Datalogging for Physics
Short course

Datalogging With LabQuest
And Computers

Introduction

There are three essential elements in a data logging system

1. A sensor to interact with the environment.

2. A LabQuest (LabQuest) to collect and store the information.

A data logging approach may be used to perform many of the listed physics experiments in the revised syllabus. While it is very suited to mechanics and electrical experiments, a conventional approach may be more appropriate in some of the other areas.

Experiments/demonstrations where many data points must be collected over very short time intervals are ideally suited to a datalogging approach. This feature is well illustrated in the electromagnetic induction and the light sensor demonstrations.

Note

The equipment being used in the in-service meets the requirements of Circular 53/2000. Whilst the supporting handout material used during the in-service was specifically written with this equipment in mind to optimise the usefulness of the handouts during the in-service day, the general principles and much of the processes involved are common and can be applied across other datalogging systems.

LEAVING CERTIFICATE PHYSICS

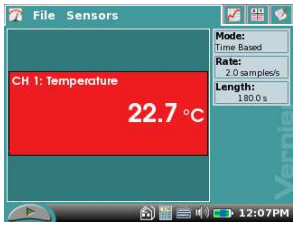
DATALOGGING EXPERIMENTS AND DEMONSTRATIONS

Contents

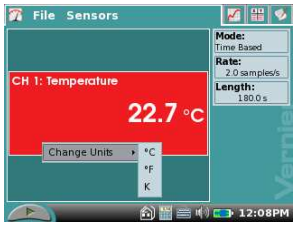
USING LABQUEST AS A METER

LabQuest may be used as a stand-alone meter, e.g. to measure temperature. This may be done by connecting the appropriate probe and starting the LabQuest app.

1. Connect the probe to LabQuest.
2. Turn LabQuest on.
3. LabQuest will automatically identify the sensor and display the current readings at the top of the screen.



4. To change the measurement units, tap the meter. A menu is displayed showing the possible units for the connected sensor. Select the unit that you want LabQuest to use.
5. Select Quit from the File menu to quit LabQuest.



MEASUREMENT OF TEMPERATURE USING LABQUEST

Apparatus

Temperature sensor and LabQuest.

Arrangement

1. Attach the temperature sensor to the CH1 input of the LabQuest.
2. Turn LabQuest on.

Procedure

1. Tap the Home icon to display the list of available applications, and then select LabQuest.
2. On the main LabQuest menu the time graph setting is set at a default value of 180 s. This refers to the experiment length in seconds.
3. Tap the Start icon. Data points appear on the display.
4. Tap the Start icon to interrupt the sampling. LabQuest displays a graph of temperature versus time.

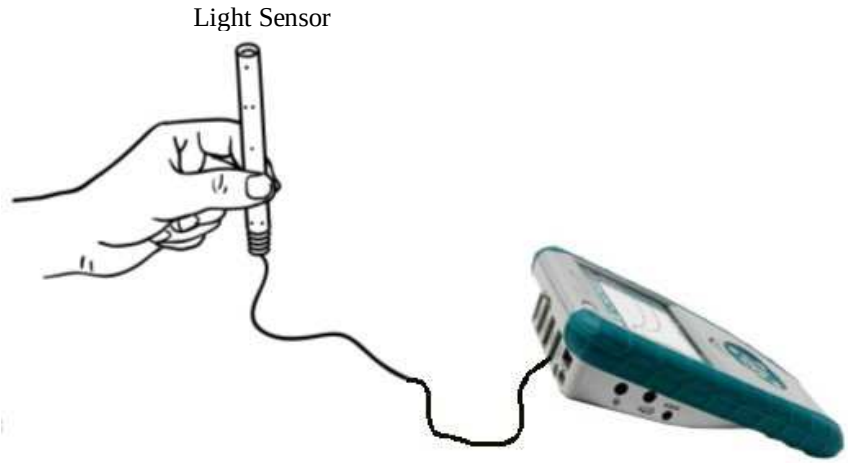
To Alter the Sampling Rate and the Length of the Experiment

1. Connect the probe to LabQuest.
2. Turn LabQuest on.
3. Tap the Home icon to display the list of available applications, and then select LabQuest.
4. Under the Sensors menu, select Data Collection. You can also tap the Rate box.
5. Tap inside the Rate field and enter 1.
6. Tap inside the Length field and enter 30.
7. Tap OK.
8. Tap the Start icon and the sampling will begin. This time the sampling will finish after 30 seconds and automatically rescale the graph to display the data.

MEASUREMENT OF THE FREQUENCY OF THE MAINS USING THE LIGHT SENSOR

Apparatus

Electric light source, light sensor, and LabQuest.

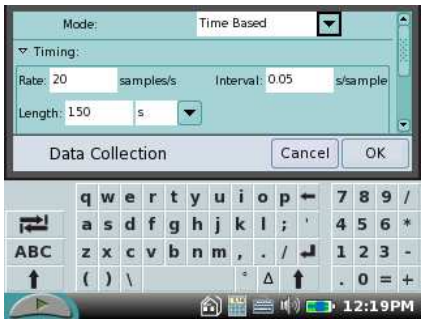


Arrangement

1. Connect the light sensor to the CH1 input of the LabQuest.
2. Turn LabQuest ON.

Procedure

1. Tap the Home icon to display the list of available applications, and then select LabQuest.
2. Under the Sensors menu, select Data Collection.
3. Tap inside the Interval field and enter 0.05.
4. Tap inside the Length field and enter 150.
5. Tap OK.
6. Rest the light sensor on the table or point it towards some light source- it should not be too close.



7. Tap the Start icon and the sampling will begin.
8. A graph of light intensity against time appears on screen when the chosen experiment time has elapsed.

Sample Analysis

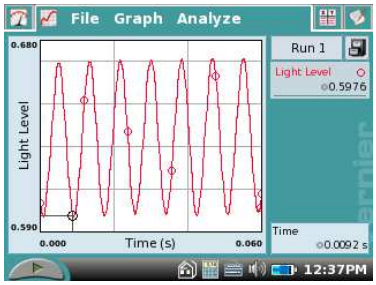


Fig. A

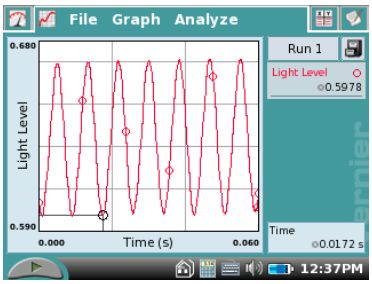


Fig. B

1. In the graph of light intensity against time (Fig. A), notice the cursor at X =0.0092 (base of first trough), where X in this situation represents the time axis.
2. Tap the point at where one loop of the graph has been traversed and the cursor has reached the point X = 0.0172 (base of second trough) shown in Fig. B.

