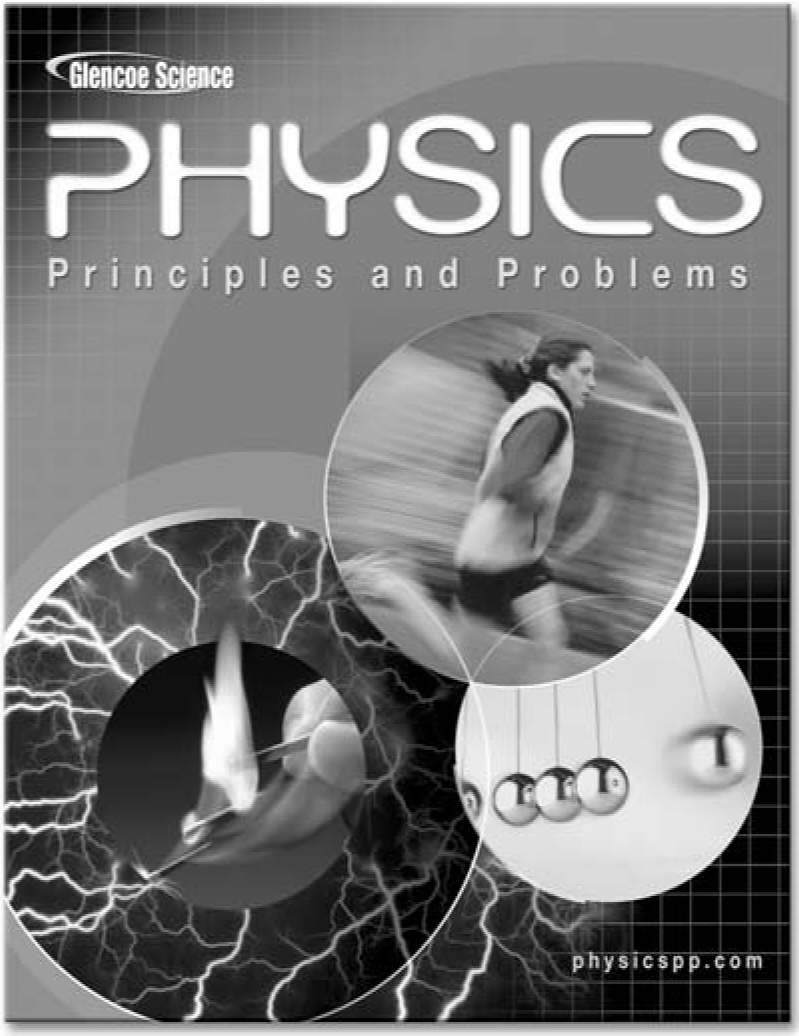

Probeware Laboratory Manual

Glencoe

New York, New York Columbus, Ohio Chicago, Illinois Peoria, Illinois Woodland Hills, California

A Glencoe Program

PHYSICS

Principles and Problems

Glencoe

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Contents

To the Student

Physics is the science of matter and energy and their interactions. In your classroom work in physics, you will learn a great deal about the information that has been gathered by scientists about matter and energy. But physics is not just information. It is also a process for finding out more about matter and energy and their interactions. Laboratory activities are the primary means that physicists use to learn about matter. The activities in the ***Probeware Laboratory Manual*** require that you form and test hypotheses, measure and record data and observations, analyze those data, and draw conclusions based on those data and your knowledge of physics. These processes are the same as those used by professional physicists and all other scientists.

CBL (computer-based laboratory) activities use graphing calculators to collect and analyze real-world data using different probes or sensors. The CBL™ system is an interface that collects data from the probes and sends the information to the calculator. The calculator, in turn, runs stored data collection and processing programs, which interpret and plot data obtained from the CBL system.

Organization of Activities

- **Introduction** Following the title and number of each activity, an introduction provides a background discussion about the problem you will study in the activity.
- **Problem** The problem to be studied in this activity is clearly stated.
- **Objectives** The objectives are statements of what you should accomplish by doing the investigation. Recheck this list when you have finished the activity.
- **Materials** The materials list shows the apparatus you need to have on hand for the activity.
- **Safety Precautions** Safety symbols and statements warn you of potential hazards in the laboratory. Before beginning any activity, refer to page vii to see what these symbols mean.
- **Procedure** The numbered steps of the procedure tell you how to carry out the activity and sometimes offer hints to help you be successful in the laboratory. Some activities have **CAUTION** statements in the procedure to alert you to hazardous substances or techniques.
- **Data and Observations** This section presents a suggested table or form for collecting your laboratory data. Always record data and observations in an organized way as you do the activity.
- **Analyze and Conclude** The Analyze and Conclude section shows you how to perform the calculations necessary for you to analyze your data and reach conclusions. It provides questions to aid you in interpreting data and observations in order to reach an experimental result. You are also asked to form a scientific conclusion based on what you actually observed, not what "should have happened." Opportunities to analyze possible errors in these activities also are given.

Sending Data to Graphical Analysis

If using a TI-83 graphing calculator:

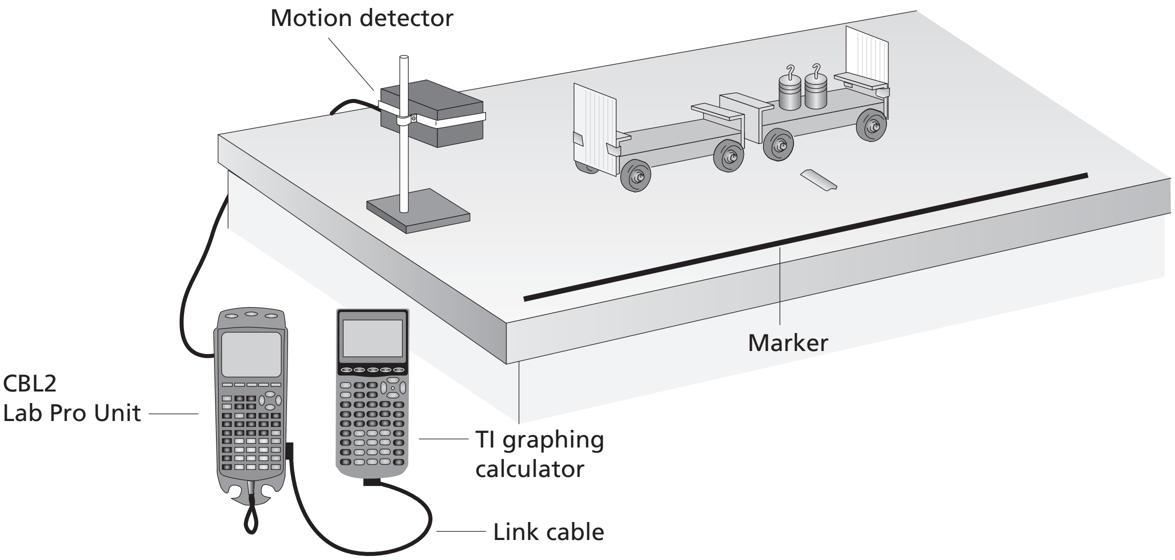
1. On the TI calculator, press 2nd Link, then select List…from the SEND menu.
2. Use the down arrow to locate the lists on the SELECT menu. Position the arrow in front of a list you want to send to GRAPHICAL ANALYSIS and press ENTER to select that particular list. More than one list may be selected in this manner. A filled box will appear beside each list that will be sent. To deselect, press ENTER. The filled-in box will disappear.
3. Press the right arrow on the calculator, then select TRANSMIT. The lists will appear in columns in the data table window of GRAPHICAL ANALYSIS. They will be labeled with simple list names from the calculator. If you want to rename the lists or add units, double-click on the column heading and enter a new name or label in the dialog box.

If using another type of graphing calculator with a PC computer:

1. Connect the TI-Graph Link cable to a free serial port of the Windows computer and to the port on the bottom edge of the TI calculator.
2. With GRAPHICAL ANALYSIS running, choose Import from the TI Calculator under the FILE MENU. If the TI-Graph Link cable is not connected to the serial port designated in the status box, click on SELECT PORT and choose the correct port for the TI-Graph Link cable.

CBL Equipment

This diagram shows the basic equipment in most of these CBL activities. Such equipment includes the CBL unit, a graphing calculator, link cable, AC adaptor for the CBL unit, DIN adapter (needed for some probes), and a probe or sensor.



Safety in the Laboratory

If you follow instructions exactly and understand the potential hazards of the equipment and the procedure used in an experiment, the physics laboratory is a safe place for learning and applying your knowledge. You must assume responsibility for the safety of yourself, your fellow students, and your teacher. Here are some rules to guide you in protecting yourself and others from injury and in maintaining a safe environment for learning.

1. The physics laboratory is to be used for serious work.
2. Never bring food, beverages, or makeup into the laboratory. Never taste anything in the laboratory. Never remove lab glassware from the laboratory, and never use this glassware for eating or drinking.
3. Do not perform experiments that are unauthorized. Always obtain your teacher's permission before beginning an activity.
4. Study your laboratory assignment before you come to the lab. If you are in doubt about any procedure, ask your teacher.
5. Keep work areas and the floor around you clean, dry, and free of clutter.
6. Use the safety equipment provided for you. Know the location of the fire extinguisher, safety shower, fire blanket, eyewash station, and first-aid kit.
7. Report any accident, injury, or incorrect procedure to your teacher at once.
8. Keep all materials away from open flames. When using any heating element, tie back long hair and loose clothing. If a fire should break out in the lab, or if your clothing should catch fire, smother it with a blanket or coat or use a fire extinguisher. Never run.
9. Handle toxic, combustible, or radioactive substances only under the direction of your teacher. If you spill acid or another corrosive chemical, wash it off with water immediately.
10. Place broken glass and solid substances in designated containers. Keep insoluble water material out of the sink.
11. Use electrical equipment only under the supervision of your teacher. Be sure your teacher checks electric circuits before you activate them. Do not handle electric equipment with wet hands or when you are standing in damp areas.
12. When your investigation is completed, be sure to turn off the water and gas and disconnect electrical connections. Clean your work area. Return all materials and apparatus to their proper places. Wash your hands thoroughly after working in the laboratory.

The ***Physics: Principles and Problems*** program uses safety symbols to alert you to possible laboratory dangers. These symbols are provided in your textbook in Appendix D and are explained on the next page. Be sure you understand each symbol before you begin an activity that displays a symbol.

