



# **DATA LOGGING**

**WITH**

**GRAPHIC  
CALCULATORS**

**AND**

**COMPUTERS**

[www.psi-net.org](http://www.psi-net.org)

## **Introduction**

There are three essential elements in a data logging system

1. A sensor to interact with the environment.
2. A data logger to collect and store the information.
3. A graphic calculator/computer to analyse/display the data.

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 data logging 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 data logging systems.

# LEAVING CERTIFICATE PHYSICS

## DATA LOGGING EXPERIMENTS AND DEMONSTRATIONS

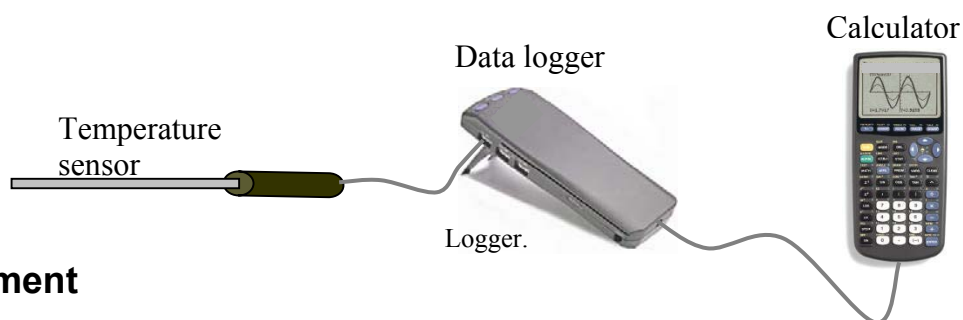
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# MEASUREMENT OF TEMPERATURE USING THE GRAPHIC CALCULATOR

## Apparatus

Temperature sensor, data logger and graphic calculator with DataMate program installed.



## Arrangement

1. Attach the temperature sensor to the CH1 input of the data logger.
2. Connect the data logger to the graphic calculator.

## Procedure

1. Turn the calculator ON.
2. Press the **APPS** button.
3. Select DataMate.
4. Press **CLEAR** to reset the program. On the main DataMate menu the TIME GRAPH setting is set at a default value of 180 - this refers to the experiment length in seconds.
5. Select START - the beeping sound signifies that sampling has begun. Data points appear on the display of the calculator.
6. Press **STO▶** to interrupt the sampling. The calculator displays a graph of best fit of temperature versus time.

## To Alter the Sampling Rate and the Length of the Experiment

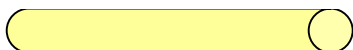
1. Press .
2. Select DataMate.
3. Select SETUP.
4. Using the cursor key  select MODE:TIME GRAPH.
5. Press .
6. Select TIME GRAPH.
7. Select CHANGE TIME SETTINGS.
8. Enter 1 for TIME BETWEEN SAMPLES.
9. Press .
10. Enter 30 for NUMBER OF SAMPLES.
11. Press .
12. Select OK.
13. Select OK again.
14. Select START 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, data logger and graphic calculator.

Fluorescent tube or other light source



## Arrangement

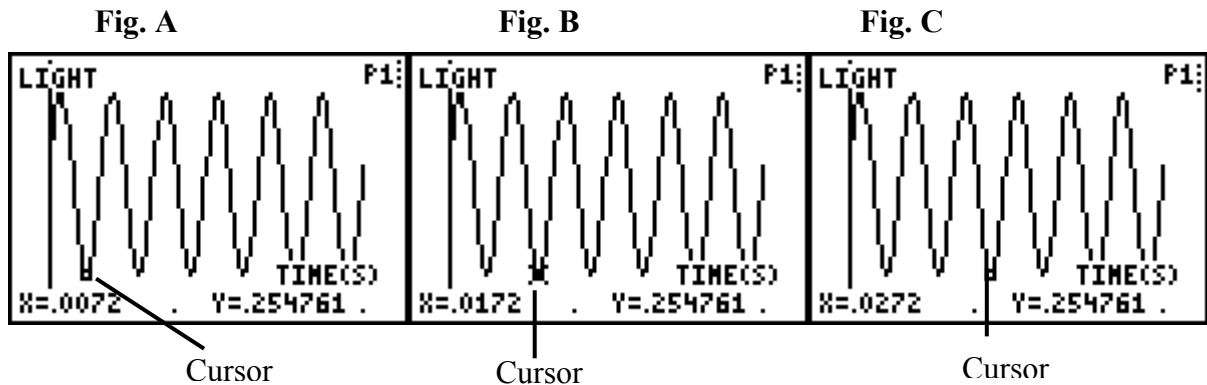
1. Connect the light sensor to the CH1 input of the data logger.
2. Connect the graphic calculator to the data logger.