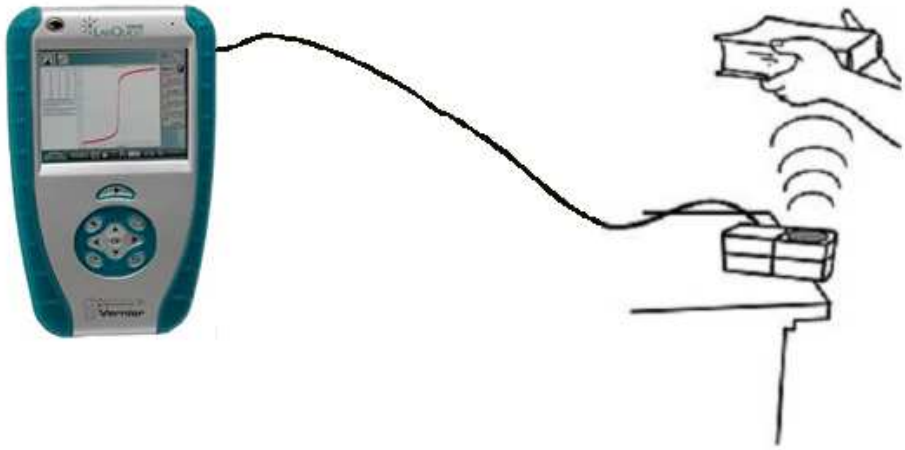
The time to complete one full cycle is (0.0172 - 0.0092) = 0.008 s.

Since $f = \frac{1}{T}$ it follows that the mains frequency is $\frac{1}{0.008}$ = 125 Hz. (The data was collected with a light source is North America.)

USING THE MOTION SENSOR WITH THE LABQUEST APP

Apparatus

Motion sensor, LabQuest, and card or book.



Arrangement

1. Connect the motion sensor to DIG 1 port of the LabQuest.
2. Turn LabQuest ON.
3. Tap the Home icon to display the list of available applications, and then select LabQuest.

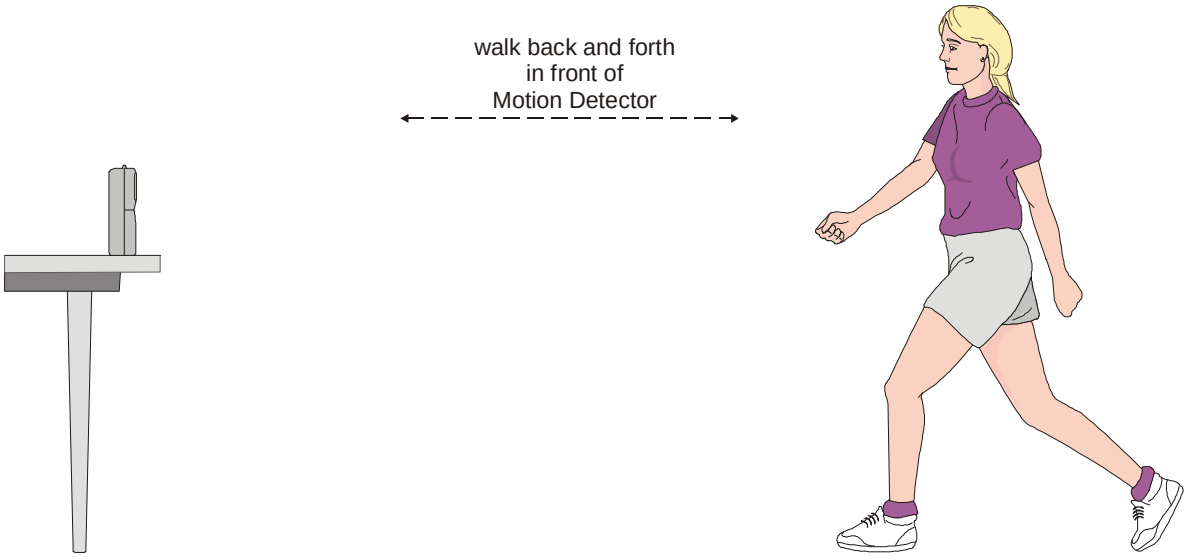
Procedure

1. Hold a piece of card 0.5m above the motion sensor – the distance from the sensor appears in the middle of the screen.
2. Tap the Start icon.
3. Move the card up and down while the data is being collected.
4. The graphs of distance and velocity versus time appears.
5. Repeat this procedure for other motions.

GRAPH MATCHING USING THE GRAPHIC LabQuest App

Apparatus

Motion sensor, LabQuest, and reflective surface.



Arrangement

1. Connect the motion sensor to DIG 1 port of the LabQuest.
2. Turn LabQuest ON.
3. Tap graph icon at the top of the screen
4. Select Motion Match ► New Position Match from the Analyze menu.

Procedure

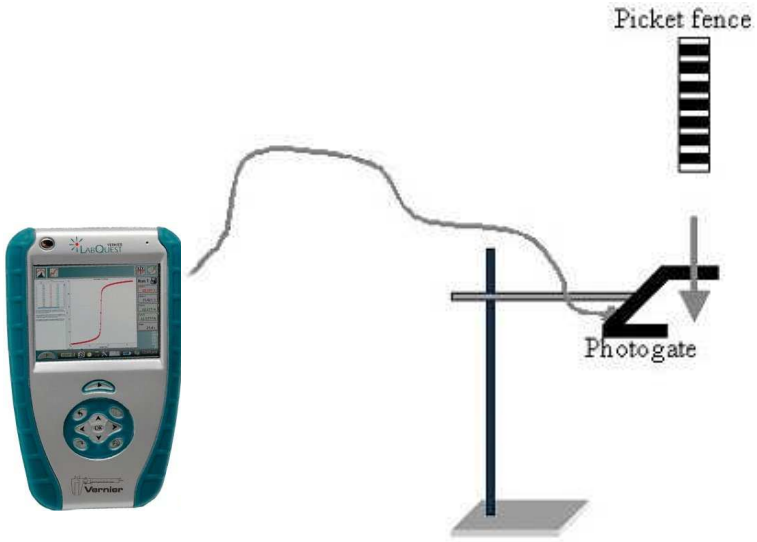
1. Tap the start icon. Move as you think is necessary to match the graph that appears on the screen.
2. A line appears on the graph.
3. Select Start and try to match the graph.
4. When data collection is complete, you have the option to try to repeat the same graph (by tapping the start icon) or matching a new graph (by selecting Motion Match ► New Position Match from the Analyze menu).