Safety Symbols

SAFETY SYMBOLS	HAZARD	EXAMPLES	PRECAUTION	REMEDY
DISPOSAL	Special disposal procedures need to be followed.	Certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.
BIOLOGICAL	Organisms or other biological materials that might be harmful to humans	Bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.
EXTREME TEMPERATURE	Objects that can burn skin by being too cold or too hot	Boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.
SHARP OBJECT	Use of tools or glassware that can easily puncture or slice skin	Razor blades, pins, scalpels, pointed tools, dissecting probes, broken glass	Practice common-sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.
FUME	Possible danger to respiratory tract from fumes	Ammonia, acetone, nail polish remover, heated sulfur, moth balls	Make sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.
ELECTRICAL	Possible danger from electrical shock or burn	Improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus.	Do not attempt to fix electrical problems. Notify your teacher immediately.
IRRITANT	Substances that can irritate the skin or mucous membranes of the respiratory tract	Pollen, moth balls, steel wool, fiberglass, potassium permanganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.
CHEMICAL	Chemicals that can react with and destroy tissue and other materials	Bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammonia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.
TOXIC	Substance may be poisonous if touched, inhaled, or swallowed.	Mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.
FLAMMABLE	Flammable chemicals may be ignited by open flame, spark, or exposed heat.	Alcohol, kerosene, potassium permanganate	Avoid open flames and heat when using flammable chemicals.	Notify your teacher immediately. Use fire safety equipment if applicable.
OPEN FLAME	Open flame in use, may cause fire.	Hair, clothing, paper, synthetic materials	Tie back hair and loose clothing. Follow teacher's instruction on lighting and extinguishing flames.	Notify your teacher immediately. Use fire safety equipment if applicable.

Eye Safety
Proper eye protection should be worn at all times by anyone performing or observing science activities.

Clothing Protection
This symbol appears when substances could stain or burn clothing.

Radioactivity
This symbol appears when radioactive materials are used.

Handwashing
After the lab, wash hands with soap and water before removing goggles.

Properties of Common Substances

Specific Heat and Density

Substance	Specific Heat (J/kg·K)	Density
Alcohol	2450	0.8
Aluminum	903	2.7
Brass	376	8.5 varies by content
Carbon	710	1.7–3.5
Copper	385	8.9
Glass	664	2.2–2.6
Gold	129	19.3
Ice	2060	0.92
Iron (steel)	450	7.1–7.8
Lead	130	11.3
Mercury	138	13.6
Nickel	444	8.8
Platinum	433	21.4
Silver	235	10.5
Steam	2020	–
Tungsten	133	19.3
Water	4180	1.0 at 4°C, 0.99 at 0°C
Zinc	388	7.1

Resistor Color Code

Suppose that a resistor has the following color bands:

1st band	2nd band	3rd band	4th band
brown	black	yellow	gold
1	0	4	±5%

The value of this resistor is $10 \times 10{,}000 \pm 5\%$ or it has a range of 80,000 Ω to 120,000 Ω.

Resistance Color Codes (resistance given in ohms)

Color	Digit	Multiplier	Tolerance (%)
Black	0	1	
Brown	1	10	
Red	2	100	
Orange	3	1000	
Yellow	4	10,000	
Green	5	100,000	
Blue	6	1,000,000	
Violet	7	10,000,000	
Gray	8		
White	9		
Gold		0.1	5
Silver		0.01	10
No color			20

Date ________________ Period ________________ Name ______________________________

CHAPTER 2

Probeware Lab 2-1

Safety Precautions

Materials

- constant-velocity vehicle
- metric ruler
- C-clamp
- CBL 2 or LabPro interface
- graphing calculator
- link cable
- motion detector
- graph paper

How fast is it going?

In this activity, you will be investigating the motion of a moving vehicle to determine its velocity. The CBL 2 or LabPro interface with a motion detector will measure time intervals and the vehicle's displacement. The motion detector emits short pulses of ultrasonic sound waves and then listens for a reflected echo of the pulse. The interface uses the speed of the ultrasonic sound waves and the time it took to return to the detector to determine the distance to the object from which the waves were reflected.

The CBL 2 or LabPro interface will collect data of time and associated distances of the moving vehicle from the detector. The average velocity can be determined by $v = \frac{\Delta d}{\Delta t} = \frac{d_f - d_i}{t_f - t_i}$.

Objectives

- **Calculate** the average velocity for a series of intervals.
- **Classify** displacement: time ratio as uniform or nonuniform motion.
- **Analyze** the relationship between total displacement and time, and velocity and time.
- **Define** operationally constant velocity.
- **Interpret** data to establish trends in events.

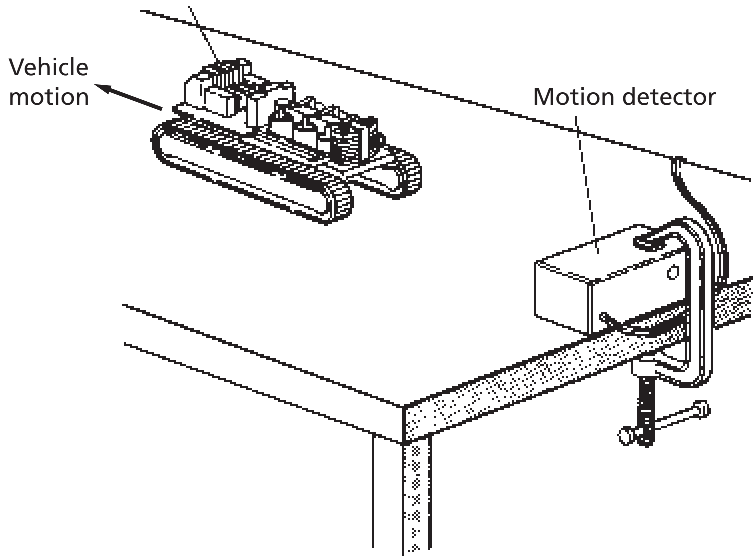


Figure A

Procedure

1. With your lab partner, set up the motion detector and vehicle as shown in **Figure A.** Place the vehicle about 0.5 m from the motion detector.

Often targets are not directly in front of the motion detector. Move the detector so that the target is directly in front of the motion detector. In using the motion detector, it is important to realize that the ultrasound is emitted in a cone about 30° wide. Anything within the cone of ultrasound can cause a reflection and possibly an accidental measurement. A common problem in using motion detectors is getting unintentional reflections from a desk, chair, or table in the room.

Tilting the motion detector slightly can minimize unintended reflections. The motion detector does not properly detect objects closer than 0.4 m. The maximum range is about 6 m, but stray objects in the wide detection cone can be problematic at this distance. If the velocity graphs are noisy, try to increase the strength of the ultrasonic reflection from the target by increasing the target's area.

2. Connect the CBL 2 or LabPro interface unit to the calculator using the unit-to-unit link cable and the link ports on the calculator and interface. Press the cable ends in firmly. Connect the motion detector to the DIG/SONIC (or DIG/SONIC 1 on the LabPro) port of the interface.

3. Turn on the calculator and start the DataMate program. Press [CLEAR] to reset the program.

4. If the motion detector is working properly, the top line of the main screen will display DIG: MOTION(M) and a reading of the distance (in meters) from the vehicle to the motion detector.

5. Select SETUP from the main screen. Press [▲] and then press [ENTER] to choose MODE. Select TIME GRAPH and then select CHANGE TIME SETTINGS. Type "0.1" as the time between samples in seconds. Press [ENTER]. Type "100" as the number of samples. Press [ENTER]. Select OK twice to return to the main screen.

6. You are ready to begin the experiment. One student should select START on the main screen of the calculator. When the motion detector begins to click, wait 1–2 s, and then another student should turn on the vehicle and release it so it moves across the table away from the motion detector.

7. When the motion detector has stopped clicking, press [ENTER] to display the DISTANCE graph.

8. Use the arrows keys to trace along the curve. On the far left, the curve represents the position of the vehicle before its motion began. The middle section of the curve represents the motion of the moving vehicle. Copy this graph into your laboratory report.

9. Chose a point on the curve at the beginning of the middle section of the graph. Record the time (x-value) and the distance (y-value) into your data table. Press [▶] three times to move to another point along the curve. Record the new time and distance values in your data table. Continue moving along the curve in increments of three steps and recording data until ten sets of data have been recorded. Press [ENTER] to return to the graph selection screen.

10. Press [▼], and then press [ENTER] to display the VELOCITY graph. Observe how the velocity of the vehicle changed during the experiment. Sketch this graph in your laboratory report. Press [ENTER] to return to the graph selection screen.

Data and Observations

Distance v. Time Graph

Velocity v. Time Graph

Data Table 1			
Time (s)	Total Displacement (m)	Interval Displacement (m)	Average Velocity (m/s)

Analysis and Conclusions

1. In the graph selection screen, cursor to the the DISTANCE graph, and then choose SELECT REGION. Cursor to the left part of the graph where the distance graph just starts to become sloped. Press ENTER. Cursor to the right part of the sloped distance line. Select Enter. Return to MAIN SCREEN. Go to ANALYZE. Choose CURVE FIT. Choose LINEAR (DIST VS TIME). Record A and B for the equation Y = Ax + B. Press ENTER to view the curve fit. If A is the slope of the graph, what does it represent?

2. Using your distance versus time graph, describe the motion of the vehicle.

3. Using Data Table 1, calculate the displacement during each time interval.

4. Using Data Table 1, calculate the average velocity between each set of displacements.

5. Using Data Table 1, calculate the vehicle's average velocity for the entire trip. Compare this value to the velocities during each interval and with the slope of the distance versus time graph.

6. Are there any time intervals on the velocity versus time curve where the velocity of the vehicle appears to be changing? Describe the graph at these points.

7. Are there any time intervals on the velocity versus time curve where velocity appears to be constant? Why?

Extension and Application

1. Analyze the motion of a basketball rolling along the floor. Design the experiment so that the ball moves with a constant velocity. Challenge your classmates to a constant-velocity challenge.

2. Suppose that a constant-velocity vehicle could double its average velocity. How would this change affect the distance during a given interval of time? How would this change the overall displacement of the vehicle in the same time?

Date ____________ Period ____________ Name ____________________

CHAPTER 3

Probeware Lab 3-1

Safety Precautions

Materials

- LabPro or CBL 2 interface
- TI graphing calculator
- DataMate program
- motion detector
- volleyball or basketball
- wire basket

How does a tossed ball move?

Toss a ball into the air. How would you describe its motion? As the ball goes up, it appears to slow down until it stops. Then it increases speed as it falls down. What types of mathematical relationships are involved?

In this experiment, you will use a motion detector to collect distance, velocity, and acceleration data for a ball thrown straight upward. You will then analyze the graphs of these data.

