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Table of Contents

Introduction

This book contains classroom activities that involve the use of the Portable DataLab in conjunction with a graphing calculator. The activities are organized by subject: Math, Physics, and Chemistry. Many of the activities, however, may be used for more than one subject.

The activities in this book provide basic information on how to set up experiments. More detailed instructions on how to conduct the experiments using specific calculator models can be found in the DataLab Companion user manuals.

Please refer to the Portable DataLab reference manual for important information on the appropriate use and safe handling of this electronic device.

For more information on educational materials for the Portable DataLab, contact:

Firmware Systems
626 NW 4th Street
Corvallis, OR 97330

Phone (541)753-3617
Fax (541)753-9250

www.firmwaresystems.com

Activities Source Book version 1.01   October 1999

Date: _____   Name: _____

Descartes with One Wheel

(Pythagorean Theorem I)

Introduction

The shortest distance between two points in a plane is a straight line. This distance is easy to find if the two points lie on a line that is parallel to the x or y axis. If the two points are the center of a circle and a point on the circumference of the circle, the distance between them can be found by the Pythagorean Theorem that relates the lengths of the legs of a right triangle to the length of the hypotenuse.
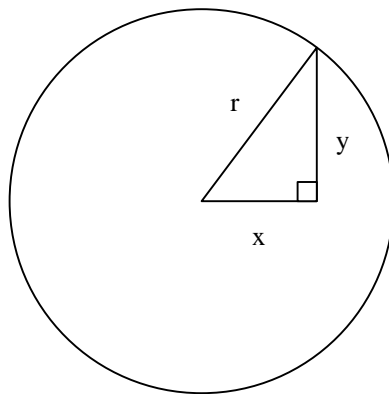
$$x^2 + y^2 = r^2$$

Equipment Required

2 Portable DataLabs*

2 motion detectors*

2 graphing calculators*, with DataLab Companion software, cable and instructions

1 metric ruler

1 dowel rod, 1/2 inch (13 mm) diameter, 18 inches (0.5 m) long
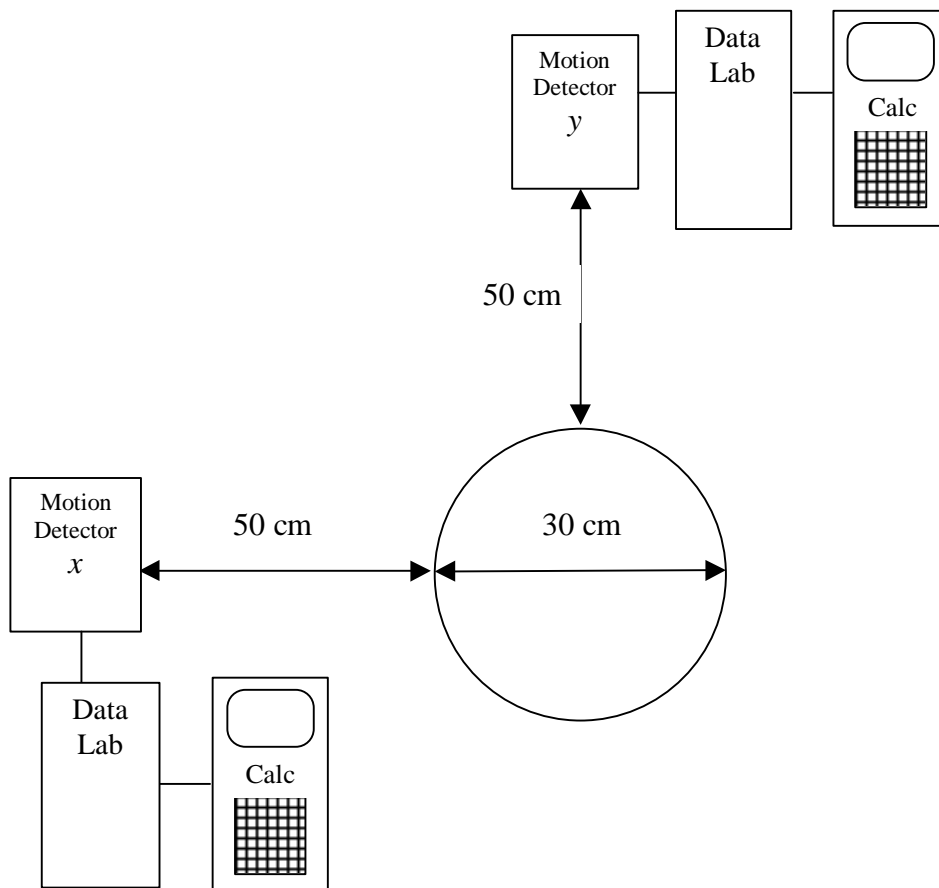
1 30 cm diameter circle made from cardboard

* If 2 sets are not available, the experiment can be done using 1 set. See Experiment
  Procedure.

Experiment Setup

1. Connect the motion detectors to the DataLab(s).

2. Connect the DataLab(s) to the graphing calculator(s).

3. Place the cardboard circle 50 cm from each motion detector.

4. Set up experiment to collect displacement data in calculator.

Experiment Procedure

In this experiment the dowel rod represents Descartes' cart. Start the dowel at a point directly opposite the *x* motion detector. The cart will follow the path of the circumference of the circle making one complete revolution. The motion detectors will record the x and y coordinates of points along the path. It is important that the dowel rod be maintained in a vertical position relative to the tabletop and move along the path described. It is suggested that the circle be placed on the floor and the motion detector(s) be placed on the edge of a table 50 cm away.

If two DataLabs, graphing calculators, and motion detectors are not available, use one set to take measurements as described above. When done collecting this first set of data (*x*), rotate either the circle or the DataLab set up 90 degrees and collect a second set of data (*y*).

Analysis and Interpretation

1. Display the data in a table using the graphing calculator. Identify the minimum and maximum value and determine the graph scale. Enter the data points in the chart below.

2. What is the total length of the path followed by Descartes' cart?

3. What do you think each of the ordered (*x,y*) pairs in your collected data are telling you? Measure the horizontal and vertical distances from each of the motion detectors to a point on the circumference of the circle. How do these distances relate to the (*x,y*) coordinates for these points?

4. Change the data so that each ordered pair gives the (*x, y*) coordinate of a point on the circumference of the circle so that the circle would be centered at the origin (0,0). To do this, measure the distance from the motion detector to the center of the circle. Using the table functions in the graphing calculator, derive columns of new *x* and y values that result when the distance value is subtracted from each *x* and *y* value of each ordered pair. Graph the new data. How does the new graph compare with the original graph?

5. In this experiment we have adjusted the data to keep the distance from the origin at 15 cm for every coordinate pair *(x,y)*. Use the distance formula $d = \sqrt{((x-0)^2 + (y-0)^2)}$ to verify that this holds true for your data. Use the power of your calculator to help you do this. (Put into a new column: $\sqrt{(x \text{ value}^2 + (y \text{ value})^2)}$.)

Date: _____   Name: _____

The Horse and Descartes

(Pythagorean Theorem II)

Introduction

The shortest distance between two points in a plane is a straight line. This distance is easy to find if the two points lie on a line that is parallel to the x or y axis. If the two points, A and B, are located anyplace in the plane the distance between them can be found by applying the Pythagorean Theorem that relates the lengths of the legs of a right triangle to the length of the hypotenuse.

B (x_2, y_2)

(x_1, y_1) A

C
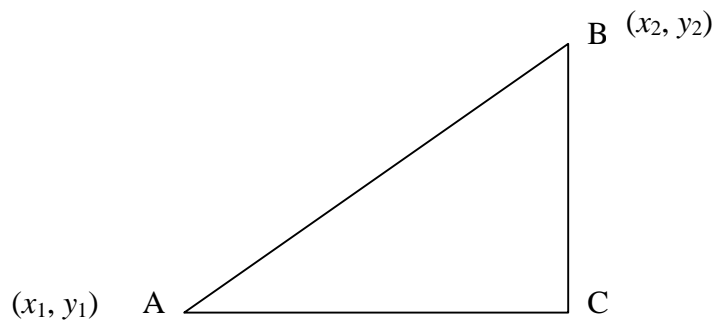
The distance from C to A is x_2-x_1 and the distance from C to B is y_2-y_1. The distance from A to B is:

$$\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

This is known as the distance formula.

Equipment Required

2 Portable DataLabs*

2 motion detectors*

2 graphing calculators*, with DataLab Companion software, cable and instructions
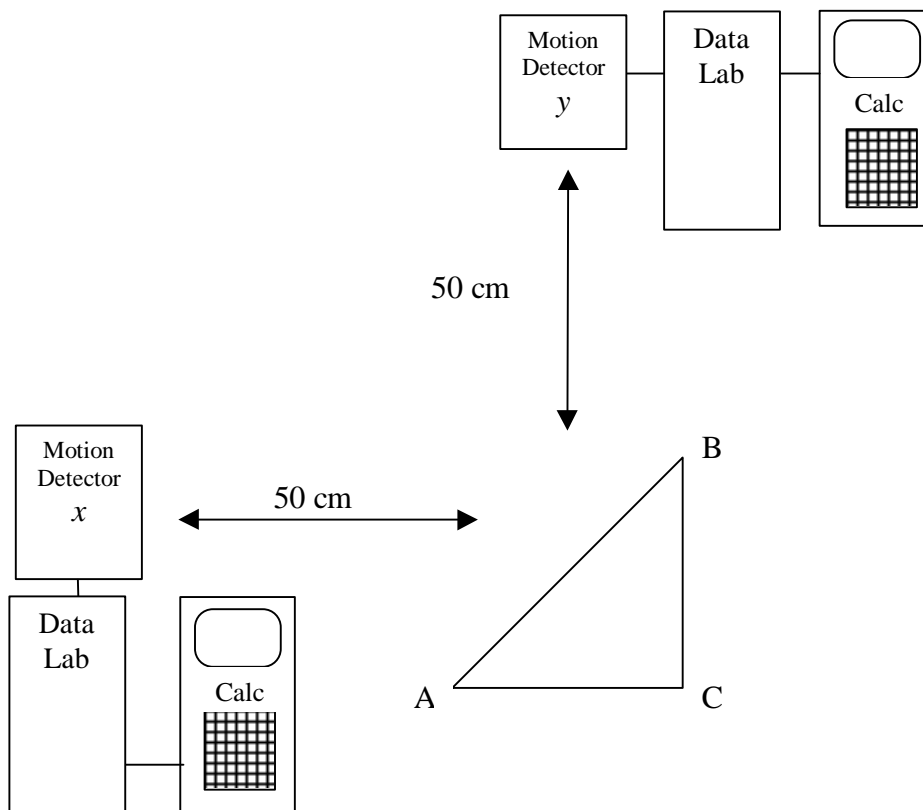
1 metric ruler

1 dowel rod, 1/2 inch (13 mm) diameter, 18 inches (0.5 m) long

1 right triangle made from cardboard

* If 2 sets are not available, the experiment can be done using 1 set. See Experiment Procedure.