## Procedure

1. Switch on the calculator.
2. Press **APPS** and select the DataMate application.
3. Press **CLEAR** to reset the program.
4. Select SETUP from the main screen.
5. Select MODE: TIME GRAPH using the scroll cursor.
6. Press **ENTER**.
7. Select TIME GRAPH.
8. Select CHANGE TIME SETTINGS.
9. Enter .0004 as the time interval between samples; press **ENTER** to confirm; enter 150 samples and press **ENTER** to confirm.
10. Select OK twice to return to the main menu.
11. Rest the light sensor on the table or point it towards some light source- it should not be too close.
12. Select START to begin collecting data – the word SAMPLING appears on screen.
13. A graph of LIGHT INTENSITY against TIME appears on screen when the chosen experiment time has elapsed.

```
ENTER TIME  
BETWEEN SAMPLES  
IN SECONDS: .0004  
  
ENTER NUMBER  
OF SAMPLES: 150
```

## Sample Analysis



1. In the graph of LIGHT INTENSITY against TIME (Fig. A), notice the cursor at  $X = 0.0072$  (base of first trough), where  $X$  in this situation represents the time axis.
2. Use the cursor key  $\blacktriangleright$  to move the cursor along the graph until 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.
3. Use the cursor key  $\blacktriangleright$  to move the cursor along the graph until two loops of the graph have been traversed and the cursor has reached the point  $X = 0.0272$  (base of third trough) shown in Fig. C.

The time to complete one full cycle is  $(0.0272 - 0.0072) = 0.02$  s.

Since  $f = \frac{1}{T}$  it follows that the mains frequency is  $\frac{1}{0.02} = 50$  Hz.

## DATA TRANSFER FROM THE GRAPHIC CALCULATOR TO THE COMPUTER

### Viewing data on the calculator

1. To see data in table format, press .
2. Select Edit.
3. The lists of data now appear on the screen as a table.
4. To see which lists are full scroll across using  and .

### Data transfer to the computer

1. Connect the calculator to the computer with the Graph-Link cable.
2. Open the Graphical Analysis program on the computer.
3. In the File menu select Import from TI Calculator.
4. Click on Select Port and select Com 1.
5. On the calculator press 2<sup>nd</sup> LINK.
6. Select List.  
Most sensors (when connected to CH1) store data in list 1 and list 2.
7. With the cursor at L<sub>1</sub> press .
8. Use the cursor  and repeat for L<sub>2</sub>.
9. Use the cursor key  to select Transmit
10. Press .
11. The data appears in the Data Table on the PC screen and a graph appears in the Graph window.

### Motion Sensor

Note that when using the motion sensor (Sonic Ranger) the data is stored as follows:

Time in	L <sub>1</sub>
Distance in	L <sub>6</sub>
Velocity in	L <sub>7</sub>
Acceleration in	L <sub>8</sub>

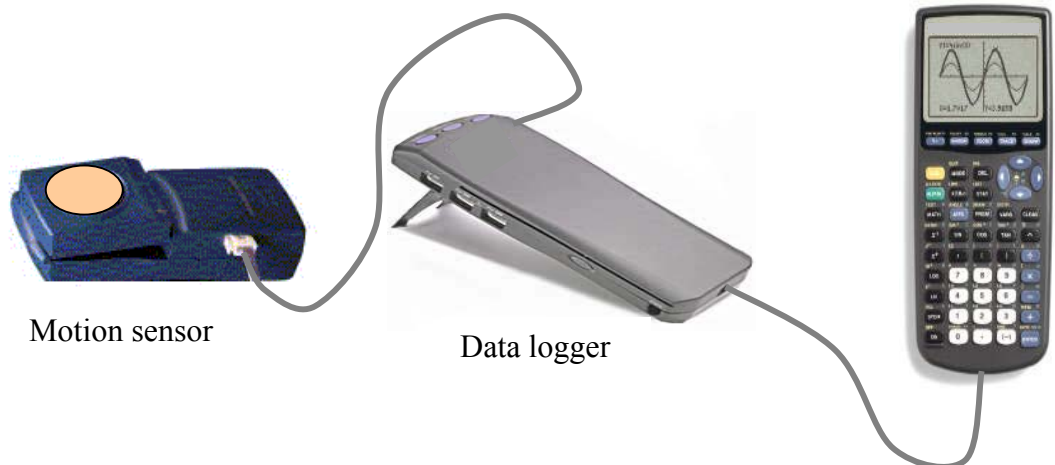
Therefore those are the lists to be transmitted when using that sensor.



# USING THE MOTION SENSOR WITH THE GRAPHIC CALCULATOR

## Apparatus

Motion sensor, data logger, graphic calculator and card.