Objectives

- **Collect** distance, velocity, and acceleration data as a ball travels straight up and down.
- **Analyze** the distance v. time, velocity v. time, and acceleration v. time graphs.
- **Determine** the best-fit equations for the distance v. time and velocity v. time graphs.
- **Determine** the mean acceleration from the acceleration v. time graph.

Procedure

1. Place the motion detector on the floor and protect it by placing a wire basket over it.

   Often targets are not directly in front of the motion detector. Move the detector so that the target is directly in front of the motion detector. In using the motion detector, it is important to realize that the ultrasound is emitted in a cone about 30° wide. Anything within the cone of ultrasound can cause a reflection and possibly an accidental measurement. A common problem in using motion detectors is getting unintentional reflections from a desk, chair, or table in the room.

   Tilting the motion detector slightly can minimize unintended reflections. The motion detector does not properly detect objects closer than 0.4 m. The maximum range is about 6 m, but stray objects in the wide detection cone can be problematic at this distance. If the velocity graphs are noisy, try to increase the strength of the ultrasonic reflection from the target by increasing the target's area.

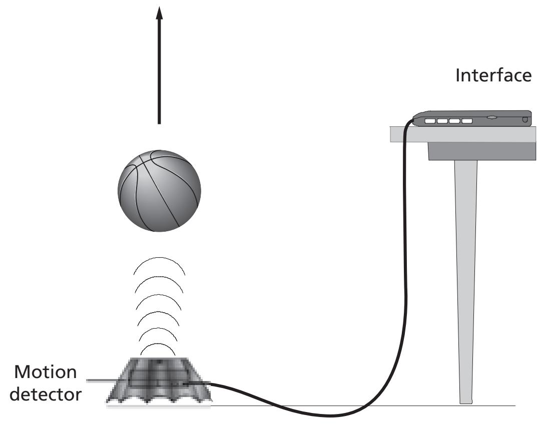


Figure A

2. Plug the motion detector into the DIG/SONIC 1 port of the LabPro or DIG/SONIC port of the CBL 2 interface. Use the link cable to connect the TI graphing calculator to the interface. Firmly press in the cable ends.
3. Turn on the calculator and start the DataMate program. Press CLEAR to reset the program.
4. In this step, you will toss the ball straight upward above the motion detector and let it fall back toward the motion detector. This step may require some practice. Data will be collected for 5 s. Hold the ball directly above and about 0.5 m from the motion detector. Use two hands. Be sure to pull your hands away from the ball after it starts moving so that your hands are not picked up by the motion detector. Select START to begin data collection. You will notice a clicking sound from the motion detector. Wait one second, then toss the ball straight upward. Be sure to move your hands out of the way after you release it. A toss of 0.5 to 1.0 m above the motion detector works well. You will get best results if you catch and hold the ball when it is about 0.5 m above the motion detector.
5. Press ENTER to display the DISTANCE graph.
6. Examine the distance v. time graph. Repeat step 4 if your distance v. time graph does not show an area of smoothly changing distance. Check with your teacher if you are not sure whether you need to repeat the data collection. To repeat data collection, press ENTER to return to the graph selection screen, and select MAIN SCREEN. Select START to begin data collection.

Data and Observations

1. Print or sketch the three motion graphs. You can see the other graphs by pressing ENTER to return to the graph selection screen; use the cursor keys to select DISTANCE, VELOCITY or ACCELERATION and press ENTER to display the graph.

Curve fit parameters:	A	B	C
Distance ($Ax^2 + Bx + C$)			
Velocity ($Ax + B$)			
Average acceleration			

Analysis and Conclusions

1. The graphs you have recorded are fairly complex and it is important to identify different regions of each graph. Record your answers directly on the printed or sketched graphs. After studying each graph, press ENTER to return to the graph selection screen. Identify the region when the ball was being tossed but still in your hands.

a. Examine the velocity versus time graph and identify this region.

b. Label this on the graph.

c. Examine the acceleration versus time graph and identify the same region.

d. Label this on the graph. Identify the region where the ball is in free fall.

e. Label the region on each graph where the ball was in free fall and moving upward.

f. Label the region on each graph where the ball was in free fall and moving downward.

g. Determine the distance, velocity, and acceleration at these specific points. Use the cursor keys on each graph to read numeric values.

On the velocity v. time graph, locate where the ball had its maximum velocity, after the ball was released. Mark the spot and record the value on the graph. On the distance versus time graph, locate the maximum height of the ball during free fall. Mark the spot and record the value on the graph.

2. What was the height and velocity of the ball at the top of its motion?

____

3. What was the acceleration of the ball at the top of its motion?

____

4. The motion of an object in free fall is modeled by $y = v_0t + \Delta gt^2$, where y is the vertical position, v_0 is the initial velocity, t is time, and g is the acceleration due to gravity (9.80 m/s^2). This is a quadratic equation whose graph is a parabola. Your graph of distance versus time while the ball was in free fall should be parabolic. To fit a quadratic equation to your data, you need to first remove the data that do not correspond to free fall.

a. Use the cursor keys to select VELOCITY.

b. Select SELECT REGION from the graph selection screen.

c. Move the left-bound cursor to the left edge of the linear free-fall region using the cursor keys.

d. Press ENTER to record the lower bound.

e. Move the right-bound cursor to the right edge of the free-fall region using the cursor keys.

f. Press ENTER to record the upper bound.

g. Once the graph selection screen returns press, ENTER to see the distance graph.

You will see the selected portion of your graph filling the width of the screen. Next you can fit a parabola to the distance versus time data. Return to the main screen by pressing ENTER, and then selecting MAIN SCREEN. Select ANALYZE from the main screen. Select CURVE FIT from the ANALYZE OPTIONS. Select QUAD (DIST V. TIME) from the CURVE FIT screen. Record the parameters of the curve fit in the data table. Press ENTER to view the fitted curve with your data.

5. How closely does the coefficient of the x^2 term in the curve fit compare to Δg?

____

____

6. The graph of velocity versus time should be linear during free fall.

a. Return to the analyze screen by pressing ENTER.

b. Select CURVE FIT from ANALYZE OPTIONS.

c. Select LINEAR (VELO V. TIME) from the CURVE FIT screen.

d. Record the parameters of the curve fit in the data table.

e. Press ENTER to view the fitted curve with your data.

7. How closely does the coefficient of the x-term compare to the accepted value for g? The graph of acceleration *vs*. time during free fall should appear to be more or less constant. Note that because the graph is automatically scaled to fill the screen vertically, small variations may appear large. Inspect the values as you scroll across the screen.

a. Return to the analyze screen by pressing ENTER.

b. Select STATISTICS from ANALYZE OPTIONS.

c. Select ACCELERATION from the SELECT GRAPH screen. Since you want the average of the entire interval you have already selected, leave the lower bound at the left edge by pressing ENTER.

d. Move the upper bound to the far right side of the graph using the cursor keys, and press ENTER to set the upper bound. Record the average value of the acceleration in the data table.

8. List some reasons why your values for the ball's acceleration may be different from the accepted value for g.

____

____

____

Extension and Applications

1. The ball used in this lab is large enough and light enough that a buoyant force and air resistance may affect the acceleration. Perform the same curve fitting and statistical analysis techniques, but this time analyze each half of the motion separately. How do the fitted curves for the upward motion compare to the downward motion? Explain any differences.

2. Perform the same lab using a beach ball or other very light, large ball. Answer the same questions as in problem 2 above.

3. Use a smaller, denser ball where buoyant force and air resistance will not be a factor. Compare the results to your results with the larger, less dense ball.

CHAPTER 3

Probeware Lab 3-2

Safety Precautions

Materials

- laboratory cart
- CBL 2 or LabPro interface
- motion detector
- link cable
- TI graphing calculator
- 100-g mass
- masking tape
- heavy string, 1.5 m
- pulley
- C-clamp

How fast is it accelerating?

The motion detector can record the movement of a small cart pulled across a table by a falling mass. The resulting data measures the displacement of the moving cart per time. In Chapter 2, you found that average velocity equals displacement for a given interval of time. Also recall that the ratio of a change in velocity to a change in time is acceleration,

$$a = \frac{(v_2 - v_1)}{(t_2 - t_1)}$$

and that this is the equation for the slope of a graph of velocity versus time.

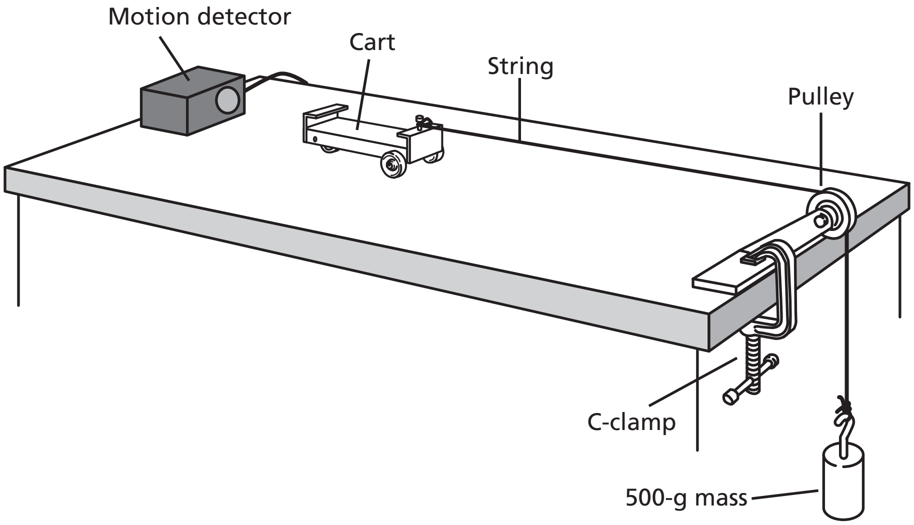


Figure A

Objectives

- **Measure** the dispalcement of a moving object in a set time interval.
- **Calculate** the velocity of a moving object.
- **Analyze** motion, using graphs of the relationship between displacement and time, velocity and time, and acceleration and time.

Procedure

1. Set up the apparatus, as shown in **Figure A** except for the 100-g mass. Put the motion detector about 1–1.5 m from the pulley. Tie 1–1.5 m of string to the opposite end of the cart and thread the string through the pulley.

   Often targets are not directly in front of the motion detector. Move the detector so that the target is directly in front of the motion detector. In using the motion detector, it is important to realize that the ultrasound is emitted in a cone about 30° wide. Anything within the cone of ultrasound can cause a reflection and possibly an accidental measurement. A common problem in using motion detectors is getting unintentional reflections from a desk, chair, or table in the room.

