the zero mark on the meter stick. Now place the short-focus lens at a distance of exactly 2f from the object. Find the image by moving the screen. Verify the fact that the lens equation, $1/p + 1/q = 1/f$, gives a value for f which is in close agreement to your measured value for f in part A. (Note: p and q are object and image distances respectively, and for the above situation should have been equal.)

(4) Move the lens to a position between one and two focal lengths away from the bulb. Again find the image by moving the screen and list the characteristics of the image in the space provided on the data sheet.

(5) Repeat the procedure for a distance of exactly 2f between bulb and lens.

(6) Repeat the procedure again for a distance of greater than 2f.

D. CONSTRUCTION OF A TELESCOPE (OPTIONAL)

Construct a telescope using the short focus lens as an eyepiece and the long focus lens as the objective lens. Start with the two lenses a distance apart equal to the sum of their focal lengths. The instructor will show you how to determine the magnification. (The magnification should be equal to the ratio of the focal length of the objective lens to that of the eyepiece.)

FOR THE ELEMENTARY CLASSROOM:

Take an ordinary dime-store magnifying glass and have your students determine its focal length. Then let them try out the different kinds of images that are found when the object-to-lens distance is changed. You may want to make a large chart or poster of the results to show how the images are affected by the various distances.

DATA SHEET
Lab Exercise 38
THE CONVEX LENS

NAME ______________________ 38 ________

A. FOCAL LENGTHS

Focal length of fat lens ____________ cm

Focal length of thin lens ____________ cm

B. VIRTUAL IMAGES: Use the short-focus lens.

Object-to-Lens Distance ____________ cm

Nature of Image: Enlarged, Reduced ____________

Erect, Inverted ____________

Real, Virtual ____________

C. REAL IMAGES: Check the characteristics that apply to each image.

Object Distance, p	Image Distance, q	Real	Virtual	Erect	Inverted	Enlarged, Reduced, Same Size
(1) 2f						
(2) < 2f but > f						
(3) f						
(4) > 2f						

D. TELESCOPE

Observed magnification: ____________

Calculated magnification: ____________

E. CONCLUSIONS