Experiment Setup

1. Connect the motion detectors to the DataLab(s).

2. Connect the DataLabs to the graphing calculator(s).

3. Place the cardboard triangle 50 cm from each motion detector.

4. Set up experiment to collect displacement data in calculator.

Experiment Procedure

In this experiment the dowel rod represents Descartes' horse. Descartes will lead his horse along a path that will travel from point A to point C. He will then turn 90 degrees to his left and travel from point C to point B. From point B he will turn to his left and travel in a straight line back to point A. The motion detectors will record the x and y coordinates of points along the trip. It is important that the dowel rod be maintained in a vertical position relative to the tabletop and moved along the path described. It is suggested that the triangle be placed on the floor and the motion detector(s) be placed on the edge of a table 50 cm away.

If two DataLabs, graphing calculators, and motion detectors are not available, use one set to take measurements as described above. When done collecting this first set of data (x), rotate either the triangle or the DataLab set up 90 degrees and collect a second set of data (y).

Analysis And Interpretation

1. Display the data in a table using the graphing calculator. Identify the minimum and maximum value and determine the graph scale. Enter the data points in the chart below.

2. Use your data and the distance formula to determine the distance that Descartes led his horse. Measure each of the distances with a meter stick and round each distance to the nearest tenth of a centimeter. Find the difference between the distances you

calculated using the distance formula and the distances you measured with the meter stick. Determine the percent difference relative to the calculated distances. How would you describe your results?

Segment	Length using data and distance formula	Length measuring with a meter stick	Difference	Percent Difference
AC				
CB				
AB				

3. What is the total length of the path followed by Descartes and his horse?

4. What do you think each of the ordered (x,y) pairs in your collected data are telling you? Measure the horizontal and vertical distances from each of the motion detectors to points A, B, and C. How do these distances relate to the (x,y) coordinates for these points?

5. Pick two points that are on the plane and are 20 cm apart but are not both on a horizontal or vertical line and label them points A and B. Using the DataLab and the distance formula, help Descartes determine the coordinates of a point where he could make his 90 degree turn. Measure the distances from Point A and Point B to the point where he will make his turn to the nearest tenth of a centimeter and use the Pythagorean Theorem to see how close your coordinates are to creating a right triangle. If you do not have a right triangle, make adjustments and try again.

Date: _____   Name: _____

Light and Squares

## (Inverse Square Law)
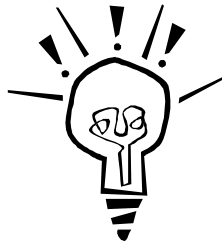
Introduction

In this experiment we are going to derive a relationship between the intensity of light from a constant source and the distance away from the light. We will also explore the inverse square law.

Equipment Required

1 Portable DataLab

1 graphing calculator, with DataLab Companion software, cable and instructions

1 light probe

1 flashlight

1 metric ruler

1 darkened pipe or dark colored posterboard (1 - 2 meters long)

1 piece of string (~ 2 meters long)

1 small toy car or similar object with wheels

Experiment Setup
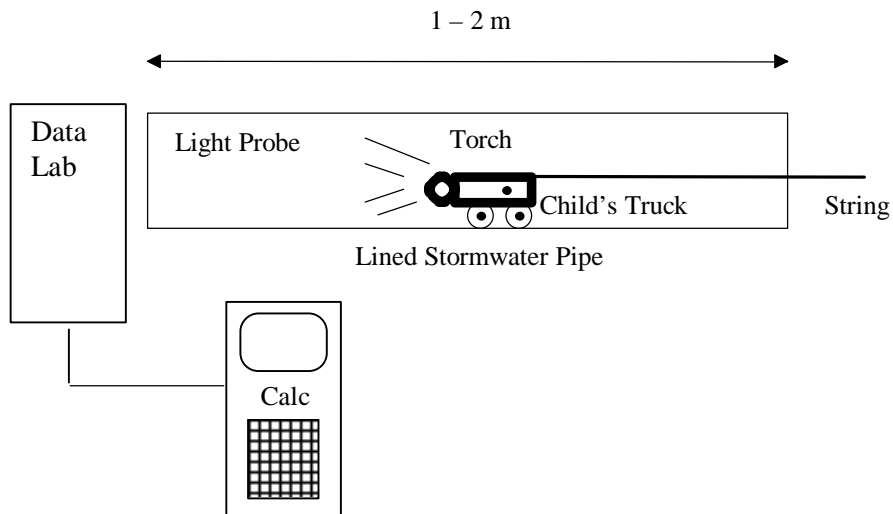
1 – 2 m

Data Lab

Light Probe   Torch

Child's Truck   String

Lined Stormwater Pipe

Calc

1. Connect the DataLab to the graphing calculator.

2. Set up experiment to collect displacement data in calculator.

3. Attach the flashlight to one end of the car.

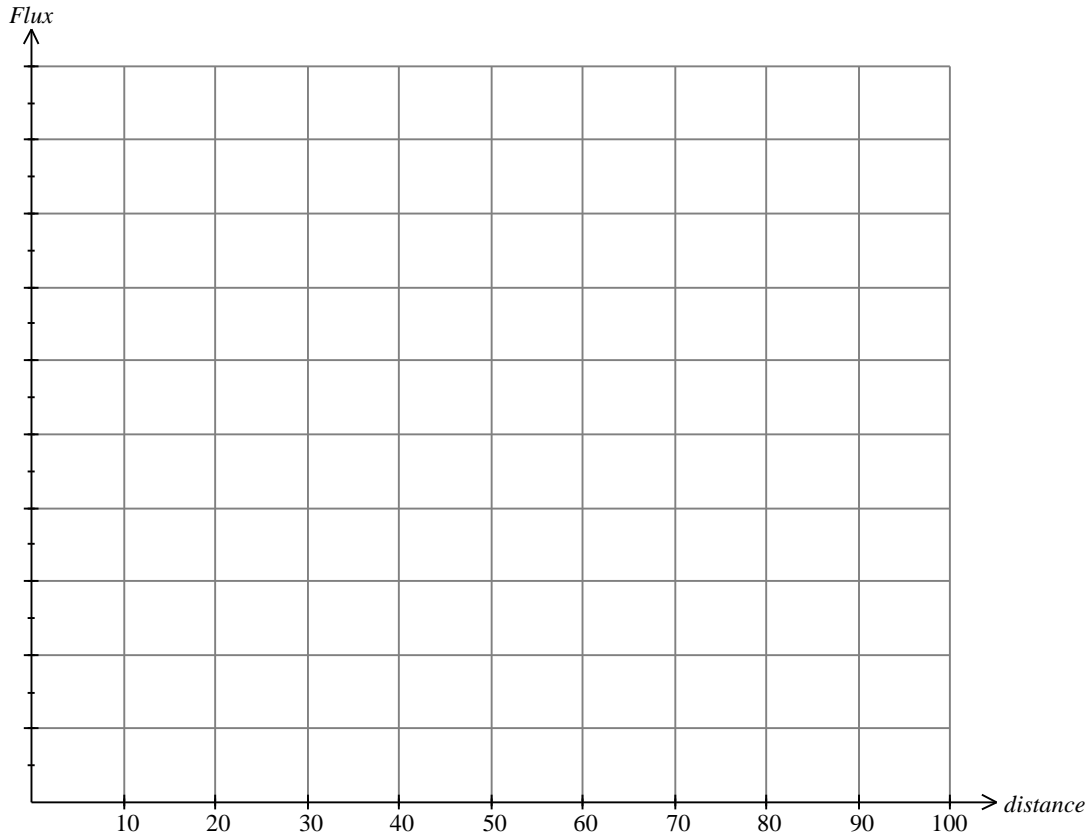4. Attach the string to the other end of the car.

Experiment Procedure

Use your DataLab and graphing calculator to measure the Lux at specific distances and complete the table.

Distance (cm)	Lux
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

Analysis and Interpretation

1. Sketch the graph of the data below and state the nature of the function(s).

Flux

distance

2. Use your graphing calculator to find the equation that best fits the data.

The relationship we should derive is known as the Inverse Square Law:
$$I = \frac{C}{d^2}$$

where C is the constant luminosity, d is the distance from the light source and I the flux (intensity of light-apparent brightness).

From the function or table you should find that if the distance is doubled, the observed intensity of light is decreased by $\left(\frac{1}{2}\right)^2 = \frac{1}{4}$ of its original value.

Here is sample data:

Distance	Lux
10	685
15	382
20	215
25	147
30	103
50	40
60	25
70	18
100	8
140	1
200	0.5

Lux and Distance

$$y = 302812x^{-2.4007}$$
$$R^2 = 0.9597$$
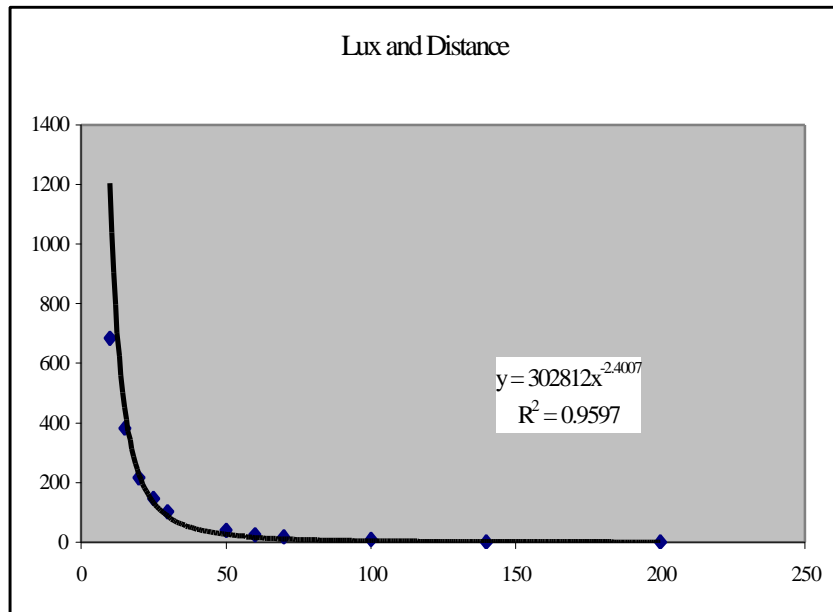
While the fit was reasonable, it was suggested that there is likely to be an error when the light source is too close and too far away. Following this advice, we treated the 10 cm, 140 cm and the 200 cm as outliers and discounted them during the fit process. The resulting function was a better match to our theoretical model than the first function.