Tilting the motion detector slightly can minimize unintended reflections. The motion detector does not properly detect objects closer than 0.4 m. The maximum range is about 6 m, but stray objects in the wide detection cone can be problematic at this distance. If the velocity graphs are noisy, try to increase the strength of the ultrasonic reflection from the target by increasing the target's area.

2. With your lab partner, set up the motion detector and vehicle, as shown in Figure A. Place the cart about 0.5 m from the motion detector.

3. Connect the CBL 2 or LabPro interface to the calculator using the unit-to-unit link cable and the link ports on the calculator and interface. Press the cable ends in firmly. Connect the motion detector to the DIG/SONIC (or DIG/SONIC 1 on the LabPro) port of the interface.

4. Turn on the calculator and start the DataMate program. Press [CLEAR] to reset the program.

5. If the motion detector is working properly, the top line of the main screen will display DIG: MOTION (M), and a reading of the distance (in meters) from the vehicle to the motion detector.

6. You are ready to begin the experiment. One student should hold the cart in place while the other student starts the data collection by selecting START on the main screen of the calculator. The student holding the cart should not release it until about 1 s after the motion detector has begun clicking. Upon release, the cart will be pulled along by the 100-g mass. Catch the cart at the edge of the table to prevent it from knocking the pulley loose or plunging to the floor.

7. When the motion detector has stopped clicking, press [ENTER] to display the DISTANCE graph.

8. The displacement graph initially will show a horizontal line until the cart began to move. Copy this graph in the space provided.

9. Use the right arrow key to go to the point on the curve where the cart began to move, and then back up one point. Record the distance (y-value) and the time (x-value) into your data table. Press the right arrow key two times to move to another point along the curve. Record the new time and distance values in Data Table 1. Continue moving along the curve in increments of two steps and recording data. Collect as many data points as possible in this manner, but stop at ten points. Press [ENTER] to return to the graph selection screen.

10. Press [▼], and then press [ENTER] to display the VELOCITY graph. Observe how the velocity of the vehicle changed during the experiment. Sketch this graph in the space provided. Repeat step 9 to record data in the Data Table 1 for the points along the velocity-time graph until the slope levels off. Press [ENTER] to return to the graph selection screen. Display the ACCELERATION graph and sketch it below. Do not turn off the calculator until you have done the Analysis and Conclusion section.

Data and Observations

Sketch graphs of displacement v. time, velocity v. time, acceleration v. time

Data Table 1		
Time (s)	**Total Displacement (m)**	**Average Velocity (m/s)**

Analysis and Conclusion

1. Return to the graph screen. Cursor to the VELOCITY graph. Choose SELECT REGION. Set the left bound to the point where the graph begins an upward slope. Press ENTER at this point. Move the cursor to the point where the upward slope ends. ENTER this point. The graph should now show a straight line with a positive slope. Draw a sketch of the graph. Return to MAIN SCREEN. Choose ANALYZE. Go to FIT CURVE. Choose LINEAR (VELO VS TIME). Use the data from Y = AX + B to find the slope of the line. What does this slope of the velocity versus time line represent?

____

____

2. Return to the graph screen. Look at the ACCELERATION graph. Draw a sketch of the graph. Go to Main Screen. Choose ANALYZE. Go to STATISTICS. Select DIG-ACCELERATION. Select LEFT BOUND and RIGHT BOUND. Record the MEAN. What does the mean of this graph tell you?

____

____

3. Return to the graph screen. Look at the DISTANCE graph. Describe this graph. Go to the MAIN SCREEN. Choose ANALYZE. Go to CURVE FIT. Choose MORE. Choose QUAD (DIST VS TIME). Record A, B, and C for $Y = AX^2 + BX + C$. Press ENTER. Draw a sketch of the graph. What does this graph mean? How does this data for $Y = AX^2 + BX + C$ represent the equation: $d_f = d_i + v_i t + .5\, at^2$?

____

____

____

4. How does your calculated acceleration of the cart compare to the acceleration due to gravity?

____

____

____

Extension and Application

1. How would the graphs look if the cart was pulled by a bigger mass?

2. What would be the advantage of building an interplanetary spacecraft that could accelerate at 1 *g* ($9.80\ m/s^2$) for a year?

Date ________ Period ________ Name ________________

CHAPTER 4

Probeware Lab 4-1

Safety Precautions

Materials

- LabPro or CBL 2 interface
- TI graphing calculator
- DataMate program
- motion detector
- five basket-style coffee filters

Terminal Velocity

Often in physics discussions, you are told to ignore air resistance and to assume the acceleration is constant. In reality, air resistance causes objects not to fall indefinitely with constant acceleration. This is observed by comparing the fall of a baseball and a sheet of paper when dropped from the same height. The baseball is still accelerating when it hits the floor. The paper does not accelerate very long before air resistance reduces the acceleration so that it moves at an almost constant velocity. When an object is falling with a constant velocity, we describe it with the term *terminal velocity,* or v_T. The paper reaches terminal velocity very quickly, but on a short drop to the floor, the baseball does not.

Air resistance is often referred to as a *drag force*. Many experiments have been done with various objects falling in air. These experiments show that sometimes the drag force is proportional to the velocity and that sometimes the drag force is proportional to the square of the velocity. In either case, the direction of the drag force is opposite to the direction of motion. Mathematically, the drag force can be described using $F_{drag} = -bv$ or $F_{drag} = -cv^2$. The constants b and c are called the *drag coefficients* that depend on the size and shape of the object.

When falling, there are two forces acting on an object: the weight, mg, and air resistance, $-bv$ or $-cv^2$. At terminal velocity, the downward force is equal to the upward force, so $mg = -bv$ or $mg = -cv^2$, depending on whether the drag force follows the first or second relationship. In either case, since g and, b or c, are constants, the terminal velocity is affected by the mass of the object. When you take out the constants, you see that either terminal velocity is proportional to mass or the square of terminal velocity is proportional to the mass. A plot of mass versus v_T or $v_T{}^2$ can determine which relationship is more appropriate.

In this experiment, terminal velocity as a function of mass for falling coffee filters will be measured. You will use the data to choose between the two models for the drag force. Coffee filters were chosen because they are light enough to reach terminal velocity in a short distance.

Objectives

- **Describe** the effect of air resistance on falling coffee filters.
- **Determine** how air resistance and mass affect the terminal velocity of a falling object.
- **Choose** between two competing force models for the air resistance on falling coffee filters.

Procedure

1. Support the motion detector about 2 m above the floor, pointing down, as shown in **Figure A.** If possible, place the motion detector as high as you safely can.

Often targets are not directly in front of the motion detector. Move the detector so that the target is directly in front of the motion detector. In using the motion detector, it is important to realize that the ultrasound is emitted in a cone about 30° wide. Anything within the cone of ultrasound can cause a reflection and possibly an accidental measurement. A common problem in using motion detectors is getting unintentional reflections from a desk, chair, or table in the room.

Tilting the motion detector slightly can minimize unintended reflections. The motion detector does not properly detect objects closer than 0.4 m. The maximum range is about 6 m, but stray objects in the wide detection cone can be problematic at this distance. If the velocity graphs are noisy, try to increase the strength of the ultrasonic reflection from the target by increasing the target's area.

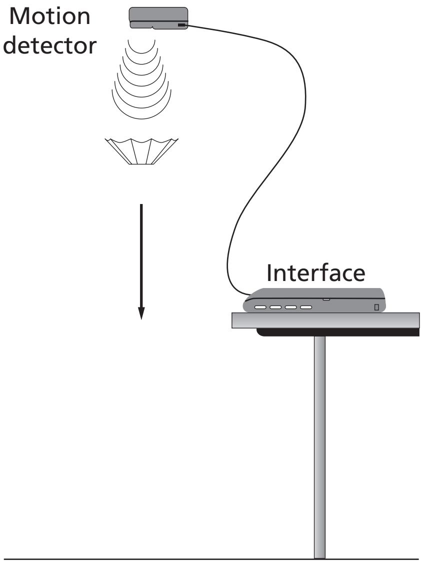


Figure A

2. Connect the motion detector to the DIG/SONIC or DIG/SONIC 1 port of the LabPro or CBL 2 interface. Use the black link cable to connect the TI graphing calculator to the interface. Firmly press in the cable ends.

3. Turn on the calculator and start the DataMate program. Press CLEAR on the calculator to reset the program.

4. Place a coffee filter in the palm of your hand and hold it about 0.5 m under the motion detector. Do not hold the filter closer than 0.4 m.

5. Select START to begin data collection. After the interface beeps, release the coffee filter directly below the motion detector so that it falls toward the floor. Move your hand out of the beam of the motion detector as quickly as possible so that only the motion of the filter is recorded on the graph.

6. View your distance graph by pressing ENTER. If the motion of the filter was too erratic to get a smooth graph, you will need to repeat the measurement. With practice, the filter will fall almost straight down with little sideways motion. Press ENTER and select MAIN SCREEN. Repeat data collection as necessary.

7. The velocity of the coffee filter can be determined from the slope of the distance v. time graph. At the start of the graph, there should be a region of increasing slope (increasing velocity), and then the plot should become linear. Since the slope of this line is velocity, the linear portion indicates that the filter was falling with a constant or terminal velocity, v_T, during that time. To fit a line to the linear region, you first need to select that portion of your data.
   - **a.** Select GRAPH from the main screen.
   - **b.** To select just the linear portion of the distance graph, select SELECT REGION.
   - **c.** Move the flashing cursor with the ◀ and ▶ keys to the left edge of the linear region corresponding to the filter in motion at constant speed and press ENTER.
   - **d.** Move the flashing cursor to the right edge of the linear region, and press ENTER.
   - **e.** View your abbreviated graph by pressing ENTER. You should see only the linear region.
   - **f.** Select MAIN SCREEN to return to the main screen.
8. Fit a straight line to the region you just selected.
   - **a.** Select ANALYZE from the main screen.
   - **b.** Select CURVE FIT from ANALYZE OPTIONS.
   - **c.** Select LINEAR (DIST VS TIME) from the CURVE FIT screen.
   - **d.** Record the slope in the data table (a velocity in m/s).
   - **e.** Press ENTER to see the fit along with your data.
   - **f.** Press ENTER, and select RETURN TO MAIN SCREEN.
9. Repeat steps 4–8 for two, three, four, and five coffee filters. (Optionally, extend to six, seven, and eight filters, but be sure to use sufficient fall distance so that a clear velocity can be measured.)