If you are feeling more confident you could select New Velocity Match and try a velocity match graph.

MEASUREMENT OF THE ACCELERATION DUE TO GRAVITY USING THE LabQuest App

Apparatus

Picket fence, retort stand with clamp, photogate, and LabQuest.



LabQuest

Arrangement

1. Clamp the photogate rigidly to a retort stand so the arms extend horizontally, as shown above. To avoid damaging the picket fence, make sure it has a soft landing surface.
2. Connect the Motion Detector to DIG/SONIC port of the LabQuest.
3. Turn LabQuest on.
4. Tap the start icon.

Procedure

1. Hold the top of the Picket Fence and drop it vertically through the photogate.
2. Examine the velocity *vs.* time (bottom) graph (Fig.1).
   - Select Curve Fit ▶ Velocity from the Analyze menu.
   - Select Linear from the Fit Equation field.

   The screen now shows the equation of the line y = mx + b (Fig.2).
   - Record the slope.
   - Tap OK to return to the graph screen.
3. Repeat procedure steps 1, 2 and 3 five more times to get average for g.

Sample Results

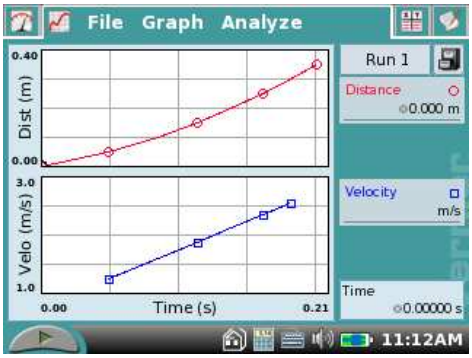


Fig. 1

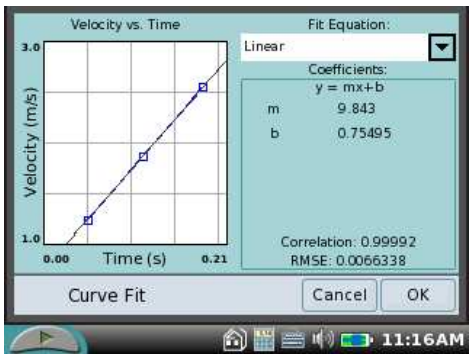


Fig 2

The slope of the velocity versus time graph, i.e. **m** as given on the screen, is a measure of acceleration due to gravity.

In this case the value of g is found from the graph to be 9.843 m/s^2.

TO OBSERVE HARMONICS AND THE QUALITY OF A MUSICAL NOTE

Apparatus

LabQuest, microphone sensor, computer, tuning forks and musical instrument.

LabQuest

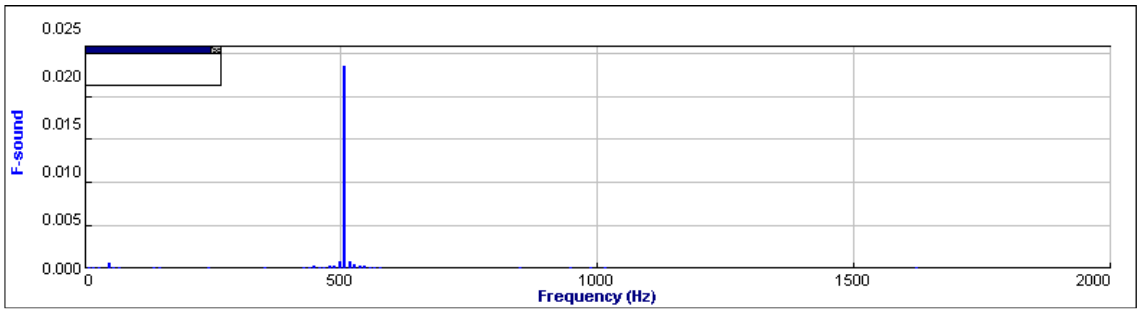
Arrangement

1. Connect the microphone to CH1 of LabQuest.
2. Connect LabQuest to the computer.
3. Start LabQuest *Pro* program.
4. Select Open from the File menu.
5. In the pop-up window, double click on Physics with Vernier.
6. Double click on Exp 35 Mathematics of Music.
7. Two graph windows appear.
8. Maximise the lower (FFT Graph) window.

Procedure

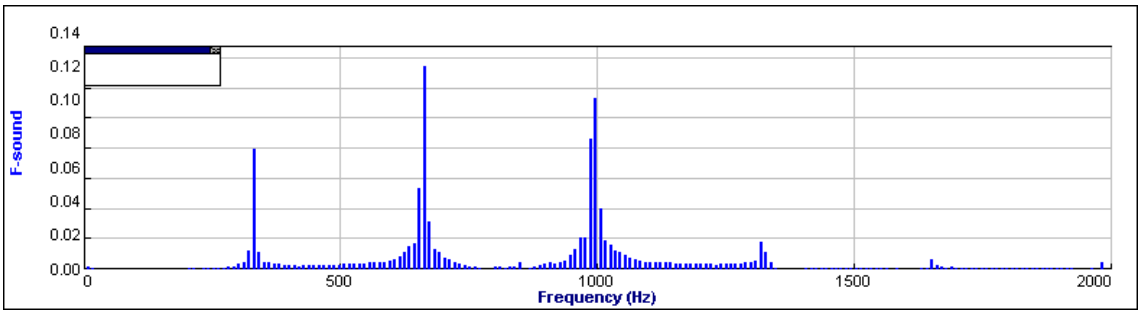
1. Hold a vibrating tuning fork in front of the microphone.
2. Click on  .
3. Observe the pattern on the screen.

The FFT (Fast Fourier Transform) graph shows the frequency or frequencies produced by the tuning fork.