Distance	Lux
15	382
20	215
25	147
30	103
50	40
60	25
70	18
100	8

Lux and distance

$$y = 93499x^{-2.013}$$
$$R^2 = 0.9976$$
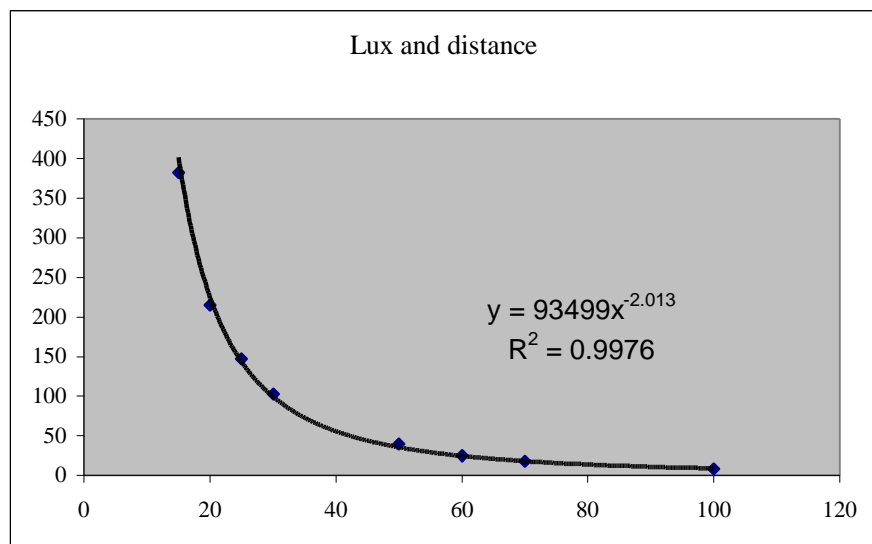
The Solar System and the Inverse Square Law

The average distance from the Earth to the Sun (149,597,870.70 km) is defined as 1 Astronomical Unit (1 AV). Similarly, the average amount of solar energy per unit area reaching the Earth could be defined as 1 solar constant. Given what you have observed about light intensity and its relation to the distance from its source, complete the table below considering other planets and their distances from the Sun and answer the following questions.

PLANET	Distance(km)	Distance(AU)	Solar Energy (Solar Constants)
Mercury	57894375.95	0.387	
Venus	108159260.5	0.723	
Earth	149597870.7	1	1
Mars	227837557	1.523	
Jupiter	778208123.2	5.202	
Saturn	1426864490	9.538	
Uranus	2869436757	19.181	
Neptune	4496463198	30.057	
Pluto (min)	4441560780	29.69	
Pluto (avg)	5900140019	39.44	
Pluto (max)	7358719258	49.19	
A Cen	4.06906E+13	272000	

Source: Educator's Guide to the Inverse Square Law
(http://www.uni-geochem.gwdg.de/solar/edu/invsquar.htm)

3. How much brighter is the Sun as viewed from the planet Mercury as compared to Earth?

4. How much fainter is it at Pluto?

Date: _____   Name: _____

The Train that Left Chicago

(Velocity)
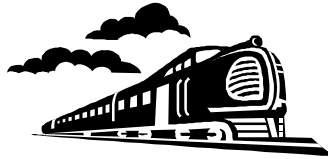
Introduction

The velocity of a particle is defined as the rate at which its position changes with time. Stated mathematically:

$$Velocity \quad = \quad \frac{change\ in\ position}{change\ in\ time}$$

The definition of velocity can be extended to the definition of the slope of a function, which is as follows (where m = slope; y_2 and y_1 are points on the y-axis; and x_2 and x_1 are points on the x-axis):

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

In this experiment we will investigate the slope of a function by relating it to the motion of a walking student.

Equipment Required

1 Portable DataLab

1 motion detector

1 graphing calculator, with DataLab Companion software, cable and instructions

Experiment Setup

1. Connect the motion detector to the DataLab.

2. Connect the DataLab to the calculator.

3. Set up experiment to collect displacement data in calculator.

4. Place the motion detector on a table so that there is enough room for a student to walk away from it.

Motion Detector   **Graphing calculator**

DataLab

> 1.5 ft
(> 0.5 m)
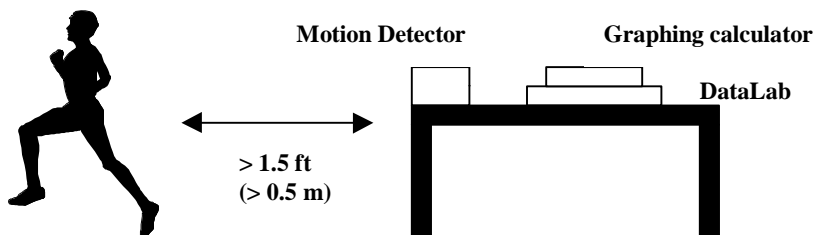
Experiment Procedure

1. Make sure that the motion detector sits flat on the table and that it is perpendicular to the motion of the walker.

2. Position one student so that he/she is about 2 feet (0.6 m) away from the motion detector. Make sure not to start walking fewer than 1.5 feet (0.5 m) from the detector because it cannot detect motion closer than that distance.

3. When ready, start the DataLab program and have the student begin walking at a constant rate, perpendicular to and away from the detector.

4. A graph of Distance vs. Time will be generated while the student is walking.

Repeat steps 1 to 4 but have the student walk at a non-constant rate (for example, speed up or slow down over time).

Analysis and Interpretation

Based on the two graphs that were generated, answer the following questions.

1. What were the total distances traveled and time spent walking during each of the two walks? Fill in the table below.

	Walk # 1	Walk # 2
Total Distance (meters)		
Total Time (sec)		

2. Determine the average velocity for each of the two walks.

3. What was the velocity of the walker at time = 3 seconds during the first walk?

4. How does this compare to the velocity at time = 3 seconds for the second walk?

5. The Distance vs. Time graph for the first walk (constant rate) should have been a line with a positive slope. Describe how the student would have to walk to produce a line with a negative slope.

6. Describe how the student would have to walk to produce a plot of a parabola.

Date: _____   Name: _____

Why do Animals Huddle?

(Temperature)

Introduction

When it is cold many kinds of animals prefer to huddle together in a tightly knit group. Why do they do this?

Your task is to use the temperature probes and the graphing calculator to test the hypothesis that huddling together keeps animals warmer or why we should place all of our frozen groceries bought from the supermarket together.

Equipment Required

1 Portable DataLab

3 temperature probes

1 graphing calculator, with DataLab Companion software, cable and instructions
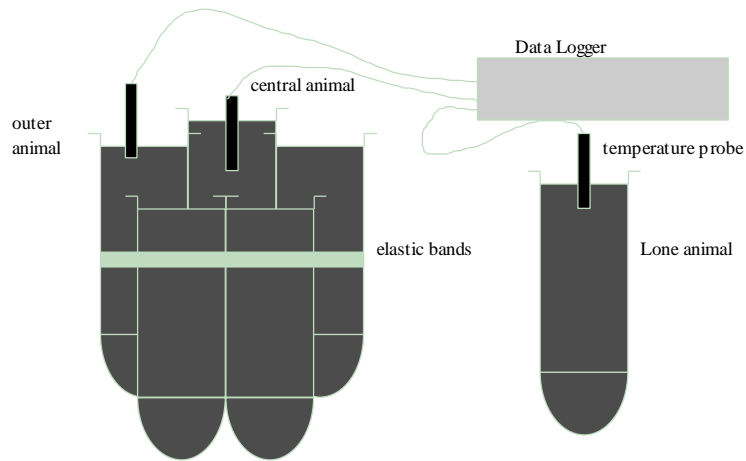
8 test tubes

2 beakers to hold test tubes

2 or 3 rubber bands

warm tap water (approximately 37 °C to simulate body temperature)

Experiment Setup

1. Connect the three temperature probes to the DataLab.

2. Connect the DataLab to the graphing calculator.

3. Set up experiment to collect temperature data in calculator.

4. Secure seven of the test tubes with the rubber bands so that one of the test tubes is in the center and place them in one of the beakers.

5. Place the remaining test tube in the other beaker.

6. Place one temperature probe in the lone test tube, another in the center tube, and another in one of the outer test tubes. Keep track of which channel each probe is connected to.

Experiment Procedure

1. Fill each test tube with warm water.

2. Collect temperature data from each of the 3 temperature probes. Collect 25 samples at 2 minute intervals (50 samples total).

Analysis and Interpretation

From the data collected, answer the following questions. In your responses you will need to use the collected data as supporting evidence.

1. From your results plot 4 suitable data points to show the general shape of the three cooling situations.
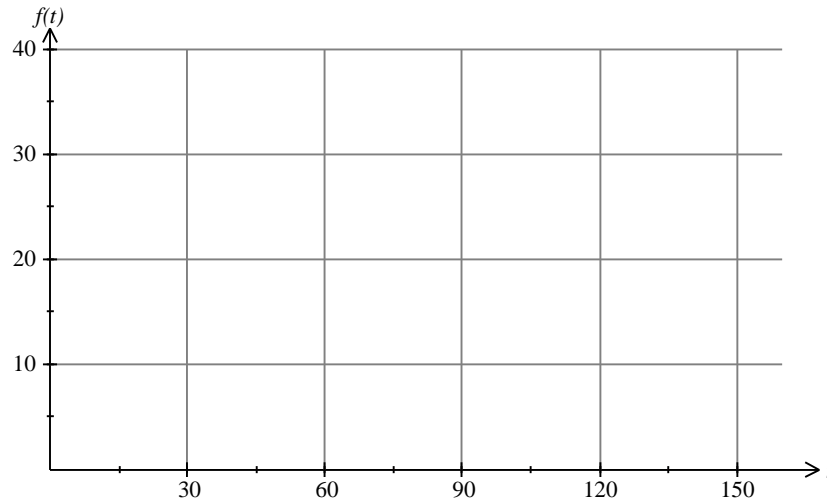
2. What type of function best describes the shape of the three graphs?