Data and Observations

Data Table

Number of Filters	Terminal Velocity v_T (m/s)	(Terminal Velocity)^2 v_T^2 (m^2/s^2)
1		
2		
3		
4		
5		

Analysis and Conclusions

1. If there is no air resistance, how would the rate of fall of a coffee filter compare to that of a brick?

____

2. When the coffee filter reaches terminal velocity, what is the net force acting on it?

____

3. To help choose between the two models for the drag force, plot terminal velocity v. number of filters (mass) on your calculator. On a separate graph, plot v_T^2 v. number of filters. Scale each axis from the origin (0, 0).

4. During terminal velocity the drag force is equal to the weight, *mg*, of the filter. If the drag force is proportional to velocity, then v_T is proportional to mass. Or, if the drag force is proportional to the square of velocity, then v_T^2 is proportional to mass. From your graphs, which proportionality is consistent with your data; that is, which graph is closer to a straight line that goes through the origin?

____

5. From the choice of proportionalities in the previous step, which of the drag force relationships, $-bv$ or $-cv^2$, appears to model the real data better? Notice that you are choosing between two different descriptions of air resistance—one or both might not correspond to what you observed.

____

Extension and Application

1. Make a small parachute and use the motion detector to analyze the air resistance and terminal velocity as the weight suspended from the chute increases.

2. Draw a free-body diagram of a falling coffee filter. There are only two forces acting on the filter. Once the terminal velocity v_T has been reached, the acceleration is zero, so the net force, $\Sigma F = ma = 0$, must also be zero, thus, $F = -mg + bv_T = 0$ or $F = mg + cv_T = 0$ depending on which drag force model you use. Given this, sketch plots for the terminal velocity (*y*-axis) as a function of filter weight for each model (*x*-axis). *Hint: Solve for v_T first.*

CHAPTER 5

Probeware Lab 5-1

Safety Precautions

Materials

- CBL 2 or LabPro interface
- Unit-to-unit link cable
- TI graphing calculator
- Dual-range force sensor
- small rectangular object
- wooden board
- string
- masking tape
- protractor
- meterstick

When will an object slide?

An object on a slanted surface may or may not slide down, depending upon the angle of the slant. If the object remains at rest, the force of friction, F_f, between the object and the surface is sufficient to resist the weight, or force of gravity, pulling down on the object. One component of the weight is a force directed down the plane. This parallel component of weight is described by this equation.

$$F_{\parallel} = F_w \sin \theta$$

In the equation, the angle θ is the smallest angle, measured relative to the horizontal, at which sliding occurs. The perpendicular component of weight, $F_{\perp}$ is represented by this equation.

$$F_{\perp} = F_w \cos \theta$$

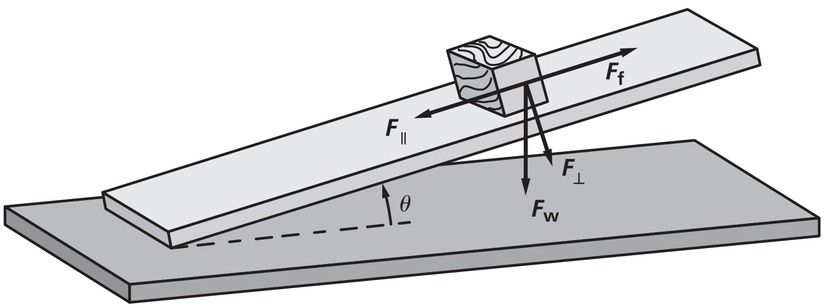


Figure A

Figure A shows the friction force and the weight force, as well as the components of the weight force when a plane is inclined at angle θ.

An important value for this system of object and inclined plane is the coefficient of friction, m. This value is represented by the following relationships.

$$\mu = \frac{F_f}{F_{\perp}} = \frac{F_{\parallel}}{F_{\perp}} = \frac{F_w \sin \theta}{F_w \cos \theta} = \tan \theta$$

The higher the value of the coefficient of friction is, the greater the friction force will be.

An object on an inclined plane is subject to two types of friction, with different coefficients of friction and different characteristic angles. Static friction exists when the object is at rest and must be overcome to start the object moving. To calculate the coefficient of static friction, you can use the equation above with θ equal to the angle at which motion begins.

If the object is already moving down the plane, sliding friction acts to resist the downward motion. To calculate the coefficient of sliding friction, use the equation above with θ equal to the angle at which the downward motion is at constant speed.

In this lab, you will design a procedure to measure the angle at which an object begins to slide down an inclined plane and, once already in motion, the angle at which it slides at constant speed. Finding those angles will give you the information you need to calculate the coefficients of static friction and sliding friction.

Objectives

- **Measure** the angle at which an object at rest begins to slide down an inclined plane.
- **Measure** the angle at which an object, already in motion, slides down an inclined plane at constant speed.
- **Calculate** the coefficients of static friction and sliding friction.

Problem

What are the coefficients of static friction and sliding friction for an object on an inclined plane?

Hypothesis

Formulate a hypothesis about the angles at which an object will begin to slide and slide at constant speed on an inclined plane, and about the relative magnitudes of the coefficients of static friction and sliding friction.

Plan the Experiment

1. Decide on a procedure that uses the suggested materials (or others of your choosing) to measure the force of sliding friction, which is the force needed to pull the object along the board at constant speed when the board is horizontal; the angle at which an object at rest begins to slide down an inclined plane; and the angle at which the same object, already in motion, slides at constant speed down an inclined plane.
2. Decide what data to collect and how to analyze it. You can record your data and calculated results in the table at the end of this lab. Make the appropriate columns.
3. Write your procedure on another sheet of paper or in your notebook.
4. **Check the Plan** Have your teacher approve your plan before you proceed with your experiment.

Analyze and Conclude

1. **Interpreting Data** Calculate the coefficient of sliding friction, using only data on weight and average force of sliding friction. Then calculate it using the angle of tilt in the equation involving the tangent of θ. Are the coefficients equal? Give reasons for any difference.

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2. **Interpreting Data** Calculate the coefficient of static friction. How does this coefficient compare to the coefficient of sliding friction that you found?

3. **Checking Your Hypothesis** Suppose you put a brick with its largest surface in contact with an inclined plane. You tilt the plane until the brick just begins to slide and measure the angle of the plane above the horizontal. Then you turn the brick on one of its narrow edges, tilt the plane, and measure the tilt angle. Will these measured angles be different? Explain your answer in terms of the equation for the force of friction.

4. **Checking Your Hypothesis** You put a brick on an inclined plane and tilt the plane until the brick just begins to slide. You measure the angle of the plane with respect to the horizontal. You wrap the brick in wax paper and put it on the plane, tilt the plane, and measure the tilt angle. Will these measured angles be different? Give a reason for your answer.

5. **Inferring** Based on your answers to questions 3 and 4, describe the factors that influence the force of friction.

Apply

1. While looking for a set of new tires for your car, you find an ad that offers two brands of tires at the same price. Brand X has a coefficient of friction of 0.90 on dry pavement and of 0.15 on wet pavement. Brand Y has a coefficient of friction of 0.88 on dry pavement and of 0.45 on wet pavement. If you live in a rainy area, which tire would give you better performance? Give a reason for your answer.

Data and Observations

Data Table

Date ____________ Period ____________ Name ____________________

CHAPTER 9

Probeware Lab 9-1

Safety Precautions

Materials

- two collision carts, one with a spring mechanism
- balance
- meterstick
- CBL 2 or LabPro interface
- motion detector
- link cable
- TI graphing calculator
- set of masses
- masking tape
- 5-in × 7-in index cards
- ring stand
- clamp

Is momentum conserved in a collision?

The law of conservation of momentum states: The momentum of any closed, isolated system does not change. This law is true regardless of the number of objects or directions of the objects before and after they collide. In a collision or interaction, the momentum before the collision equals the momentum after the collision.

The change in an object's momentum is equal to the product of the force acting on the object and the interval of time within which the force acts. In this investigation, two carts will be pushing away from each other. Thus, from Newton's third law of motion, each cart will give the other an equal, but opposite, impulse. The change of momentum from the first cart will equal the change of momentum of the second cart. The two carts in this investigation will have unequal masses. The two carts will be placed together, compressing a spring in one of the carts. The carts will move apart when the spring is released.

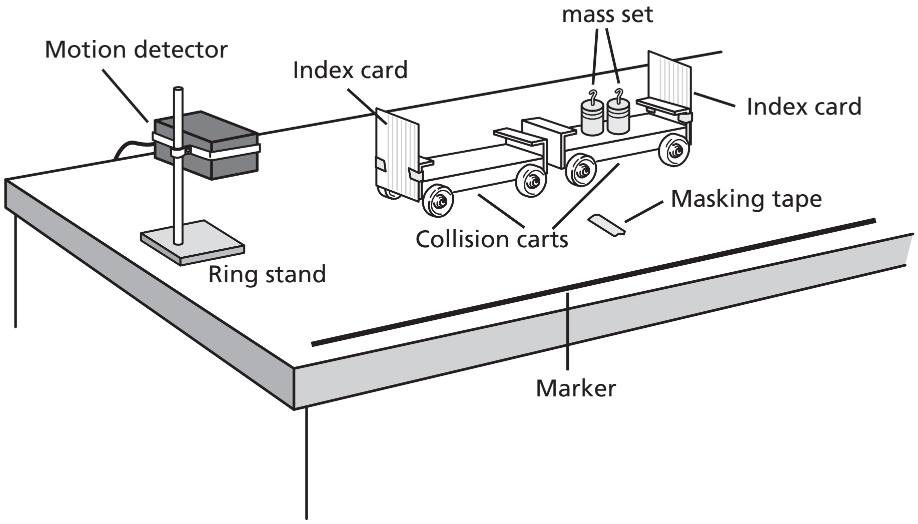

Figure A

Objectives

- **Measure** the masses and velocities of two carts.
- **Calculate** the momentum of the two carts.
- **Apply** conservation of momentum to a system.
- **Demonstrate** conservation of momentum for an interaction.

Procedure

1. Select a counter space with 2–3 m of clear space. Place a piece of masking tape in the middle of this space as shown in **Figure A.**
2. Tape an index card onto each collision cart. This will make the carts more easily seen by the motion detector. Measure the mass of each cart and record these values in Data Table 2. Using a mass set, add enough masses to cart 2 so that its mass is twice the mass of cart 1. Secure the masses to the cart with a small piece of masking tape. It is desirable to have the mass of cart 2 within 5 percent of twice its original mass. Record the mass added to cart 2 in Data Table 2. Compress the spring mechanism and place the carts centered over the tape marker, as shown in Figure A above.
3. Use a clamp to mount the motion detector on a ring stand, using tape if necessary. Adjust the height of the sensor so it is at the same height as the middle of the index card. Place the motion detector about 1.5 m away from the masking tape marker.