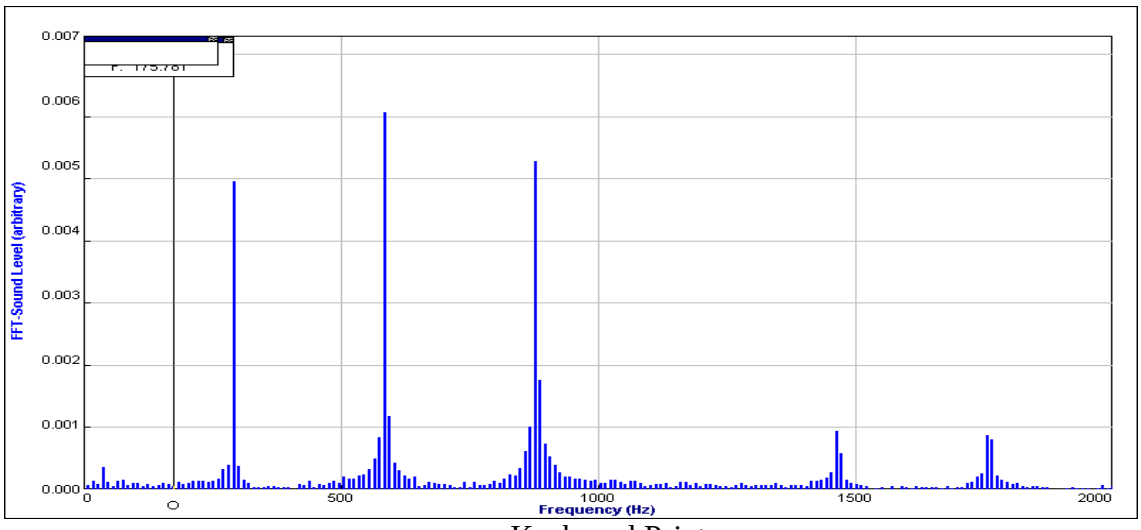


This arrangement with the FFT facility can be used to examine the range of frequencies produced by the human voice or any musical instrument. It is useful when discussing harmonics, overtones, quality, etc.

The panels below show a note produced by the human voice and by a keyboard. Observe the harmonics. The frequencies of the harmonics can be found by clicking on Analyse (on toolbar) and using the Examine function.



Human Voice Print



Keyboard Print

TO OBSERVE THE INTERFERENCE OF SOUND WAVES

Apparatus

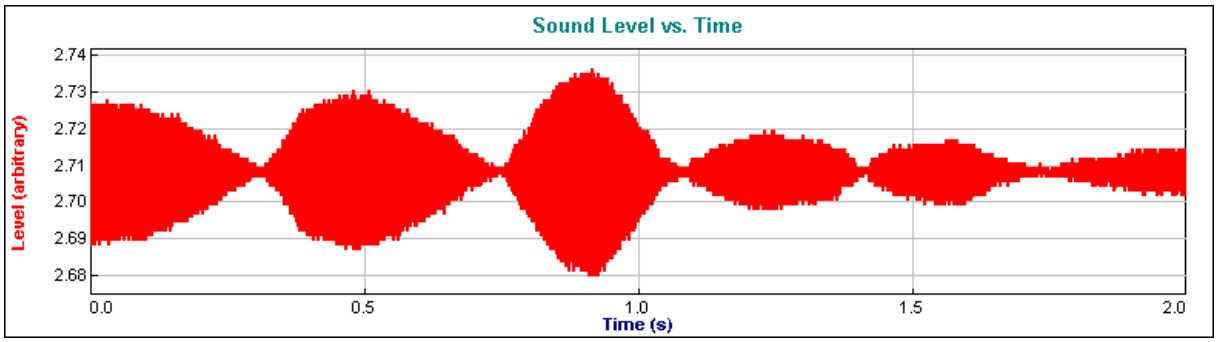
LabQuest, microphone sensor, computer and tuning fork.

Arrangement

1. Connect the microphone to CH1 of LabQuest.
2. Connect LabQuest to the computer.
3. Start LabQuest *Pro* program.
4. Select Open from the File menu.
5. In the pop-up window, double click on Physics with Vernier.
6. Double click on Expt 35 Mathematics of Music.
7. Two graph windows appear.
8. Click on Data Collection (on toolbar).
9. Set Experiment Length at 2s.
   Set Sampling Speed at 2000 samples per second.
10. Click Done.

Procedure

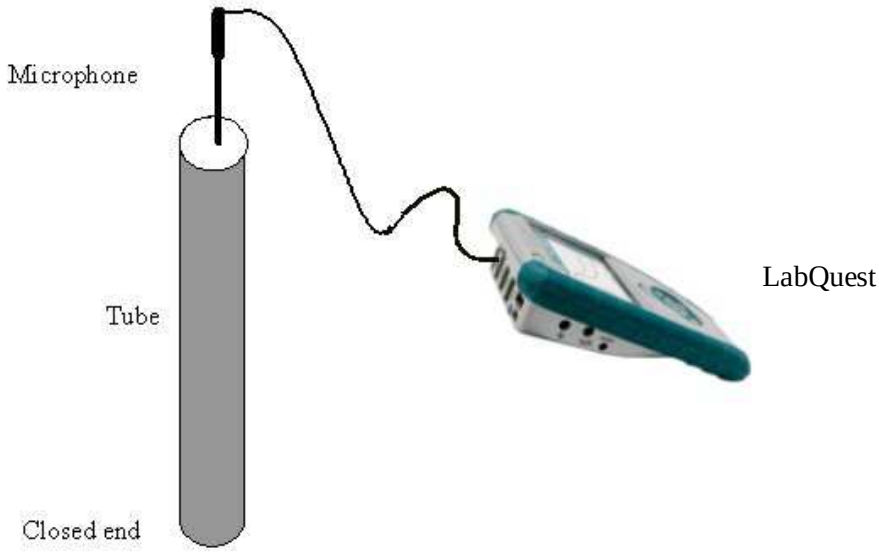
1. Hold a vibrating tuning fork in front of the microphone and rotate it.
2. Click on  while the tuning fork is rotating.
3. Observe the pattern on the screen.



MEASUREMENT OF THE SPEED OF SOUND IN AIR USING THE LabQuest App

Apparatus

Cardboard or plastic tube, microphone and LabQuest.