3. What does the graph tell you about the temperature of the lone animal?

4. What does the graph tell you about the temperature of the huddling animals?

5. How does each graph show which animal cooled fastest?

6. Does huddling keep an animal warmer? If so, explain why you think this happens.

7. Describe the difference between the cooling of the lone animal with that of the outside animal.

8. Find an equation that best fits the three groups of data.

9. Predict the temperatures for the three situations at $t = 71$ and $t = 140$ minutes.

10. At what times will the temperature be 17.001ºC?

Date: _____   Name: _____

Ben Franklin Plays Carnegie Hall
(Musical Notes)

Introduction

Many simple tunes can be played within an octave. Some familiar tunes are Row Row Row your boat, Three Blind Mice, or Happy Birthday to You. This experiment allows you to explore sound waves produced by musical notes. Your goal is to replicate the 8 notes in a major scale octave and play a musical tune.

Equipment Required

1 Portable DataLab

1 graphing calculator, with DataLab Companion software, cable and instructions

1 tuning fork for middle C or A (440cps) and a rubber hammer

Table of frequencies for notes Middle C to C:
       C-261.626
       D-293.183
       E-329.628
   F-349.228
       G-391.995
       A-440
       B-493.883
       C-523.251

8 soda pop bottles (twelve to sixteen ounce) and straws, or 8 water goblets

4 liters water

Experiment Setup

1. Connect the Portable DataLab to the graphing calculator.

2. Set up experiment to collect sound wave data in calculator. Make sure that the sample interval is 0.01 sec or lower.

3. Strike the tuning fork with the rubber hammer and hold the vibrating fork close to the microphone. Immediately start the DataLab to collect sound wave data.

4. Determine the period of the wave and record it. Also record the frequency listed on the tuning fork.

5. Arrange eight 12-16 oz soda pop bottles or water goblets on a table.
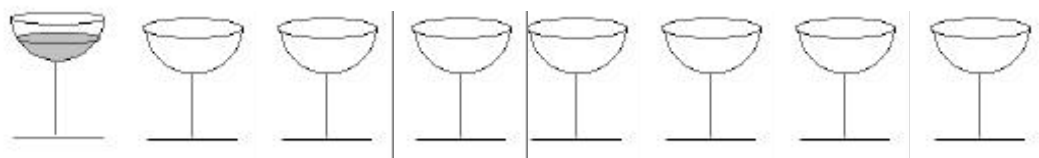
Experiment Procedure

1. Partially fill one bottle/goblet with water.

2. Create a tone by gently blowing air through a straw across the top of the bottle or rubbing a wet finger around the rim of the top of the goblet.

3. Run the program to collect the data to determine the frequency of the note.

4. Compare the frequency with the desired frequency from the frequency table and adjust the amount of water in the bottle/goblet until the desired frequency is obtained.

Sample Data


```
VOLTS/TIME
2.721



2.515
START NEW■ VIEW BAT■    QUIT
```
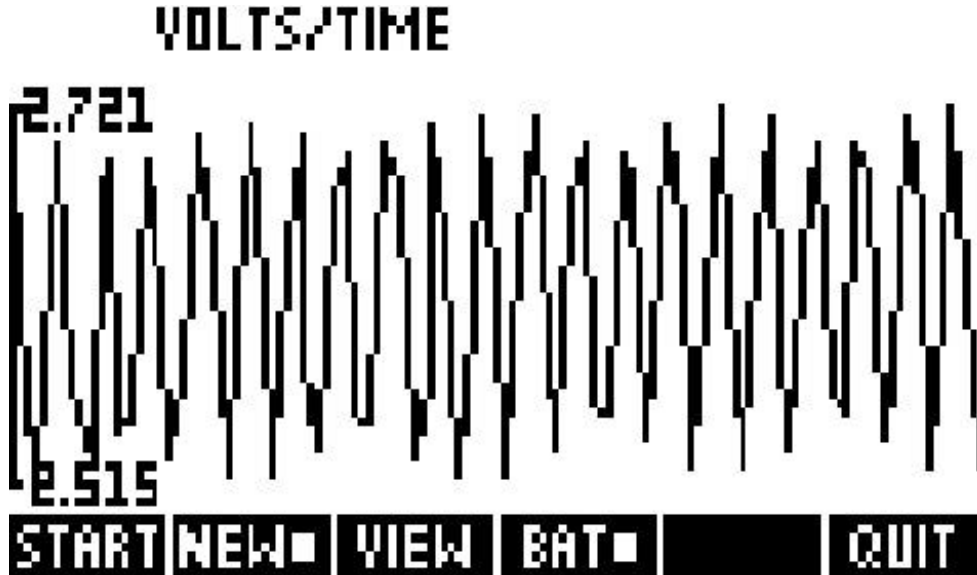
The distance between any two consecutive maximum or minimum values is the time for one period. The frequency is periods per second so 1/time for one period equals the frequency. In this example the difference between two consecutive maximum values is .00145 and the frequency is 1/.00145 or about 690 periods per second.

Analysis and Interpretation

1. Describe the relationship between period and frequency as determined by the tuning fork experiment.

2. Two notes harmonize producing a pleasing sound when the ratio of their frequencies is an integer or a rational number. Determine if pairs of your notes

produce a pleasing sound when played at the same time and determine the ratio of the frequencies.
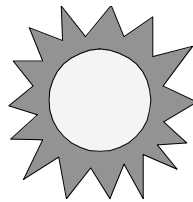
3. Create a frequency vs. period graph. Based on this graph, describe the relationship between frequency and period.

4. Measure and graph the height of the air column compared to its frequency for each note. What does the graph look like?

Date: _____   Name: _____

Body and Sol

(Solar Energy)

Introduction

Solar energy and making use of the sun to heat homes has been a topic of discussion during the last half of the 20th century. Heating our homes with the rays of the sun would certainly be a good use of a natural resource. We need, however, a means of storing the energy from the sun. What resources do we have to capture this energy and prolong its effectiveness for the greatest amount of time?

This experiment will allow you to determine the heat retention of collectors of solar energy. This experiment involves constructing a building that is capable of capturing solar rays, selecting suitable energy collectors and collecting temperature data over time.

Equipment Required

1 Portable DataLab

1 temperature probe and cable

1 graphing calculator, with DataLab Companion software, cable and instructions

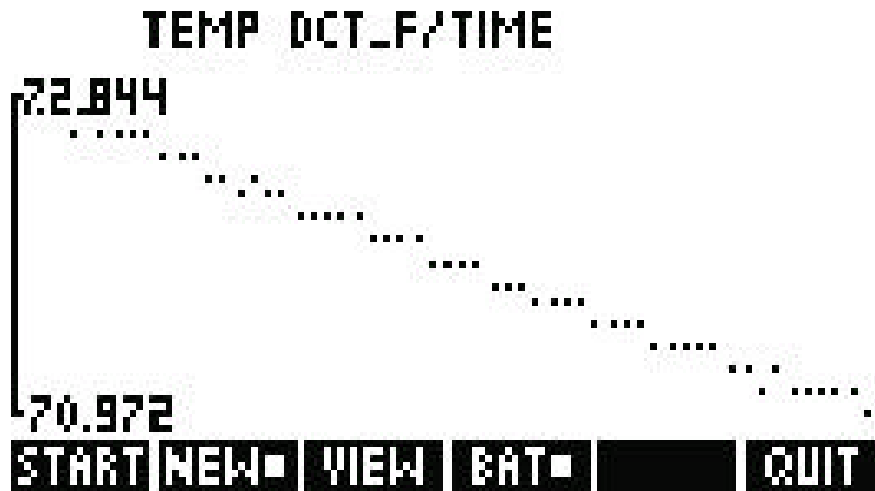2 or more solar collectors

1 heat lamp

building

Experiment Setup

1. Solar collectors may be made with white PVC or black PBS plastic pipe 5 to 8 cm in diameter and filled with liquid or solid material. The pipe should be capped at both ends with plastic caps using the appropriate glue. All of the collectors should have the same volume to compare their effectiveness.

2. The building should be designed so that it has a volume of three to four cubic feet (.08 to .1 cubic meters), an insulation factor, windows to allow the solar energy access to the collector and a means of closing and insulating the windows to the interior of the building.

3. Place the solar collector in the building.

4. Place the heat lamp so that the heat will radiate into the building and onto the solar collector.

5. Place the temperature probe in the building and connect the probe to the DataLab.

6. Set up experiment to collect temperature data in calculator.

Experiment Procedure

1. Record the initial temperature in the interior of the building and the exterior temperature.

2. Apply heat to the closed building through the windows with the heat lamp for 30 minutes.

3. Cover the windows of the building as if closing the drapes.

4. Record the new interior temperature and the heat gain.

5. Run the program to collect temperatures at one minute intervals for 60 minutes

6. Repeat this procedure using a different solar collector.

Sample Data

```
        TEMP DCT_F/TIME
 72.844
     . . . . .
        . . .
         . .  . .
            . . . .
             . . . .
                . . . .
                   . . . .
                    . . . . .
                       . . . .
                         . . . .
                            . . . . .
                              . . .
                               . .  . . . . .
 70.972                             . .
 START NEW■ VIEW BAT■        QUIT
```

Analysis and Interpretation

1. Create a scatter plot comparing temperature to time for each collector. Describe the shape of each graph.

2. Describe how the rate of heat loss changes over time for each collector.

3. Describe how the color of the collector affects its effectiveness in collecting and retaining heat.

4. Develop a mathematical model that fits the data in each graph.

5. Based on your observations and data, which factors influence the effectiveness of the heat collectors you created?

6. Based on your observations and data, which collector would you recommend to a prospective purchaser and why?

Date: _____   Name: _____

Doing the Wave
## (Simple Harmonic Motion)

Introduction

In this experiment we are going to model simple harmonic motion (SHM) and find the equation that best fits the data. The general model of SHM we can use is either:

$$y = A \sin B (x - \alpha) + C \qquad \text{or} \qquad y = A \cos B (x - \beta) + C$$

Equipment Required

1 Portable DataLab

1 motion detector

1 graphing calculator, with DataLab Companion software, cable and instructions

1 sheet of cardboard

Experiment Setup
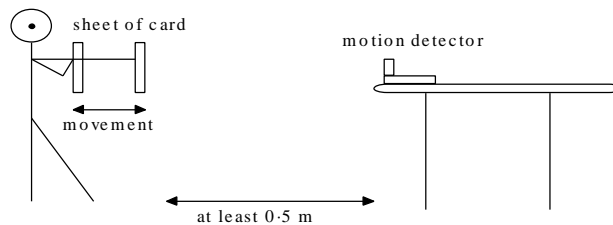
1. Connect the DataLab to the graphing calculator.