   Often targets are not directly in front of the motion detector. Move the target so that it is directly in front of the motion detector. In using the motion detector, it is important to realize that the ultrasound is emitted in a cone about 30° wide. Anything within the cone can cause a reflection and possibly an accidental measurement. A common problem in using motion detectors is getting unintentional reflections from a desk, chair, or table in the room.

   Tilting the motion detector slightly can minimize unintended reflections. The motion detector does not properly detect objects closer than 0.4 m. The maximum range is about 6 m, but stray objects in the wide detection cone can be problematic at this distance. If the velocity graphs are noisy, try to increase the strength of the ultrasonic reflection from the target by increasing the target's area.
4. Connect the CBL 2 or LabPro interface to the calculator using the unit-to-unit link cable and the link ports on the calculator and interface. Press the cable ends in firmly. Connect the motion detector to the DIG/SONIC (or DIG/SONIC 1 on the LabPro) port of the interface.
5. Turn on the calculator and start the DataMate program. Press [CLEAR] to reset the program.
6. You are ready to begin the experiment. While preventing the carts from moving, one student should select START on the main screen of the calculator. When the motion detector begins to click, depress the spring-release mechanism to release the carts. Stop the carts before one cart either strikes the motion detector or falls to the floor.
7. When the motion detector has stopped clicking, press [ENTER] to display the DISTANCE graph. Use this graph to verify that the motion detector can track the cart properly throughout the entire range of motion. You may need to adjust the position of the motion detector. If it is necessary to conduct a second trial, choose MAIN SCREEN, then press [ENTER] and return to step 6.
8. The displacement graph initially will show a horizontal line until the cart begins to move. Sketch the graph in Data Table 1. The beginning of the graph will show where the cart accelerated as the spring was released. Press [ENTER] to return to the graph selection screen. Choose SELECT REGION. Select the left bound and right bound for the section of graph that has a constant slope. Press [ENTER] to return to the graph selection screen, and then select MAIN SCREEN.
9. Select ANALYZE. Select CURVE FIT. Choose LINEAR (DIST VS TIME). Record the value of Slope "A" from $Y = AX + B$ in Data Table 2.
10. Rotate the two carts so the second cart is facing the motion detector. Repeat the experiment collecting data for the second cart.
11. When you have completed the experiment, select QUIT from the main screen to exit the DataMate program.

Data and Observations

Data Table 1	
Sketch distance v. time graphs	
Cart 1	**Cart 2**

Data Table 2			
	Slope "A"	**Mass (kg)**	**Mass Added (kg)**
Cart 1			NA
Cart 2			

Analysis and Conclusions

1. What is the velocity of each cart? How do the velocities of the carts compare?

____

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2. Calculate the momentum of each cart after they were released.

____

____

____

3. What is the total momentum of the two carts before they were released?

4. What is the total momentum after the carts are released?

5. What assumptions are being made in performing step 10?

Extension and Application

1. While playing baseball or softball with your friends, your hand begins to sting after you catch several fast throws. What method of catching the ball might prevent this stinging sensation?

2. If an incident ball, A, hits two target balls, B and C, at an angle, predict what would happen to the total momentum of the system after the collision. Give a reason for your answer and write an equation that proves your answer.

3. When an incident ball, A, collides at an angle with a target ball, B, of equal mass that is initially at rest, the two balls always move off at right angles to each other after the collision. Use a familiar equation for a right triangle to show that this statement is true. *Hint: Since the collision is elastic, kinetic energy is conserved.*

Date ____________ Period ____________ Name ____________________

CHAPTER 12

Probeware Lab 12-1

Safety Precautions

Possible Materials

- large coffee can with lid
- small coffee can with lid
- sheet of plastic wrap
- sheet of wax paper
- piece of polyethylene
- small pane of glass
- shredded newspapers
- CBL 2 or LabPro unit
- TI graphing calculator with unit-to-unit link cable
- TI temperature probe
- TI-Graph Link
- colored pencils

How efficient are solar collectors?

When fossil fuels such as coal and oil are used up, they cannot be replaced. Harnessing other energy sources becomes increasingly important as nonrenewable resources disappear. Solar power is a promising renewable energy source. Solar collectors gather the sun's energy in a form that people can easily use. In this lab, you will design and build a simple solar collector. You will use a CBL 2 or LabPro system to measure and compare the heat collected by four cover materials: plastic wrap, wax paper, polyethylene, and glass. Then you can check the cover materials' efficiency.

Objectives

- **Design** a procedure for investigating heat collection.
- **Measure** temperatures and times.
- **Compare** the heat-collecting abilities of four materials.

Problem

How do four materials compare in their ability to collect and trap heat from solar energy?

Hypothesis

Formulate a hypothesis about the relative efficiencies of plastic wrap, wax paper, polyethylene, and glass in collecting and trapping heat from solar energy.

Plan the Experiment

1. Work in a small group. Decide on a procedure that uses the suggested materials (or others of your choosing) to gather data on how well the four materials (plastic wrap, wax paper, polyethylene, glass) collect heat from sunlight.
2. Decide what kind of data to collect and how to analyze it. You can record your data in the table on the next page. Label the columns appropriately.
3. Write your procedure on another sheet of paper or in your notebook. On the next page, draw the setup you plan to use.
4. **Check the Plan** Have your teacher approve your plan before you proceed with your experiment. Make sure that you understand how to operate the CBL 2 or LabPro unit, graphing calculator, and temperature probe. Be careful with the electric power source.

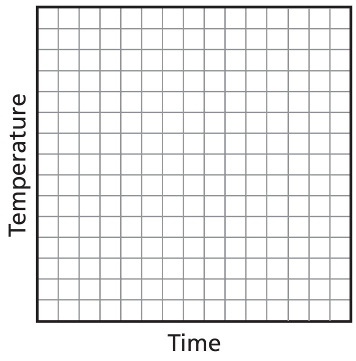
Setup

Data and Observations

Data Table

Analyze and Conclude

1. **Graphing Data** Use the grid below to graph temperature and time data from your table. How do your plots compare with the graphs on the TI graphing calculator?



2. **Analyzing Data** Which cover material is most efficient at collecting heat? Which is least efficient? Cite your data to support your answers.

3. **Checking Your Hypothesis** Suppose you were stranded on a sunny but cold island in the Arctic Ocean. Luckily you have a supply of glass, polyethylene, wax paper, and plastic wrap and all the tools and structural supports that you need to use them. Which material would you use to build a shelter? Give reasons for your answer.

Apply

1. If you wanted to build an inexpensive greenhouse, would you use glass or less-expensive polyethylene in the roof and sides? Why? How could you further improve the efficiency of the structure?

Date ____________ Period ____________ Name ____________________

CHAPTER 15

Probeware Lab 15-1

Safety Precautions

Materials

- LabPro or CBL 2 interface
- TI graphing calculator
- DataMate program
- Vernier microphone
- temperature probe
- tube, 0.5–2 m long, 6–10 cm in diameter
- book or plug to cover end of tube
- meterstick or tape measure
- two pieces of wood, such as drumsticks

How fast does sound move in air?

You are at a football game in a very large stadium. As the drummers march in you see the drums being hit by sticks, but you don't hear the sound right away. The same thing happens when you see a lightning bolt, but don't hear the thunder until moments later. Compared to most objects, sound waves travel very fast. It is fast enough that measuring the speed of sound is a technical challenge. One method you could use would be to time an echo. For example, if you were in an open field with a large building one-fourth of a kilometer away, you could start a stopwatch when a loud noise was made and stop it when you heard the echo. You could then calculate the speed of sound.

To use the same technique over short distances, you need a faster timing system, such as a LabPro or CBL 2 interface. In this experiment you will use this technique with a microphone connected to an interface to determine the speed of sound at room temperature. The microphone will be placed next to the opening of a hollow tube, as in **Figure A.** When you make a sound by hitting two sticks together next to the opening, the interface will begin collecting data. After the sound reflects off the opposite end of the tube, a graph will be displayed showing the initial sound and the echo. You will then be able to determine the round trip time and calculate the speed of sound.

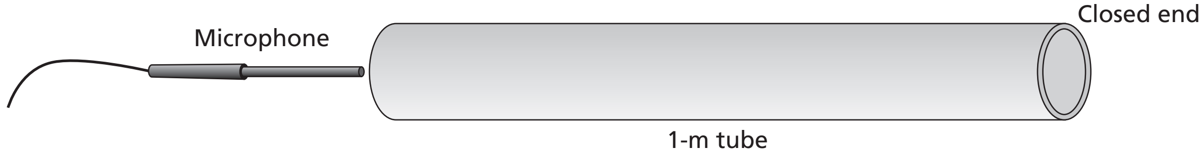


Figure A

Objectives

- **Measure** how long it takes sound to travel down and back in a long tube.
- **Calulate** the speed of sound.
- **Compare** the speed of sound in air to the accepted value at a given temperature.

Procedure

1. Use the temperature probe to measure the air temperature of the classroom. To do this, connect a Temperature Probe to the Channel 1 input on the LabPro or CBL 2 interface. Use the black link cable to connect the interface to the TI graphing calculator. Firmly press in the cable ends.

2. Turn on the calculator and start the DATAMATE program. Press CLEAR to reset the program.
3. If the calculator displays a temperature probe in CH 1, proceed directly to step 4. Otherwise, set up the calculator and interface for the temperature probe.
   a. Select SETUP from the main screen.
   b. Press ENTER to select CH 1.
   c. Select TEMPERATURE from the SELECT SENSOR menu.
   d. Select the Temperature Probe you are using (in °C) from the TEMPERATURE menu.
   e. Select OK to return to the main screen.
4. The temperature will be displayed on the calculator screen. With the tip of the temperature probe in open air, away from sunlight, wait until the readings become stable. Variations in the tenths digit are not important. Record the room temperature in your data table.
5. Disconnect the temperature probe and connect the Vernier microphone to the channel 1 input on the interface. Press CLEAR to reset the program.
6. Set up the calculator and interface for the microphone.
   a. Select SETUP from the main screen.
   b. If the calculator displays a microphone in CH 1, proceed directly to the following step. If it does not, continue with this step to set up your sensor manually.
   c. Press ENTER to select CH 1.
   d. Choose MICROPHONE from the SELECT SENSOR list.
   e. Select CBL, ULI, or MPLI, according to the type of microphone you are using.
7. Set up the interface to trigger on the first loud sound the microphone detects.
   a. Press ▲ once to select MODE and press ENTER.
   b. Select TIME GRAPH from the SELECT MODE screen.
   c. Select ADVANCED from TIME GRAPH SETTINGS.
   d. Select CHANGE TRIGGERING from ADV. TIME GRAPH SETTINGS.
   e. Select CH1-MICROPHONE from SELECT TRIGGERING.
   f. Select INCREASING from TRIGGER TYPE.
   g. Enter "0.1" for a trigger threshold. End this and all other numeric entries by pressing ENTER. (Use "2.6" if you are using a ULI or CBL microphone.)
   h. Enter "0" for the prestore.
   i. Select OK three times to return to the main screen.
8. Close the end of the tube. This can be done by inserting a plug or standing a book against the end so it is sealed. Measure the length of the tube and record in the data table.
9. Place the microphone as close to the end of the long tube as possible. Position the microphone so that it can detect the initial sound and the echo coming back down the tube.
10. Select START to begin data collection. Snap your fingers near the opening of the tube. Or you can clap your hands at the opening of the tube. This sharp sound will trigger the interface to begin collecting data.