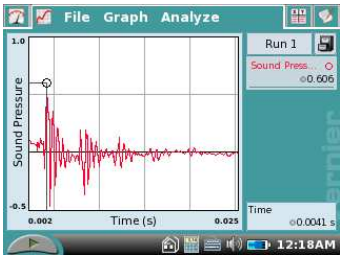


Arrangement

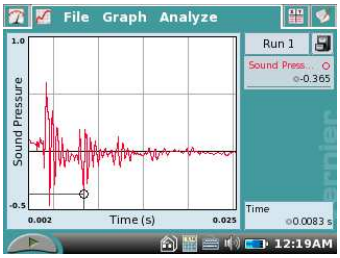
1. Close one end of the tube with e.g. packing tape.
2. Place the microphone as close to the open end as possible.
3. Attach the microphone to the CH1 input of the LabQuest.
4. Connect the motion sensor to DIG 1 port of the LabQuest.
5. Turn LabQuest on.
6. Tap the Home icon to display the list of available applications, and then select LabQuest.
7. Select Data Collection from the Sensors menu.
8. Tap on Triggering.
9. Check the box next to Enable Triggering.
10. Select increasing and enter 0.1.
11. Enter 0 in the points before trigger field.
12. Tap OK to return to the main screen.

Procedure

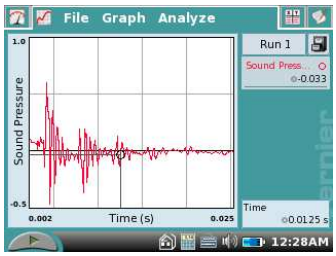
1. Tap the start button to enable data collection.
2. Near to the open end of the tube, either snap your fingers or gently hit two sticks together. This sharp sound triggers data collection.
3. A graph such as that shown is generated. The peaks represent the sharp sound and its reflections.
4. Move the cursor to the first peak and note its time value. In the example shown the value is 0.0041.



5. Move the cursor to first reflection of this peak and note its time value. **Note:** if the first peak is above the axis its reflection will be below the axis, and vice versa. This is because waves change phase when reflected at the open end of the tube. The value in the example shown is 0.0083.



6. Move the cursor to the next reflection and note its time value. The value in the example shown is .0125.



Data Manipulation and Analysis

The time interval between a peak and its reflection represents the time taken for the sound pulse to travel up and down the tube. The intervals in this example are both .0042 s.
The length of the tube is 71 cm, thus the distance travelled by the pulse between reflections is 1.42 m.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

This gives a value for the speed of sound of 338 m s^{-1}.

VERIFICATION OF BOYLE'S LAW USING THE LabQuest App

Apparatus

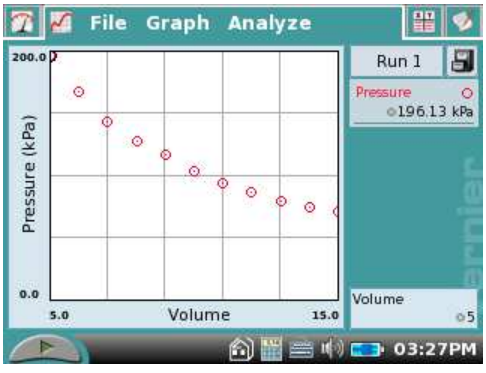
Gas Pressure Sensor and LabQuest

Arrangement

1. Set the syringe to 10 cm^3 and attach by screwing onto the Gas Pressure Sensor.
2. Attach the Gas Pressure Sensor to CH1 of the LabQuest.
3. Turn LabQuest on.
4. Tap the Home icon to display the list of available applications, and then select LabQuest.
5. Select Data Collection from the Sensors menu.
6. Select Events with Entry from the Mode pop-up menu.
7. Enter "Volume" in the Name field and "V" in the Units field.
8. Tap OK.

Procedure

1. Pull out the syringe to 15 cm^3. Tap the start icon to prepare for data collection. Data will be collected only when you later tap Keep.
2. Wait for the value displayed on LabQuest to stabilize. Tap Keep and record the volume, 15. Tap OK to conclude your entry.
3. Release the syringe and hold at 14 cm^3 and repeat Step 2, this time record 14 for the volume.
4. Continue adjusting the syringe in 1 cm^3 decrements until the volume of air is 5 cm^3, collecting data as before. After the final data point has been taken, tap the Stop icon to end data collection.
5. A graph of Pressure *vs.* Volume has been generated on the screen, as shown.



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Data Manipulation and Analysis Using the LabQuest App

To view data

Tap the Table icon in the top of the screen.

The pressure and volume data appears on the screen.

Further values can be seen by scrolling down.

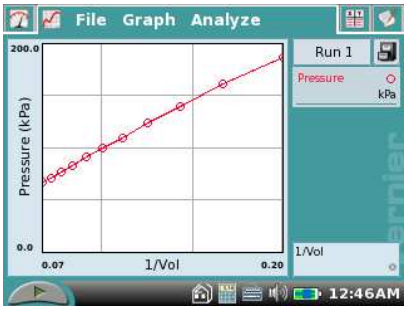
To Calculate $\frac{1}{\text{Volume}}$

- Select New Calculated Column from the Table menu.
- Enter 1/Vol in the name field.
- Select A/X from the Select Equation pop-up menu.
- Select volume from the Column for X pop-up menu.
- Enter 1 in the A: field.
- Tap the OK button.

To calculate values of PV

- Select New Calculated Column from the Table menu.
- Enter PV in the name field.
- Select XY from the Select Equation pop-up menu.
- Tap the OK button.

To Plot P against $\frac{1}{V}$



- Tap the graph icon in the top of the screen.
- Tap the label along the y-axis and select Pressure.
- Tap the label along the x-axis and select 1/Vol.

VERIFICATION OF BOYLE'S LAW USING A COMPUTER

Apparatus

Gas Pressure Sensor, LabQuest and computer.

Arrangement

1. Set the syringe to 10 cm^3 and attach by screwing onto the gas pressure sensor.
2. Attach the Gas Pressure Sensor to CH 1 of LabQuest.
3. Attach LabQuest to the computer.
4. Start Logger *Pro* on the computer desktop.
5. Select Open from the File menu.
6. In the pop-up window, double click on the folder Chemistry with Vernier.
7. In the new window scroll right and double click on Boyle's Law. .
8. The Graph Window now has appropriate labels and the correct sampling mode has been set.

Procedure

1. With the syringe set at 15 cm^3 press Collect at the top of the screen.
2. When the Pressure reading is stable press Keep.
3. In the pop-up window, record 15 for volume and click OK .
4. Change the syringe volume to 14 cm^3 and repeat Steps 2 and 3, this time recording 14 for the volume.
5. Continue changing the syringe volume in 1cm^3 decrements down to 5 cm^3, collecting data as before.
6. After the final data point press Stop to end data collection. A graph of P against V has been generated in the Graph Window.