Connect the motion detector to the DataLab.

Set up experiment to collect displacement data in calculator.

Experiment Procedure

A student standing at least 0.5 meters from the motion detector with arms fully extended in front of them will create the motion. The student will extend the arms, letting them drop (swing) downward and then back up again at a regular pace to simulate the motion of a pendulum/spring. It is suggested that records be taken for 5 seconds at every 0.05-second, that is 100 records.

After plotting and saving the graph of the motion data you are in a position to answer the following questions.

Analysis and Interpretation

1. Complete the table below and use this to sketch the graph showing the motion of the cardboard over the time period.

Time (x) (sec)	0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.0
Dist (y) (cm)														
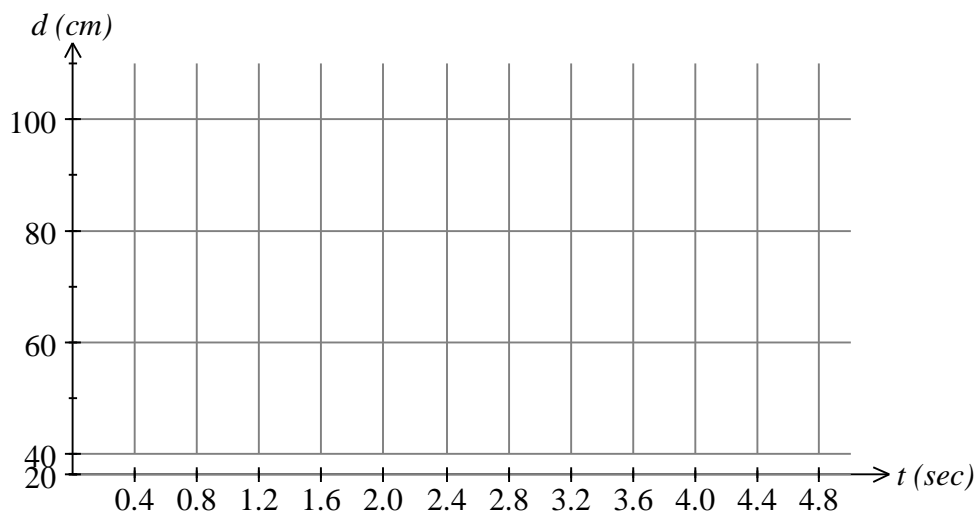
2. Write down the maximum and minimum values of y.

    a) Maximum value =_____ b) Minimum value = _____

3. What do these two values represent in the experiment?

4. The amplitude of the motion, A, can be calculated by finding half of the difference between the maximum and minimum values of y.

$A = 0.5$ (maxvalue - minvalue) $\therefore\ A =$ _____

5. The value of C, the vertical shift, can be found by subtracting A from the maximum value of y. (or adding A to the minimum value)

$C =$ maxvalue $- A$ $\therefore\ C =$ _____

6. The value of B is related to the period, P, of the motion by the equation.

$$P = \frac{2p}{B} \text{ or } P = \frac{6.28}{B}$$

Write down the value of the period   _____

Write down the value of B _____

7. The value of *a* is known as the phase shift and it is related to the movement left or right of the function. It is calculated by finding the distance particular points have been moved left or right. Use the maximum points to find the value of the movement. An example is given on the following page:

A sin graph showing a phase shift of -1·2

y= 40sin 2x +60   y = 40 sin 2(x - 1·2) +60

phase shift
of -1·2
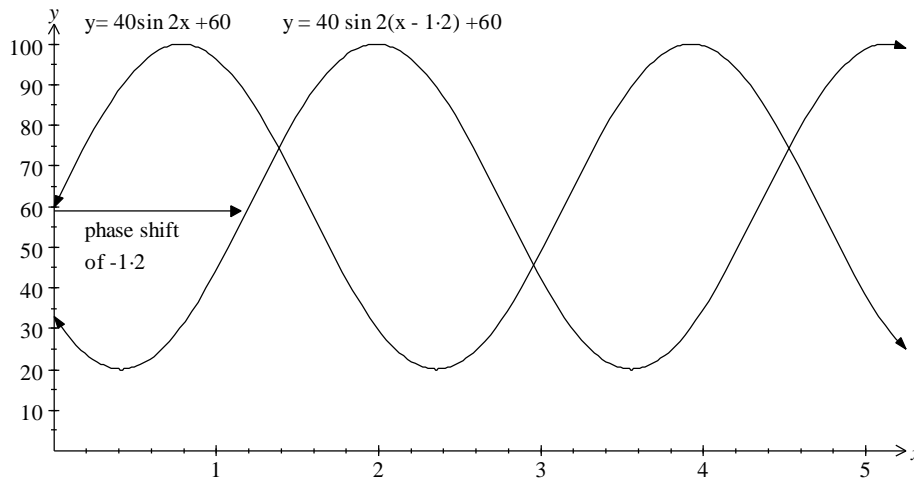
8. Draw the function $y = A\ sin\ Bx + C$ using your values of A, B and C. Use the cursor keys to find the distance this function has to be moved to the right to match the trace of the motion. This distance is the value of **a**.
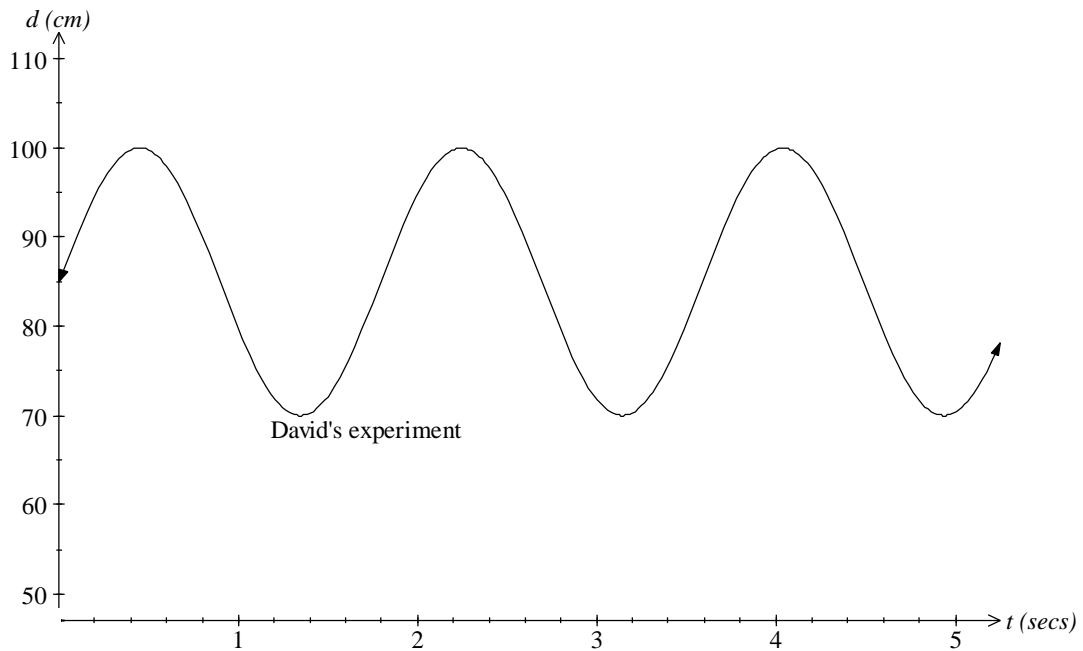
    a = _____

9. Use all your values to write down the equation of motion in the form

    $y = A\ sin\ B\ (\ x - \alpha\ ) + C$

    $y = $ _____

10. Place the above function into your calculator's curve-fitting tool and compare it with the collected data. Comment on any similarities or differences.

11. In an earlier experiment David produced the following graph.

d (cm)

David's experiment

t (secs)

12. From this graph estimate:

    a)   The distance David's chest was away from the motion detector ....

    b)   The length of David's outstretched arms...

    c)   The time taken for David to complete one cycle of arm movement. ....

13. Danielle also did the experiment starting at the same time as David. Given the following details draw a trace of her movements on the graph above.

    a)   The distance Danielle's chest was away from the motion detector was 80 cm.

    b)   The length of Danielle's outstretched arms was 28 cm.

    c)   The time taken for Danielle to complete one cycle of arm movement was 3.6 seconds.

Date: _____   Name: _____

Full Speed Ahead

(Acceleration)
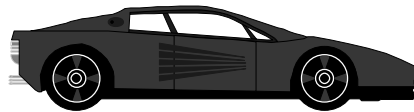
Introduction

Acceleration is defined as the rate of change of velocity, i.e. $a = \dfrac{\Delta v}{\Delta t}$.

Velocity is measured in meters per second (ms^{-1}), therefore acceleration is measured in $\dfrac{ms^{-1}}{s}$ or meters per second per second (ms^{-2}). An acceleration of 4 ms^{-2} means that an object's velocity changes by 4ms^{-1} for every second it undergoes that acceleration.

If an object's initial velocity is 10 ms^{-1} and it undergoes a constant acceleration of 4ms^{-2} then its velocity will change from 10 ms^{-1} to 14ms^{-1} in the first second, 14 ms^{-1} to 18 ms^{-1} in the second second and so on.