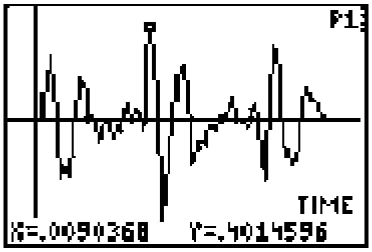


Figure B

11. If you are successful, the graph will resemble the one in **Figure B.** You may not see a third reflection. In this figure each of three highest peaks corresponds to the same point on a waveform. The first peak is the initial sound, the second is the first reflection, and the third is a second reflection. Repeat your run if necessary by pressing ENTER and returning to the previous step. Use the cursor keys to trace across the graph. Determine the time interval between the start of the first vibration and the start of the echo vibration. Record these two times in your data table.

12. Repeat the measurement for a total of five trials.

Data and Observations

Data Table

Length of tube	m
Temperature of room	°C

Trial	Time of Direct Sound Start (s)	Time of Echo Start (s)	Time Interval (s)
1			
2			
3			
4			
5			
Average			

Speed (m/s)	

Analysis and Conclusions

1. From the time-pairs you recorded in the data table, calculate the differences to find the time interval, and then calculate the average time interval.
2. Calculate the speed of sound. Remember that your average time interval represents the time for sound to travel down the tube and back.
3. The accepted speed of sound at atmospheric pressure and 0°C is 331.5 m/s. The speed of sound increases 0.607 m/s for every Celsius degree. Calculate the speed of sound at the temperature of your room and compare your measured value to the accepted value. Calculate the percent error.

Extension and Application

1. Repeat this experiment, but collect data using a tube with an open end. How do the reflected waves for the closed-end tube compare to the reflections with an open-end tube? It might be easier to see any changes by striking a rubber stopper held next to the opening instead of snapping your fingers. Explain any differences. Calculate the speed of sound and compare it to the results with a tube with a closed end.
2. This experiment can be performed without a tube. You need an area with a smooth surface. Multiple reflections may result (floor, ceiling, windows, etc.), adding to the complexity of the recorded data.
3. Fill a tube with another gas, such as carbon dioxide or helium. Be sure to flush the air out with the experimental gas. For gases that are heavier than air, such as carbon dioxide, orient the tube vertically and use a sealed lower end. Invert the tube for gases that are lighter than air.
4. Use this technique to measure the speed of sound in air at different temperatures.
5. Develop a method for measuring the speed of sound in a medium that is not a gas.

CHAPTER 16

Probeware Lab 16-1

Safety Precautions

Materials

- LabPro or CBL 2 interface
- TI graphing calculator
- DataMate program
- light sensor
- meterstick
- mini-flashlight

How does light intensity depend on distance?

You may have studied in another science class that the brightness of a star depends on how big it is and how far away it is. If this page is illuminated by a single lightbulb, more light will strike the page the closer you get to the lightbulb. Using the light sensor, the brightness of a lightbulb can be measured as the distance from the bulb is changed. Since there are many ways to measure light brightness (luminuous flux, illuminance, luminous intensity, irradiance, etc.), and many different types of light sensors can be used, the term *intensity* will be used during this experiment, even though this term is not appropriate for your sensor. This is possible because the relative changes in distance will be measured as compared to the relative amounts of intensity at these distances. After you have measured light intensities at various distances from the light source, you will determine the mathematical relationship of these variables using the graphing calculator.

Objectives

- **Predict** the effect of distance on light's intensity.
- **Determine** the relationship between intensity and distance from a light source.

Procedures

1. Attach the light sensor to channel 1 on the LabPro or CBL 2 interface. If the sensor has a range switch, set it to 6000 lux. Use the black link cable to connect the interface to the TI graphing calculator. Firmly press in the cable ends.
2. Turn on the calculator and start the DataMate program. Press CLEAR to reset the program.
3. If CH 1 displays the Light Sensor and its current reading, skip the remainder of this step. If it does not, manually set up DataMate for the sensor. To do this,
   a. Select SETUP from the main screen.
   b. Press ENTER to select CH 1.
   c. Choose LIGHT from the SELECT SENSOR list.
   d. Choose 6000 LUX from the LIGHT list. The sensor will read in units of lux.
   e. Select OK to return to the main screen.
   f. Set up the calculator and the interface for the appropriate data collection mode.

4. Select SETUP from the main screen.
5. Press [▲] to select MODE and press [ENTER].
6. Select EVENTS WITH ENTRY from the SELECT MODE menu to collect light intensity data as a function of distance. In this mode you will trigger the interface to record the light intensity for each position you choose. Select OK to return to the main screen.
7. Make sure that the filament axis of the lightbulb is horizontal and pointing directly at the light sensor. This makes the lightbulb look more like a point source of light as seen by the light sensor. See an example of the set-up in **Figure A.**

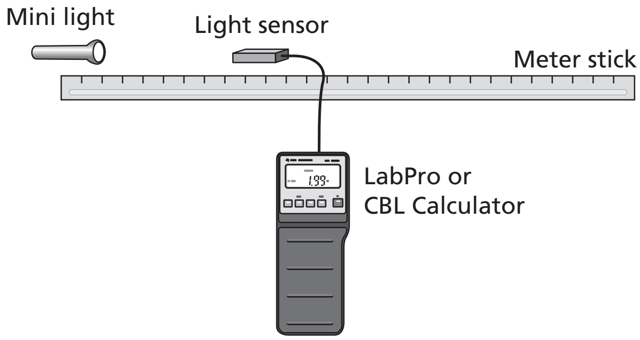


Figure A

8. The filament and light sensor should be at the same vertical height. Place the end of the filament (not the glass) at the 0.0-cm mark of the meterstick.
9. Turn down the lights to darken the room. A very dark room is critical to obtaining good results. There should be no reflective surfaces behind, beside, or below the bulb.
10. Place the light sensor 10 cm from the lightbulb filament. Move the sensor away from the bulb and watch the displayed intensity values on the calculator screen. What is your prediction for the relationship between intensity and the distance to a light source?
11. Again place the light sensor 10 cm from the lightbulb filament. The distance must be measured carefully. Be sure you measure from the filament of the lamp to the sensor tip on the light sensor.
12. Select START from the main screen to prepare for data collection. (Data will be collected only when you press [ENTER].)
13. Wait for the value displayed on the calculator to stabilize. Press [ENTER], and then enter the distance between the light sensor and the light source on the calculator. Press [ENTER] to conclude your entry.
14. Move the light sensor 1 cm farther away from the light source and repeat step 13.
15. Continue moving the sensor in 1-cm increments until the light sensor is 20 cm from the light source, collecting data as before. After the final data point, press [▶] to end data collection.

Data Table

Distance from Lightbulb (cm)	Intensity

Data and Observations

1. Use the cursor keys to move through the data points from the graph. Record the data in the data table.
2. Make a sketch of your graph.

Analysis and Conclusions

1. Return to Main Screen.
   a. Go to ANALYZE.
   b. Choose CURVE FIT.
   c. Go to MORE.
   d. Choose POWER (Ch1 vs Entry).

e. Write down the power equation in the form Y = AX^B

f. Sketch the graph shown on the calculator screen.

2. What does the value of B tell you about the relationship between the intensity of the light bulb versus the distance from it?

3. How does your graph of light intensity v. distance compare to your prediction made in step 10?

4. What are some reasons your experimental setup did not exactly match the relationship you predicted in step 10 concerning intensity and distance?

Extension and Application

1. To confirm the relationship between light intensity and distance, find the linear plot of $I = k \cdot 1/d^2$. Use your calculator to verify the inverse square relationship between intensity and distance. Enter data so that intensity v. $1/\text{distance}^2$ can be graphed. How can you tell if the inverse square relationship holds for your data?

2. Use the light sensor to test other light sources. For example, how does intensity vary as you move away from a fluorescent bulb?

Date ________ Period ________ Name ________________

CHAPTER 18

Probeware Lab 18-1

Safety Precautions

Materials

- Logger Pro or CBL 2 interface
- TI graphing calculator
- DataMate program
- link cable
- tube black light
- UVA sensor
- UVB sensor
- selection of eyeglass and sunglass lenses
- selection of glass plates and plastic materials
- polarizing filters

Measuring Ultraviolet Light

What causes you to get sunburn? The wavelength of light responsible for your red and blistering skin is ultraviolet (UV) light. It turns out that UV light is also responsible for many other health concerns, some well known, and others not so well known.

Ultraviolet light is broken down into three types identified as UVA, UVB, and UVC, as shown in **Figure A.** The most harmful of these is UVC (100–250 nm). It usually does not reach the Earth's surface because ozone in the upper atmosphere absorbs it long before it can damage things on the Earth's surface. UVB light (250–320 nm) is responsible for many skin problems, such as sunburns and several forms of skin cancer. It is also a cause of cataracts and other types of eye damage. The longer wavelength, UVA (320–400 nm), was thought to be the most benign form of UV, but it can deeply penetrate the skin, causing tanning, wrinkles, and some forms of skin cancer. Over time, UVA also can lead to some forms of eye damage.

In this experiment, a black light will be used to produce UVA wavelengths. A tube black light is basically a fluorescent lamp with a different type of phosphor coating. This coating absorbs harmful shortwave UVB and UVC light and emits UVA light (in the same basic way the phosphor in a fluorescent lamp absorbs UV light and emits visible light). The "black" glass tube itself blocks most visible light, so in the end only benign long-wave UVA light and some blue and violet visible light pass through. You will study what types of materials can absorb or transmit UVA light. Using this data, you can determine the relative safety of how to decrease your exposure to UVA light.