Data Manipulation and Analysis

To generate a graph of P against 1/V.

- Select New Calculated Column from the Data menu.
- Type 1/Volume in the Name field and 1/V in the units field.
- Type 1, then select Volume after clicking the Variables button.
- Click the Done button.
- Click on the label of the horizontal axis.
- In the window click the button 1/Volume.
- Click on Analyze in the menu bar and click on Autoscale.

To see the origin

- Select Graph Options from the Options menu.
- Click on the Axis Options tab.
- Select Autoscale from 0 from the Scaling pop-up.

To draw a line of best fit

- Click on Analyze in the menu bar.
- In the drop down menu select Linear Fit.

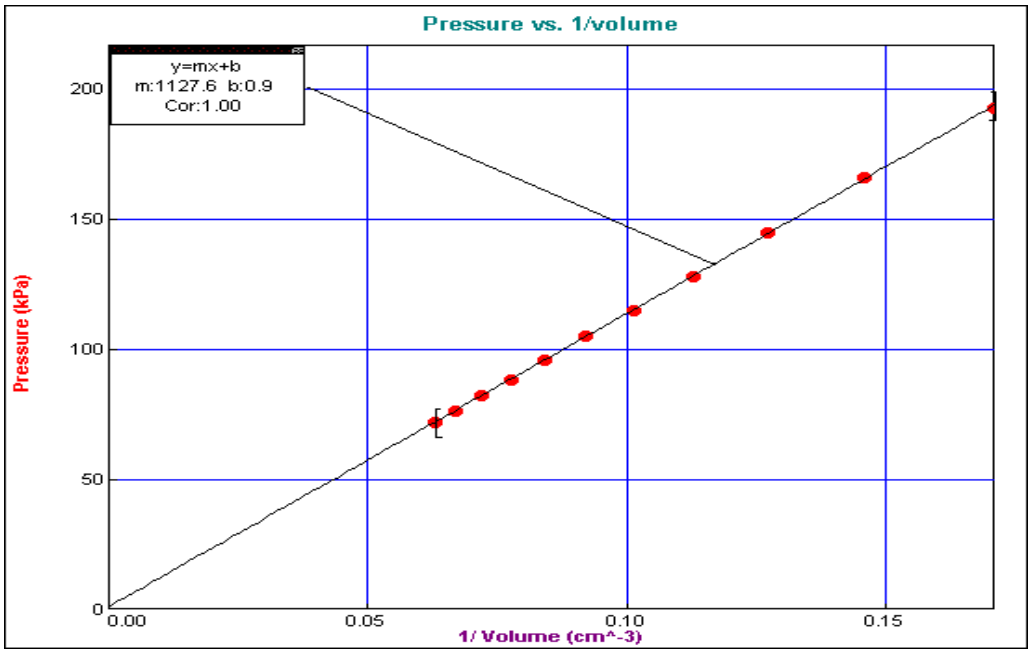
A line of best fit appears in the graph window. A floating box gives numerical details.

To view column for PV

Click on the table. To see values of PV either maximise the window, or scroll to the right.

Sample Data

Syringe(cm^3)	Pressure(kPa)	Volume(cm^3)	1/Volume(cm^{-3})	PV/kPa (cm^3)
15.00	72.00	15.70	0.06369	1130
14.00	76.66	14.70	0.06802	1126
13.00	82.33	13.70	0.07299	1127
12.00	88.57	12.70	0.07874	1124
11.00	95.72	11.70	0.08547	1119
10.00	105.5	10.70	0.09345	1128
9.000	115.3	9.700	0.1030	1118



Note

Using the supplied software (without amendments), it is found that calculated values of PV are not constant, and the graph does not go through the origin. Therefore these results do not support Boyle's law. However, the values of Volume recorded are only the volumes of air in the syringe. No allowance has been made for the air in the connection to the sensor, or in the gas pressure sensor itself. A correction of the order of 0.7 cm^3 added to each volume improves matters considerably. The true volume of air is the syringe reading added to approximately 0.7 cm^3. It is possible to create a file which allows for this, and which can be saved to provide a ready-made template for the experiment.

Setting up the software for Boyle's law with no logger attached

1. Open LabQuest program on the computer desktop.
2. In the File menu click on Open.
3. In the pop-up window, double click on the folder Chemistry with Vernier.
4. In the new window double click on Exp 06 Boyle's Law.
5. The Graph Window now has appropriate labels and the correct sampling mode has been set.

To create a column for Syringe Reading

1. Click on Data in the menu bar.
2. In the drop-down menu select Column Options, then select Volume.
3. In the pop-up window type Syringe Reading as the Name, SV for the Short Name and cm^3 for the Units.
4. Click Done.

To create a column for Volume

1. Click on Data in the menu bar.
2. In the drop-down menu select New Calculated Column.
3. Click the Column Definition tab. Type in the appropriate names: Volume, V, cm^3.
4. In the Equation field type 0.7 +.
5. Click the Variables button and select Syringe Reading and click Done.
6. The column Volume immediately appears in the data table window.

To create a column for 1/V

1. Click on Data in the menu bar.
2. In the drop-down menu select New Calculated Column.
3. Click the Column Definition tab. Type in the appropriate names: Inverse Volume, 1/V, cm^-3.
4. In the Equation field type 1/.
5. Click the Variables button and select Volume and click Done.
6. The column 1/V immediately appears in the data table window.

To create a column for PV

1. Click on Data in the menu bar.
2. From the drop down menu select New Calculated Column.
3. In the new window click on the Column Definition tab.

4. Place the cursor in the Equation field.
5. Click the Variables button and select Pressure, and type*.
6. Click the Variables button and select Volume and click Done.

To save this file

1. In the File menu click on Save As…
2. In the pop-up window Save in Physics with Computers.
3. Type in a name for the file, e.g. “Boyle’s Law Amended”.
4. Click Save.

The experiment file is now saved in the computer and can be called up when required.