This experiment looks at the motion of an object undergoing constant acceleration. The object is allowed to roll down an incline and its displacement is recorded using a motion detector. The data collected is modeled by an algebraic function linking displacement (s) and time (t).

Equipment Required

1 Portable DataLab

1 motion sensor

1 graphing calculator, with DataLab Companion software, cable and instructions

1 small toy car or similar object with wheels

1 flat board (ramp)

1 block or brick to elevate the ramp

Experiment Setup
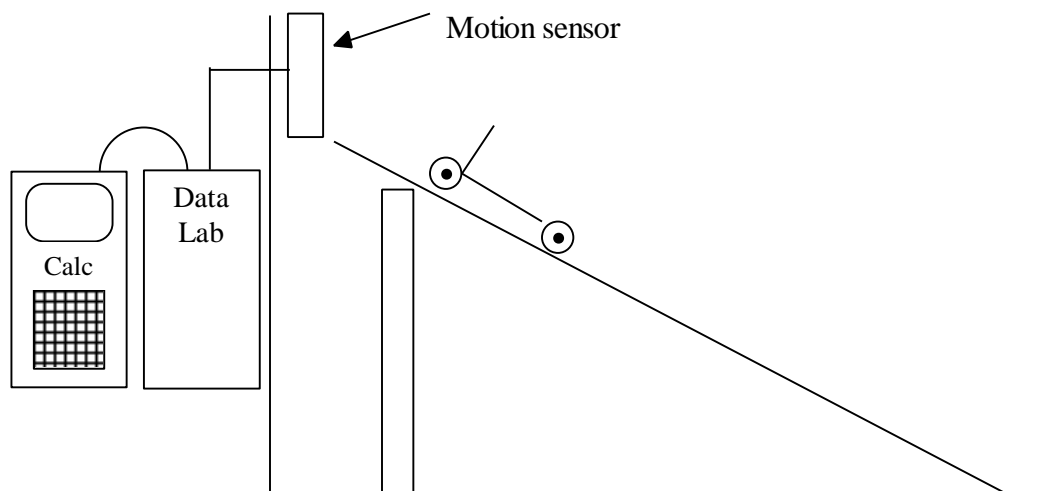
1. Connect the motion sensor to the DataLab.

2. Connect the DataLab to the graphing calculator.

3. Set up experiment to collect displacement data in calculator.

4. Construct the ramp using the board and block.

Experiment Procedure

1. Roll the car down the ramp and record its displacement every 0.1 second.

2. Use your DataLab and graphing calculator to complete the table below.

Time (sec)	Displacement (cm)	Time (sec)	Displacement (cm)
0		1.0	
0.1		1.1	
0.2		1.2	
0.3		1.3	
0.4		1.4	
0.5		1.5	
0.6		1.6	
0.7		1.7	
0.8		1.8	
0.9		1.9	

From your table sketch the resulting graph on the axes below.

Displacement

```
250 ┤
    │
200 ┤
    │
150 ┤
    │
100 ┤
    │
 50 ┤
    │
    └────┬──────┬──────┬──────┬──────┬──→ Time
        0.5    1.0    1.5    2.0    2.5
```

Analysis and Interpretation

1. Consider the shape of the graph and state the nature of the function(s) this graph could represent. It may be necessary to delete some of the data at the beginning when the object was being released and at the end when it had stopped.

2. The data could be modeled by a quadratic function where $s = At^2 + Bt + C$. Fit a quadratic function to the data.

3. Explain what C represents.

4. This quadratic function links displacement and time, that is $s = f(t)$. How do we find an equation that links velocity and time? What is this equation?

5. The function obtained in question 4 links velocity with time, is linear and of the form $v = 2At + B$. What does B represent?

6. Why is the initial velocity not zero?

7. How is acceleration found from the equation linking velocity and time? Find an expression for the acceleration.

8. What is the constant acceleration undergone by the object rolling down the incline?

9. Write an expression for displacement *(s)* in terms of the initial velocity *(u)*, acceleration *(a)*, time *(t)* and the initial displacement *(s$_0$)*.

10. If we wanted to adjust the data to have the initial velocity equal zero, what would have to be done to the data?

11. Below is a set of data that was gathered in an earlier experiment.

Time (sec)	Displacement (cm)	Time (sec)	Displacement (cm)
0	79.58	1.0	118.27
0.1	79.62	1.1	125.81
0.2	81.21	1.2	133.28
0.3	84.17	1.3	141.35
0.4	86.87	1.4	150.31
0.5	90.57	1.5	159.81
0.6	94.83	1.6	170.58
0.7	99.67	1.7	180.79
0.8	105.26	1.8	191.53
0.9	111.73	1.9	203.31

Use this data to work through the earlier questions and determine the constant acceleration undergone by the object.

Date: _____   Name: _____

Weight Swings
(Pendulum)

Introduction

A pendulum at rest exerts a normal force equal to its weight. When a pendulum is in motion, the normal force varies with the swing of the pendulum. In this experiment, you will investigate the normal force as a function of time, the angle the pendulum travels through, and the length of the pendulum.

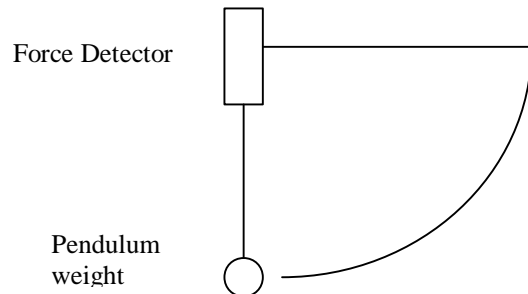## Equipment Required

1 Portable DataLab

1 Vernier force detector, with stand

1 graphing calculator, with DataLab Companion software, cable and instructions

1 pendulum: a 50-cm string with a 50-gm weight

1 protractor

Experiment Setup

1. Attach the force detector to the stand at a height of 60 cm.

2. Attach the free end of the pendulum string to the force detector.

3. Connect the force detector to the DataLab.

4. Connect the DataLab to the calculator.

5. Set up experiment to collect force data in calculator.
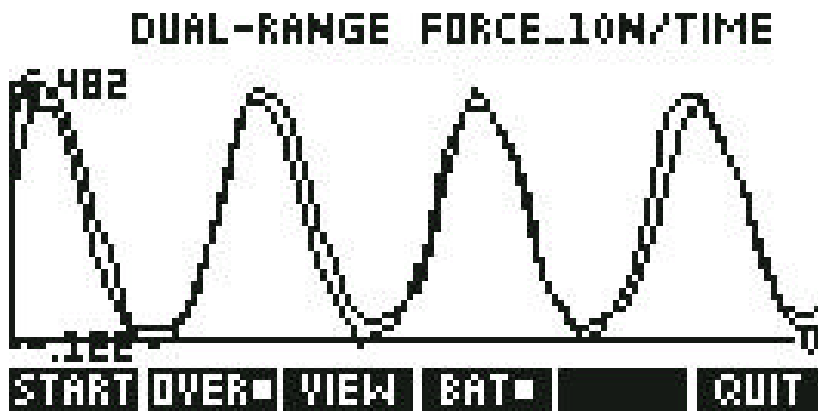
Experiment Procedure

1. Start with a pendulum swing of 60 degrees, 30 degrees from vertical.

2. The program should be set to take at least 50 readings at .05 second intervals.

3. Run the program to collect the data as the pendulum is swinging.

Sample Data

```
DUAL-RANGE FORCE_10N/TIME
```
5.482

.122

```
START NEW□ VIEW BAT□        QUIT
```
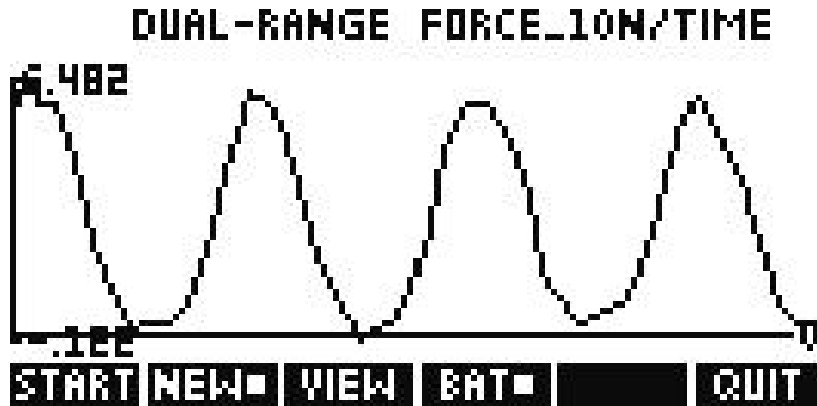
The graph of the data suggests a periodic function.

```
DUAL-RANGE FORCE_10N/TIME
```
5.482

.122

```
START OVER□ VIEW BAT□        QUIT
```

The function that describes the data is f(x) = .3 + .5cos(8x-.5) where x is in terms of radians.

Analysis and Interpretation

1. Where in the swing does the normal force reach a minimum?

2. Where in the swing does the normal force reach a maximum?

3. Define a function that matches the data.

4. Develop a table that shows the magnitude of the normal force relative to the angle of the pendulum throughout the swing phase of the pendulum.

5. Develop a table that shows the magnitude of the normal force at various angle positions of the pendulum throughout its swing.