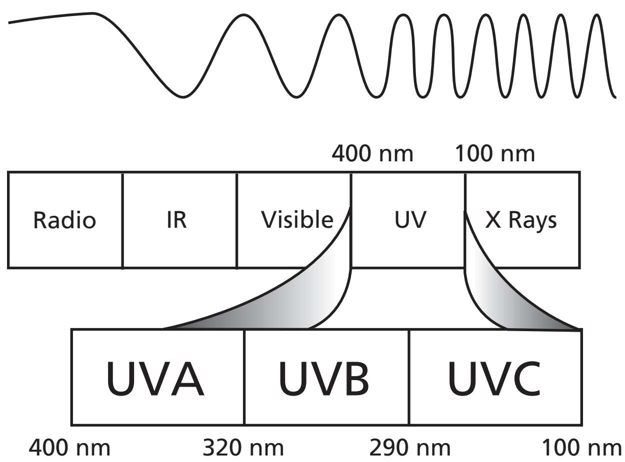


Figure A

Objectives

- **Compare** absorption and transmission of UV light through glass, plastic, and various filters.
- **Calculate** the ability of a material, such as sunglasses, polarizing filters, and glass to filter UV light.
- **Discuss** safety concerns of UV light.

Procedure

1. Firmly connect the link cable from the calculator to the LabPro or CBL2. Plug the UVA sensor into Channel 1 of the LabPro or CBL2.
2. Turn on the calculator and start the DataMate program. Press CLEAR to reset the program. The program should set up the UVA probe. You will be able to monitor the level of UV on the calculator screen throughout the experiment.
3. Next, zero the UVA probe. From the main screen choose SETUP. Go to ZERO. Select CH1. Making sure the end of the probe is blocked from any UV source, press ENTER to zero the probe.
4. Place the UVA probe about 15 cm from a tube black light. Turn on the black light. Take a reading of UVA intensity from the calculator screen. Wait for reading to stabilize. Enter your value in Data Table 1.
5. Leaving the UVA probe in the same position from the black light, place a glass plate between the black light and the probe. Take a reading of UVA intensity from the calculator screen and record the data in Data Table 1. Next, place two pieces of glass plates together and take a reading. Then, try three pieces of glass and take a reading.
6. Repeat step 5, except use a polarizing filter between the black light and the probe. Rotate the filter. Record the UVA intensity in Data Table 1.
7. Repeat step 5, except use various types of eyeglass and sunglass lenses. Record UVA intensity for each in Data Table 1.
8. Repeat step 5, except use various types of colored filters. Record UVA intensity for each in Data Table 1.
9. Repeat step 5, except use various types of plastics. Record UVA intensity for each in Data Table 1.

Data and Observations

Data Table 1			
Type of Filter	**UVA (mW/m^2) for Sample 1**	**UVA (mW/m^2) for Sample 2**	**UVA (mW/m^2) for Sample 3**
No filter			
Glass plate			
Polarizing			
Eyeglass lens			
Sunglass lens			
Colored filters			
Plastics			

Analysis and Conclusions

1. Calculate the percent UVA blockage of each type of filter used. Use the formula: % UVA blockage = (UVA of bulb − UVA with filter) × 100 %/UVA of bulb.

2. From your data, what types of materials appear to effectively block UVA?

3. If you had tested the tube black light with a UVB probe, what results would you have gotten in this experiment?

4. If a regular fluorescent lamp is available, test for UVA intensity. How does this compare to the black light?

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Extension and Application

1. Compare ultraviolet intensity (A or B) on cloudy and sunny days. This can be done outside as a long term investigation.

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2. Test for UVA and UVB sunglass protection from the sun. Determine how sunglass lenses are rated for UVA and UVB protection.

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3. Investigate the latest research into UVA health concerns for skin and eyes.

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4. Investigate the types of bulbs used in tanning booths.

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Date ____________ Period ____________ Name ____________________

CHAPTER 22

Probeware Lab 22-1

Safety Precautions

Materials

- power supply or battery: two 1.5-V cells
- connecting wire
- knife switch
- 100-Ω, 150-Ω, and 220-Ω resistors
- CBL 2 or LabPro interface
- link cable
- Vernier current probe
- voltage probe
- TI graphing calculator

Current, Resistance, and Potential Difference in Circuits

Ohm's law is a statement of the relationship between potential difference (commonly called voltage), current, and resistance. As electrons flow through ordinary conductors, they encounter forces that oppose their motion. This opposition to electron flow is called resistance. The force that moves the electrons is potential difference (voltage). The quantity of electrons that move is the current.

Every electronics company must use Ohm's law to design its products. Electric companies use this law when they design high-voltage power lines. A wire must be able to carry enough current at a given voltage, and Ohm's law is used to determine how much resistance that wire can have. Ohm's law applies not only to direct-current circuits, but to any circuit where current is carried through a resistor, including alternating current.

Objectives

- **Measure** the current flowing through a resistor and the potential difference across a resistor.
- **Calculate** resistance from the measured values.
- **Analyze** the relationship between potential difference and current for a resistor.

Problem

What is the relationship between current, resistance, and potential difference in a circuit?

Hypothesis

Formulate a hypothesis about the relationship between current, resistance, and potential difference in a circuit.

Plan the Experiment

1. Decide on a procedure that uses the suggested materials (or others of your choosing) to measure voltages. Using the relationship $I = V/R$, predict the relationship between the current through the circuit and the voltage across the resistor in the circuit.
2. On the next page, draw a circuit with the resistor that you will use for the experiment. Indicate position where you will place the voltage and current probes. Remember that a voltage probe must be wired in parallel and that the current probe must be wired in series.

3. Decide what kind of data to collect and how to analyze it. You can record your data in the table below. Label the columns appropriately.
4. Write your procedure on another sheet of paper or in your notebook.
5. **Check the Plan** Have your teacher approve your plan before you proceed with your experiment.

Current, Resistance, and Potential Difference in Circuits

Data Table				

Analysis and Conclusions

1. Why can you use the slope of the graph of potential difference versus current to find the value of the resistor?

____

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2. Compare the printed values of the resistors you used with your "A" slope values. Determine the relative error for each resistor.

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3. If your values were not within the tolerance range of the printed values, suggest some reasons for the discrepancy.

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____

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4. Describe the proper placement of an ammeter in a circuit.

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____

____

5. Describe the proper placement of a voltmeter in a circuit.

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____

6. What is the relationship between current through a circuit, the potential difference, and the resistance of the circuit?

____

____

____

Apply

1. Obtain a resistor of unknown value from your teacher. Use the procedure above to determine its resistance in ohms.

2. A lightbulb, after it has reached its operating temperature, has a potential difference of 120 V applied across it, while 0.50 A of current passes through it. What is the resistance of the light bulb?

3. The lightbulb in question 2 has a resistance of 21 Ω when cold. What is the current, in amperes, at the instant the bulb is connected to a potential difference of 120 V?

Date ______________ Period ______________ Name ______________________

CHAPTER 23

Probeware Lab 23-1

Safety Precautions

Materials

- power supply with variable voltage
- wires with clips
- resistors, 100 Ω, 150 Ω, 220 Ω, 470 Ω
- voltage probe
- current probe
- knife switch
- CBL 2 or LabPro unit
- unit-to-unit link cable
- TI graphing calculator

What happens to voltage across a resistor in a series circuit?

A series circuit has two or more devices connected so that all the current in the circuit flows through each device in turn. When all the devices are resistors, you have a series resistance circuit. In a properly constructed series circuit, all devices have the same amount of current through them. Think of a series circuit as if it were several pieces of hose with different diameters, connected end-to-end. The volume of water that flows out of the hose must be the same as the volume that enters the hose, no matter what the diameter. Each resistance in a series circuit can be analyzed using the relationship $I = V/R$. The voltage across the entire series circuit must be equal to the sum of the voltages across each part of the circuit.

Series resistance circuits have many electric and electronic applications. They are most often used to divide a voltage into two or more smaller voltages, such as allowing one battery or power supply to provide more than one value of voltage. Series circuits can also reduce a large voltage to a smaller one, which is how it is possible for a multimeter to measure a wide range of voltages.

Objectives

- **Measure** the voltage across each resistor in a series circuit.
- **Measure** the current in a series circuit.
- **Observe** the voltage drop across a resistor and the total voltage drop across the series circuit.
- **Determine** the relationship between the voltage drop across a resistor and its reference.

Problem

What is the relationship between the voltage drops across resistors in a series circuit and the total voltage across the circuit?

Hypothesis

Formulate a hypothesis about the relationship between voltage across resistors in a circuit and the circuit's total resistance.

Plan the Experiment

1. Decide on a procedure that uses the suggested materials (or others of your choosing) to measure voltages in a series resistance circuit that includes a source of voltage. Using the relationship $I = V/R$, predict the relationship between the current through the circuit and the voltage across each resistor in the circuit.

2. On the next page, draw a series circuit with three resistors that you will use for the experiment. Indicate positions where you might make voltage or current measurements. Remember that voltmeters must be wired in parallel and that ammeters must be wired in series.
3. Decide what kind of data to collect and how to analyze it. You can record your data in the table below. Label the columns appropriately.
4. Write your procedure on another sheet of paper or in your notebook.
5. **Check the Plan** Have your teacher approve your plan before you proceed with your experiment.

Series Circuit with Three Resistors

Data and Observations

Data Table				

Analyze and Conclude

1. **Analyzing Results** What is the relationship between the voltage drop across the individual resistors in the circuit and the power-supply voltage?

2. **Analyzing Results** Is the voltage drop across each resistor related to the value of the resistor? Give a reason for your answer.

3. **Checking Your Hypothesis** Would removing a resistor affect the voltage drops across the remaining resistors in a series resistance circuit? Give a reason for your answer.

4. **Checking Your Hypothesis** Describe the total current in a series resistance circuit in relation to the total resistance and to the voltage applied to the circuit.

5. **Predicting** Predict the equivalent resistance of a circuit when the circuit consists of resistors in series. Use several resistors and an ohmmeter to check your prediction.

Apply

1. A set of 100 lightbulbs wired in series lines a sidewalk. The set of lights is designed to operate on 120 V. If the set uses 0.5 A of current, what is the average resistance of each individual bulb? What is the average voltage across each lightbulb?

2. You are asked to determine the resistance value of an unmarked resistor. You have a voltmeter, a battery, and several resistors of known value. Explain the method you would use to determine the value of the unmarked resistor using only these items.

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