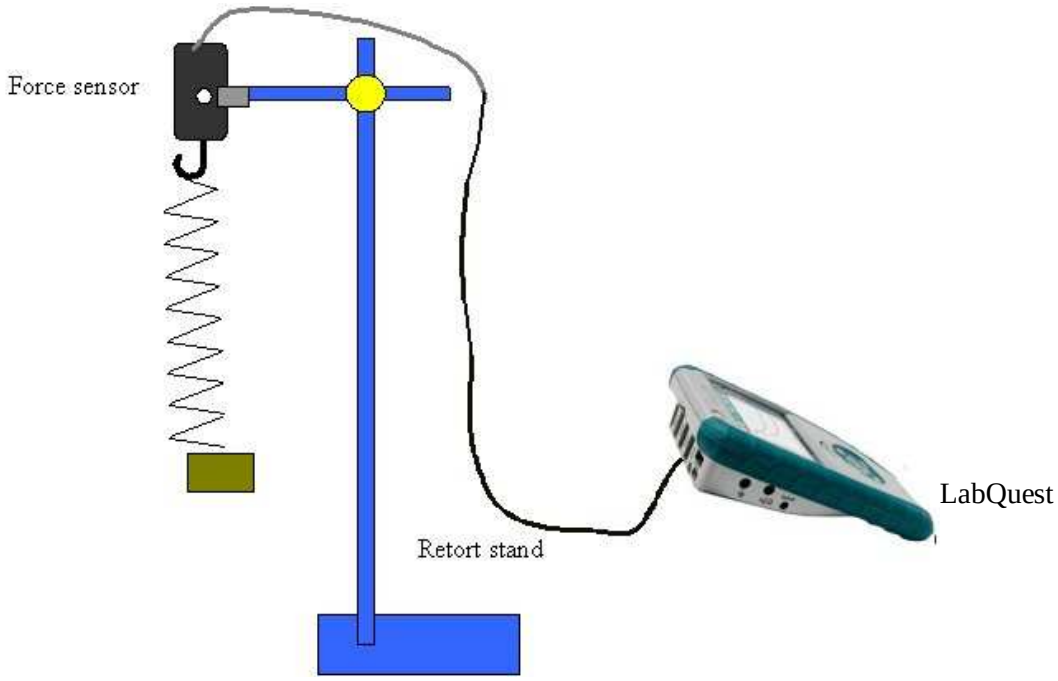
INVESTIGATING SIMPLE HARMONIC MOTION

Simple Harmonic Motion

One simple system that vibrates is a mass hanging from a spiral spring. The force applied by an ideal spring is proportional to how much it is stretched or compressed. Given this force behaviour, the up and down motion of the mass is called *simple harmonic motion* (shm).

Apparatus

Force sensor, LabQuest, spiral spring.



Procedure

1. Clamp the force sensor to the retort stand and ensure it is on the 10 N scale.
2. Connect the force sensor to the CH1input of the LabQuest.
3. Attach the spiral spring to the force sensor.
4. Hang 1.0 N from the spring.
5. Turn LabQuest on.
6. Lift the 1.0 N mass up a little and then leave go.
7. Tap the Start icon
8. Examine the shm curve.

Calibration of the force sensor

The force sensor is already calibrated but if you wish to recalibrate the sensor proceed as follows.

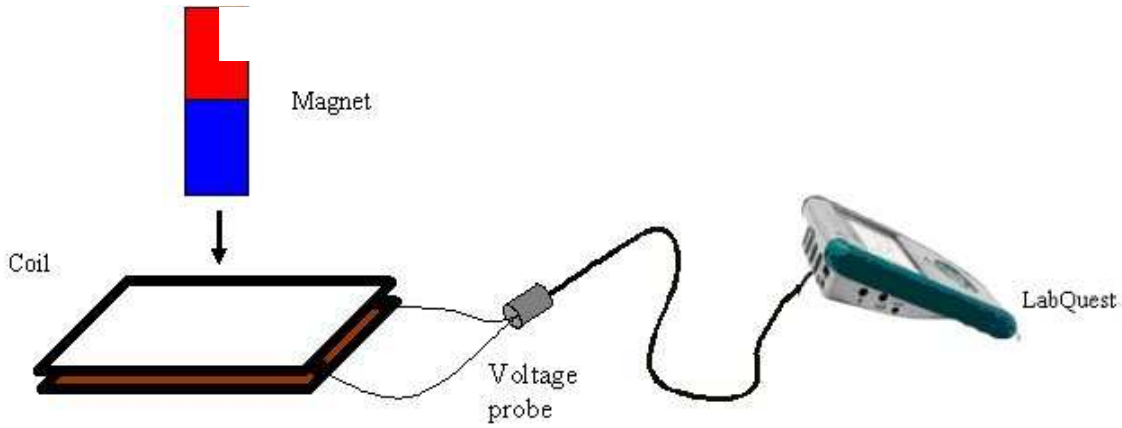
1. Select Calibrate ► CH 1: Dual Range Force 10 N from the Sensors menu.
2. Tap the Calibrate Now button.

3. Remove any weight from the sensor.
4. Enter value 0.0 and tap the Keep button.
5. Hang a 500g mass (4.9 N) from the force sensor.
6. Enter value 4.9 and tap the Keep button.
7. Tap the OK button to return to the main screen.

TO EXAMINE a.c. VOLTAGE USING THE LabQuest App

Apparatus

LabQuest, voltage probe, a.c.supply and 330 Ω resistor.



Arrangement

1. Set up the circuit shown in the diagram.
2. Attach the voltage probe to CH1 of LabQuest.

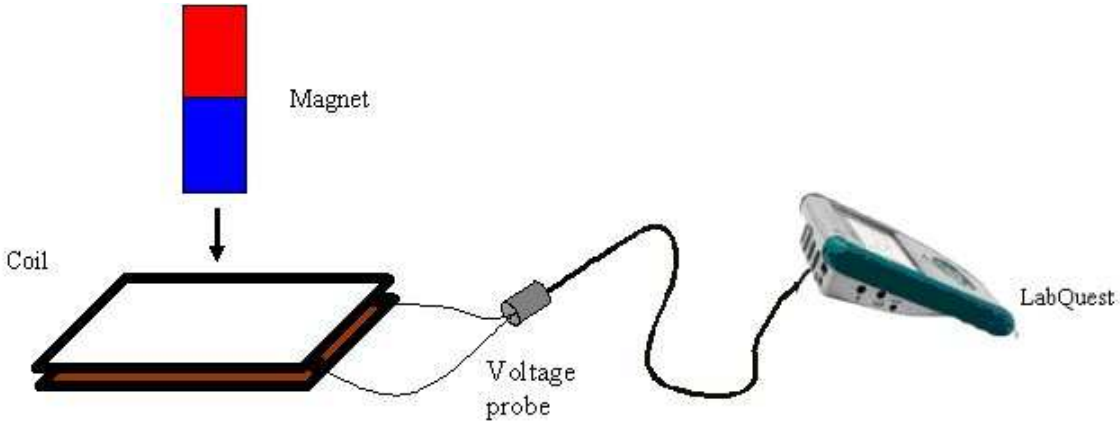
Procedure

1. Turn LabQuest on.
2. Tap the Home icon to display the list of available applications, and then select LabQuest.
3. Select Data Collection from the Sensors menu.
4. Enter 0.0005 in the Interval field.
5. Enter.075 s in the Length field.
6. Tap the OK button.
7. Switch on the a.c. supply.
8. Tap the OK button.
9. Tap the value of the peak voltage and the period of the a.c. wave. The frequency should be 50 Hz and the peak voltage ≈ (√2)6 V.