Position (°) off vertical	Normal force (g)	Position (°) off vertical	Normal force (g)	Position (°) off vertical	Normal force (g)

6. What function describing the pendulum motion matches your data?

Date: _____   Name: _____

Under Pressure
(Boyle's Law)

Introduction

This experiment looks at the relationship between pressure and volume. Boyle's Law states that, at constant temperature, the volume of a given mass of gas is inversely proportional to the pressure upon the gas. Stated mathematically, Boyle's law takes the following form:

$$V = k \times \frac{1}{P}$$

Where V = volume, P = pressure and k = a constant.
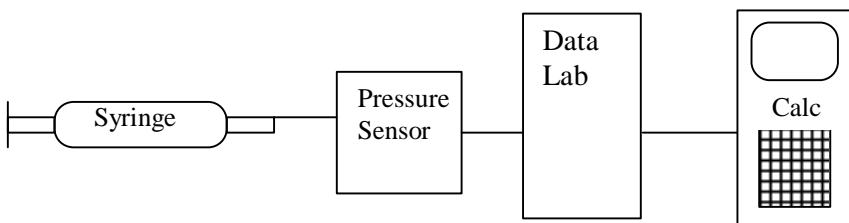
Equipment Required

1 Portable DataLab

1 Vernier pressure sensor

1 graphing calculator, with DataLab Companion software, cable and instructions

1 syringe with a capacity of 20 cc (cm^3) or greater

Experiment Setup

1. Connect the pressure sensor to the DataLab.

2. Connect the DataLab to the graphing calculator.

3. Connect the syringe to the pressure sensor.

4. Set up experiment to collect pressure data in calculator.

Experiment Procedure

1. Use your DataLab and graphing calculator to complete the table below.

Volume (cc or cm^3)	Pressure (atm)
5	
8	
10	
12	
15	
18	
20	

2. From your table sketch the resulting graph on the axes below.
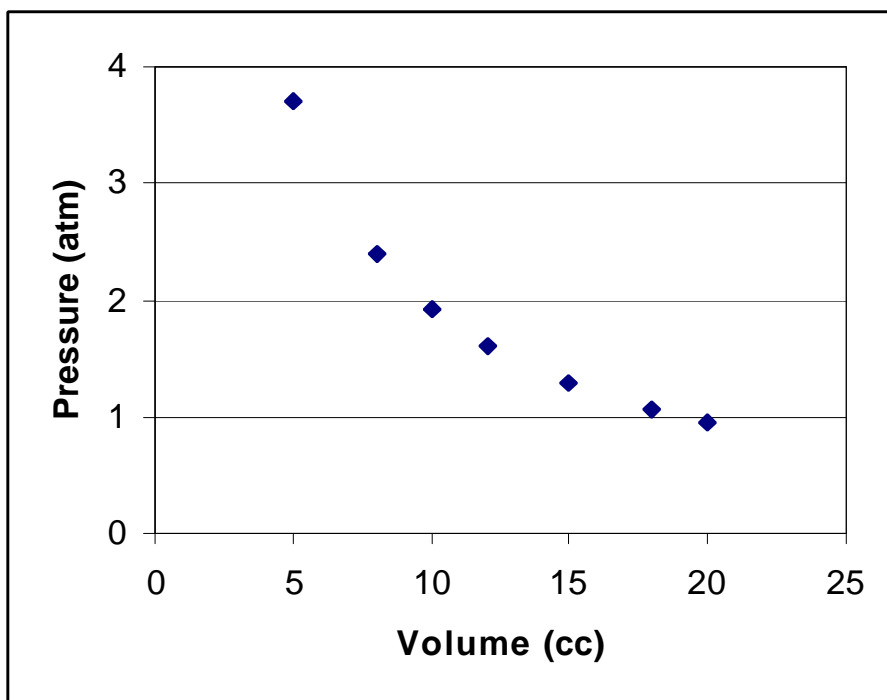
Pressure

Analysis and Interpretation

1. By consideration of the shape of the graph, state the nature of the function(s) this graph could represent.

2. Find the equation of f(x). Does it follow the pattern of Boyle's Law?

Below is a set of data and its graph that was gathered in an earlier experiment.

Volume (cc or cm^3)	5	8	10	12	15	18	20
Pressure (atm)	3.70	2.39	1.93	1.61	1.28	1.06	0.95

The derived equation is a reciprocal function

$$y = 270 \ x^{-0.985}$$

Date: _____   Name: _____

Cold as Ice

(Freezing and Melting)

Introduction

The freezing and melting temperatures of substances are defining physical characteristics. The state in which a substance exists is largely dependent on the balance between the kinetic energies of its particles and the bonding forces of its particles.

Kinetic energy tends to keep the particles moving, whereas bonding forces tend to pull them together. With decreasing temperature, particles move more slowly. If the temperature keeps decreasing, eventually the bonding forces may exceed the kinetic energies of the particles and a liquid becomes a solid (or a gas becomes a liquid). Conversely, with increasing temperature, kinetic energy may eventually exceed the bonding forces and a solid becomes a liquid (or a liquid becomes a gas).

In this experiment you will monitor the temperature of a sample of water as it is frozen and then melted. The freezing and melting temperatures of water will be determined from the collected data.
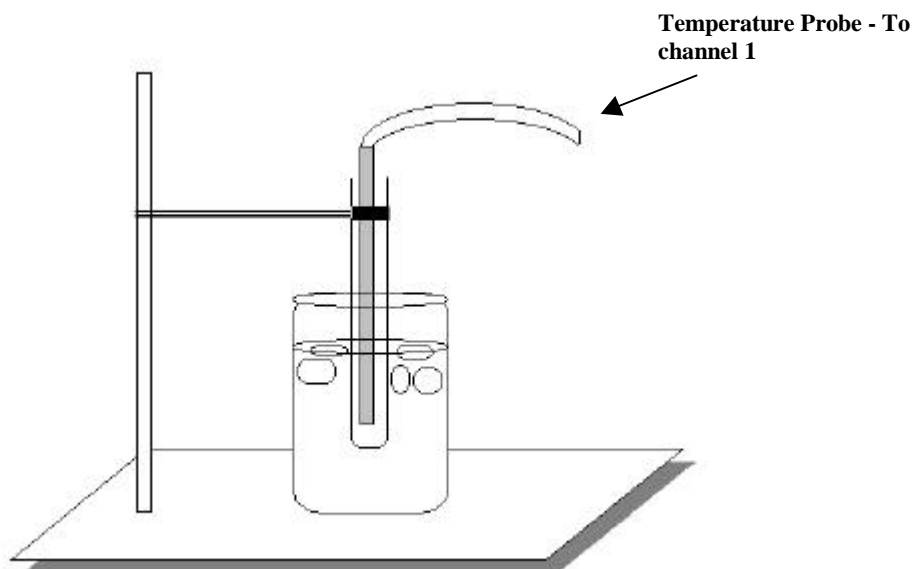
Equipment Required

    1 Portable DataLab

    1 temperature probe and cable

    1 graphing calculator, with DataLab Companion software, cable and instructions

    1 ring stand and utility clamp

    1 500 ml beaker and 1 graduated cylinder

    1 stirring rod

1 test tube

water, salt, ice

Experiment Setup

Temperature Probe - To
channel 1

1. Connect the temperature probe to the DataLab.

2. Connect the DataLab to the graphing calculator.

3. Set up experiment to collect temperature data in calculator.

Experiment Procedure

A.   Freezing Point

1. Put about 100 ml of tap water and 4-6 ice cubes into the 500 ml beaker. Place the beaker on the ring stand.

2. Using the graduated cylinder, measure 5 ml of tap water and transfer it into the test tube. Position the test tube above the beaker and clamp it onto the ring stand.

3. Place the temperature probe in the test tube so that its tip is in the water. Then connect the temperature probe to the DataLab.

4. Load the DataLab Companion software and turn on the DataLab. Immediately lower the test tube into the ice bath.

5. Record the temperature of the water in the test tube every 10 seconds for 15 minutes (90 readings).

6. Right after lowering the test tube into the beaker, add 4-5 spoons of salt to the beaker and mix with the stirring rod.

7. Continue stirring during the data collection and replace any melted ice with fresh cubes. After about 10 minutes, the water in the test tube should begin to freeze. At this point, do not move the temperature probe; allow it to freeze in the ice.

8. View the plot of temperature vs. time on the graphing calculator. The region on the plot that is flat is the freezing temperature of the water. Record this value.

B. Melting Point

1. Start the DataLab again and begin collecting data.

2. Immediately raise the test tube up out of the beaker and re-secure it to the ring stand.

3. Pour out the saltwater mixture from the beaker and replace with 300 ml of warm tap water. After 72 records have been collected (12 minutes have passed), lower the test tube into the beaker containing the warm water. Continue to collect data for another 36 minutes.

4. View the plot of temperature vs. time on the graphing calculator. The region on the plot that is flat is the melting temperature of the water. Record this value.

Analysis and Interpretation

1. The freezing point of the water was _____ °C.

   The melting point of the water was _____ °C.

2. Explain the relationship between the freezing point and the melting point values.

3. Why do you think this relationship exists?

Date: _____   Name: _____

Is There a Warming Model?

(Rate of Warming)

Introduction

Most of us have heard of Newton's Law of Cooling, but is there a Newton's Law of Warming? In this experiment we are going to measure the rate of warming of cooled water which is contained in a polystyrene calorimeter.

During the experiment the room temperature needs to be monitored and if possible this should be maintained at a constant temperature.
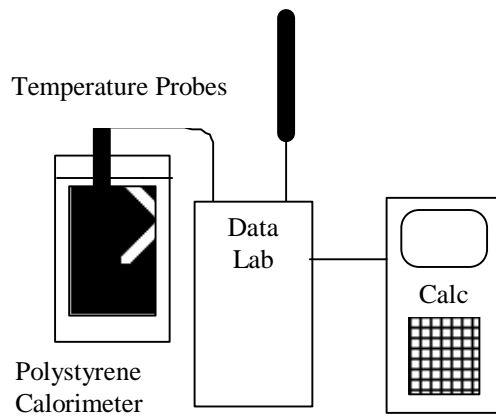
Equipment Required

1 Portable DataLab

2 temperature probes

1 graphing calculator, with DataLab Companion software, cable and instructions

1 polystyrene calorimeter

ice water

Experiment Setup

Temperature Probes

Data Lab

Calc

Polystyrene Calorimeter

1. Connect the two temperature probes to the DataLab.

2. Connect the DataLab to the graphing calculator.

3. Set up experiment to collect temperature data in calculator.

4. Fill the calorimeter with ice water and place one of the temperature probes in it.

Experiment Procedure

1. Record the room temperature.

2. Use your DataLab and graphing calculator to complete the table below for the temperature in the calorimeter.

Time (min)	Temperature (°C)	Time (min)	Temperature (°C)
0		65	
5		70	
10		75	
15		80	
20		85	
25		90	
30		95	
35		100	
40		105	
45		110	
50		115	
55		120	
60		125	