DEMONSTRATION OF ELECTROMAGNETIC INDUCTION

Apparatus

LabQuest, voltage probe, retort stand and clamp, magnet and coil (800 turns).



Arrangement

1. Connect the voltage probe across the coil.
2. Connect the voltage probe to CH1 of the LabQuest.
3. Turn LabQuest on.
4. Tap the Home icon to display the list of available applications, and then select LabQuest.
5. Select Data Collection from the Sensors menu.
6. Enter 0.01 in the interval field.
7. Enter 0.4 s in the Length field.
8. Tap Triggering.
9. Check the box next to Enable Triggering.
10. Select Increasing and enter 0.1 in the field.
11. Enter 0 in the points before trigger field.
12. Tap the OK button to return to the main screen.

Procedure

1. Tap the Start button – WAITING FOR TRIGGER appears. LabQuest will not start to sample until the voltage reaches 0.1V.
2. Note the magnet pole and drop the magnet into the coil.
3. Observe the graph on the screen.
4. Repeat with the other pole of the magnet.

Notes

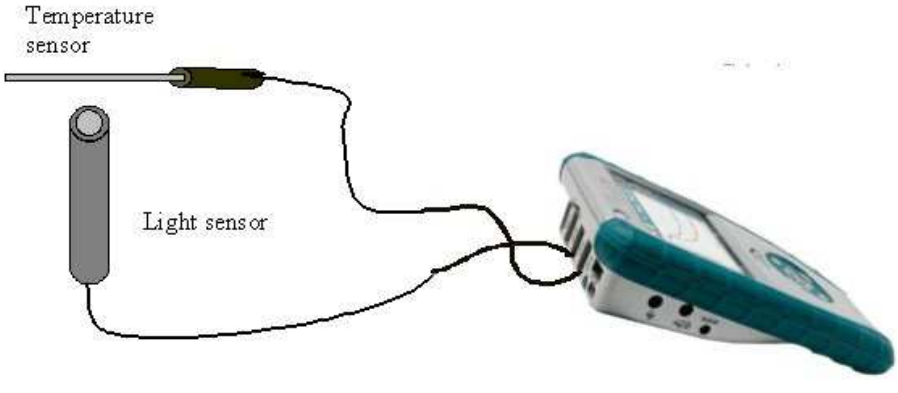
Repeat for different speeds of the magnet and with coils that have different numbers of turns.

A cardboard tube can be placed in the coil to guide the magnet as it falls.

USING TWO SENSORS WITH THE LabQuest App

Apparatus

LabQuest, temperature sensor, and light sensor.



Arrangement

Attach the temperature probe to CH1 and the light probe to CH2 of the LabQuest.

Procedure

1. Turn LabQuest on.
2. Tap the Home icon to display the list of available applications, and then select LabQuest.
3. Select Data Collection from the Sensors menu.
4. Enter 0.5 in the interval field.
5. Enter 90 s in the Length field.
6. Tap the OK button.
7. Tap the Start button.
8. Tap the Stop button, after 15 seconds, to interrupt the sampling.
9. The temperature versus time graph is displayed.
10. View the light versus time (bottom) graph.
11. Tap the x-axis label and select Temperature to view the light versus temperature graph.

To Alter the Sampling Rate, the Length of the Experiment and set a Trigger

1. Attach the temperature probe to CH1 of the LabQuest.
2. Turn LabQuest on.
3. Tap the Home icon to display the list of available applications, and then select LabQuest.
4. Select Data Collection from the Sensors menu or tap the meter screen.
5. Enter 0.5 in the interval field.
6. Enter 12 s in the Length field.
7. Tap Triggering.
8. Check the box next to Enable Triggering.
9. Select Increasing and enter 19 in the field.
10. Enter 0 in the points before trigger field.
11. Tap the OK button to return to the main screen.
12. Tap the Start button - the WAITING FOR TRIGGER on the screen signifies that sampling will begin when the temperature value reaches 19 °C.
13. Hold the temperature sensor tightly until the temperature reaches 19 °C and graphed data appears on the screen.
14. The temperature versus time graph is displayed.
15. The experiment cannot be repeated until the temperature of the probe goes below the trigger value of 19 °C.
16. Select Quit from the file menu to leave the LabQuest App.

DATA TRANSFER FROM THE LABQUEST TO THE COMPUTER

VIEWING DATA ON THE LABQUEST

1. To see data in table format, tap the Table icon at the top of the screen.
2. The lists of data now appear on the screen as a table.

DATA TRANSFER TO THE COMPUTER

1. Connect the device to the computer by USB.
2. Launch Logger *Pro*, if it is not already running.
3. Logger *Pro* will detect the presence of remote data, and display the Remote Data Available dialog.

You can choose any of the following options:

Cancel - Logger Pro will ignore the device and the data will remain on the device intact.
No - Select this option if you wish to proceed to live data collection. Data will remain on the device and can be retrieved at a later time by choosing **Remote > Retrieve (device name)** from the **Experiment** menu.

If you choose **Yes**, the following window will appear:

Retrieve Remote Data into the Current File... The data will be retrieved into the current Logger *Pro* session. This option is useful when you have already prepared Logger *Pro* to display your data in a particular way.

Retrieve Remote Data into a Chosen File... Import the data into a previously customized and saved file. The remote data will be retrieved, and then you can choose an existing experiment file into which the data will be placed. This option is useful if you have prepared a file to display your data, but it is not currently open.

If you want to put the remote data onto two or more computers, check **Make Data Available for Multiple Retrievals.**