3. From your table sketch the resulting graph on the axes below:

Temperature

30 ┤

25 ┤

20 ┤

15 ┤

10 ┤

5 ┤

→ *Time*

5
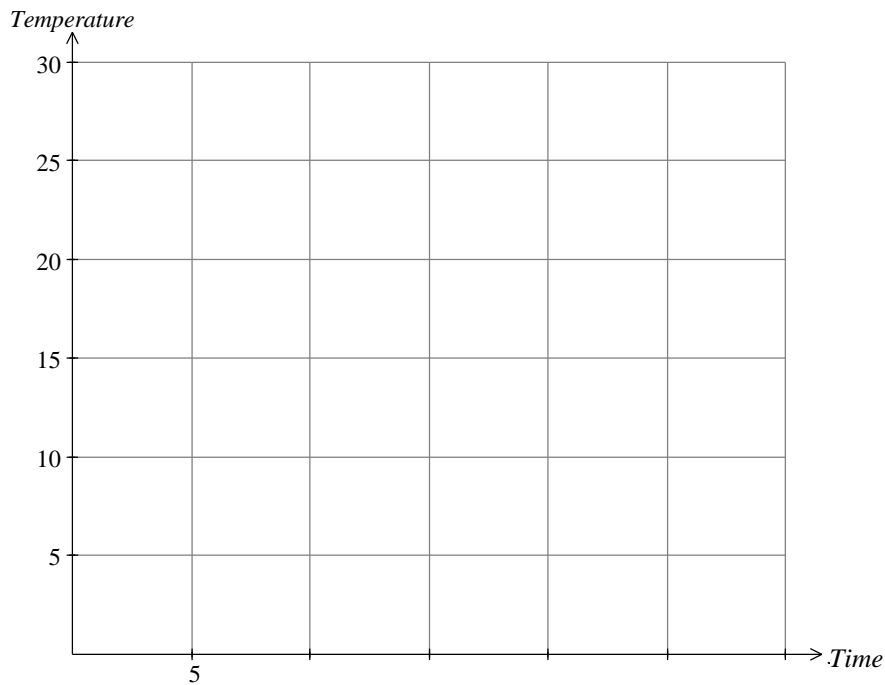
Analysis and Intrepretation

1. By consideration of the shape of the graph, state the nature of the function(s) this graph could represent.

2. If we let the function be represented by f (x) what transformation would we need to make to match the rate of cooling function?

3. Find the equation of f (x) and state whether it follows the pattern associated with Newton's Law of Cooling.

4. Below is a set of data and its graph that was gathered in an earlier experiment

Time (min)	Water Temp(C)	Time (min)	Water Temp(C)
0	4.4	73	13
5	4.9	78	13.8
10	5.4	83	13.9
15	6.3	87	14.4
19	6.8	92	15.1
24	7.8	97	15.3
29	8.4	102	15.4
34	9.2	107	15.8
39	9.5	112	16.6
44	10.1	117	16.5
49	10.4	121	17.1
53	11.3	126	17.2
58	11.7	131	17.8
63	12.3	136	18.2
68	12.3		
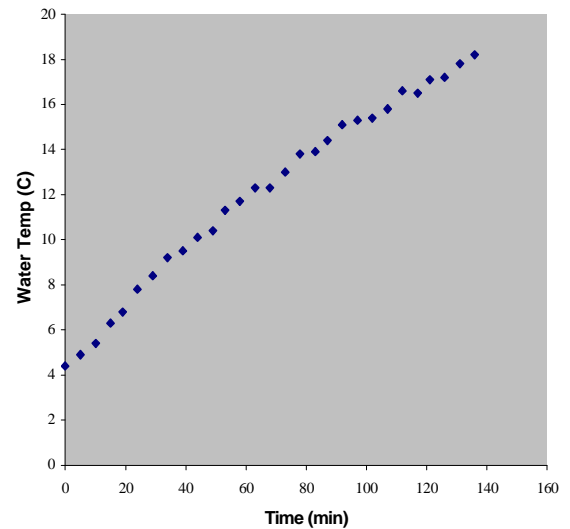
We then considered a transformation of this graph which will enable us to use the in-built function $y = ae^{kx}$ of the graphics calculator.

Let the warming function be f (x) then the transformed equation will be room temperature (28) minus f (x). I.e., g (x) = 28 – f(x).

Transform the data and find the function that best fits the transformed data.

Date: _____   Name: _____

pHun with pH

Introduction

The measure of a solution's acidity or basicity (alkalinity) is its pH. A pH value indicates the concentration of hydrogen ions in the solution. Since the concentrations of hydrogen ions in most solutions are often very small numbers, a more convenient way for expressing pH (that does not involve using very small numbers) has been devised. The expression used is defined below:

$$pH = -\log[H^+] = \log \frac{1}{[H^+]}$$ Where [H$^+$] is the hydrogen ion concentration.

The log transformation of the hydrogen ion concentration results in a pH scale that ranges for most solutions from 1 to 14. Solutions with a pH of less than 7 are considered acidic and solutions with a pH of greater than 7 are considered basic. A pH value of 7 is considered neutral. In this experiment you will evaluate the pH for a number of solutions.

Equipment Required

1 Portable DataLab

1 Vernier pH sensor

1 graphing calculator, with DataLab Companion software, cable and instructions

1/2 cup each of a variety of fluids (tap water, distilled water, lemon juice, etc.)

1 250 ml beaker

1 stir plate and 1 magnetic stir bar (optional)

Experiment Setup

pH sensor

To channel 1

Stir plate
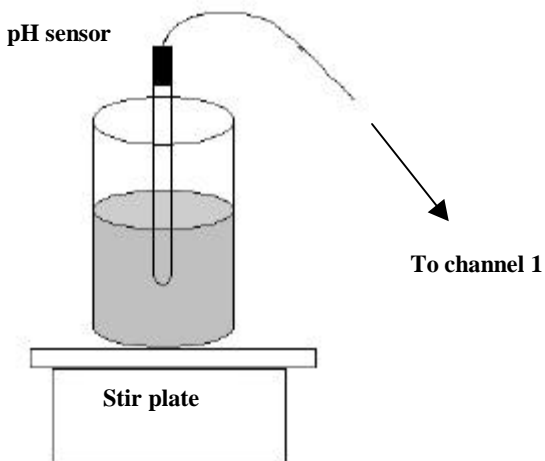
1. Connect the pH sensor to channel 1 on the DataLab.

2. Connect the graphing calculator to the Portable DataLab.

3. Set up experiment to collect pH data in calculator.

Experiment Procedure

1. Calibrate the pH sensor.

2. Pour about one-half cup of one of the liquids into the beaker.

3. Place the pH sensor in the liquid and record the pH.

4. Repeat measurement for a variety of different liquids (rinse the beaker with tap water in between measurements).

5. Measure the pH of a mixture of two of the liquids (use equal volumes of each liquid).

Name of liquid	pH

Analysis and Interpretation

1. Which liquid was most acidic?

2. Which was most basic?

3. Explain what happened to the pH in the mixture.

Date: _____   Name: _____

Pressure Cooker

(Pressure and Temperature)

Introduction

As a gas is heated, it expands, and as it is cooled it contracts. For example, a balloon that is left in direct sunlight for a long time may burst. Why does this happen? As the temperature rises, the air in the balloon expands. Eventually, its maximum volume is reached, and as the temperature keeps increasing, the increasing pressure causes it to burst. In this experiment you will investigate the relationship between pressure and temperature.

Equipment Required

1 Portable DataLab

1 Vernier Pressure sensor

1 temperature probe and cable

1 graphing calculator, with DataLab Companion software, cable and instructions

2 one-liter beakers

ice

a source of near boiling water

1 conical flask with a one-hole stopper fitted with a glass tube leading to plastic tubing of a suitable size to attach to the pressure sensor

Experiment Setup

1. Connect the cables from the temperature and pressure probes to channels 1 and 2 on the DataLab.

2. Connect the graphing calculator to the DataLab.

3. Set up experiment to collect temperature and pressure data in calculator.

4. Fully open the relief valve on the pressure sensor to equalize pressures. Now close the valve fully and re-open it one complete turn counterclockwise. This will open the side valve which connects to the pressure sensor.

Experiment Procedure

Place the ice into one of the beakers and fill it with about 500 ml cool tap water. Put this
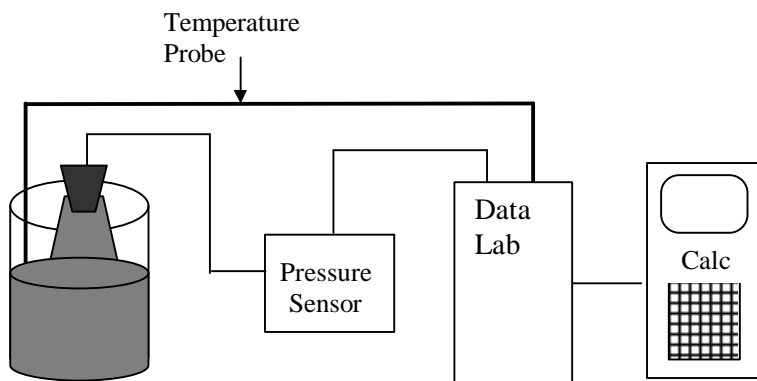
beaker aside to allow the ice to melt and the temperature to stabilize.

1. Lower the conical flask into the beaker that does not contain ice water and place the temperature probe in this beaker. Fill the beaker about two-thirds full with near boiling water. When the pressure and temperature values for this beaker seem to be stable, save a pair of pressure/temperature readings.

2. Empty about half of the near boiling water from the beaker and replace it with tap water. Wait again while the pressure and temperature readings stabilize and then save another data pair.

3. Empty the beaker completely and refill it with tap water. Wait again while the pressure and temperature readings stabilize and then save another data pair.

4. Now place the flask into the beaker that you previously filled one-half full with ice water. Wait again while the pressure and temperature readings stabilize and then collect a data pair.

5. Stop recording and turn off the DataLab.

6. Obtain a plot on the graphing calculator of the pressure and temperature values that you collected. You should notice a linear relationship.

7. Convert the temperature values that you collected from Celsius to Kelvin by adding 273 to them. Look at the plot again.

Analysis and Interpretation

1. For each of the pressure/temperature data pairs, calculate a value for pressure divided by temperature by filling in the table below.

Type of Water	Pressure/Temperature
boiling water	
half boiling water/half tap water	
tap water	
ice water	

2. What do you notice about the pressure/temperature values that you calculated above?

3.   Predict what the pressure will be when the temperature is 200 K.

4.   Describe the relationship between pressure and temperature