## Arrangement

1. Connect the calculator to the data logger.
2. Connect the motion sensor to DIG/SONIC port of the data logger.
3. Turn calculator ON.
4. Press **APPS**.
5. Select DataMate.
6. Press **CLEAR** to reset the program.
7. Wait for screen to settle.

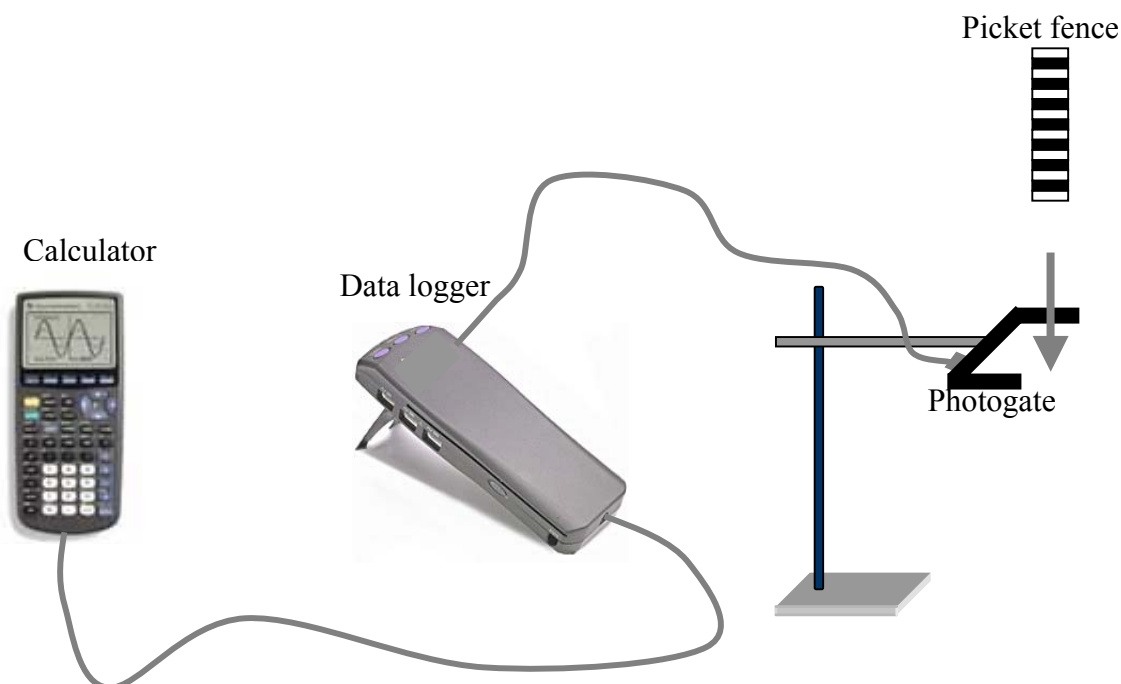
## Procedure

1. Hold a piece of card 0.5m above the motion sensor – the distance from the sensor appears on the top right of the screen.
2. Select START.
3. Move the card up and down while the data is being collected.
4. Select DIG-DISTANCE.
5. Press **ENTER**.
6. The graph of distance versus time appears.
7. Press **ENTER**.
8. Using the cursor **▼** select DIG- VELOCITY and press **ENTER**.
9. The graph of velocity versus time appears.
10. Repeat this procedure for other motions.

# MEASUREMENT OF THE ACCELERATION DUE TO GRAVITY USING THE GRAPHIC CALCULATOR

## Apparatus

Picket fence, retort stand with clamp, photogate, data logger and graphic calculator with DATAGATE program installed.



## 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 calculator to the data logger.
3. Connect the photogate to DIG/SONIC port of the data logger.
4. Turn calculator ON.
5. Press **PRGM**.
6. Select DATAGATE.
7. Press **ENTER**.
8. Select SETUP.
9. Select MOTION.
10. Select PICKET FENCE.
11. Select OK.
12. Select START.

## Procedure

1. Hold the top of the Picket Fence and drop it vertically through the photogate.
2. Using the cursor  $\blacktriangledown$  select VELOCITY and press  $\text{ENTER}$ .
3. Examine the VELOCITY VS TIME graph (Fig.1).
  - Press  $\text{ENTER}$
  - Select RETURN TO MAIN SCREEN
  - Select ANALYZE
  - Select CURVE FIT
  - Select LINEAR (VELOCITY VS TIME)  
The screen now shows the equation of the line  $v = gt + u$  ( Fig.2)
  - Record the slope
  - Press  $\text{ENTER}$  to see the fitted line with the data
  - Press  $\text{ENTER}$
  - Select RETURN TO ANALYZE SCREEN
  - Select RETURN TO MAIN SCREEN
- 4 Repeat procedure steps 1, 2 and 3 five more times to get average for g.

## Sample Results

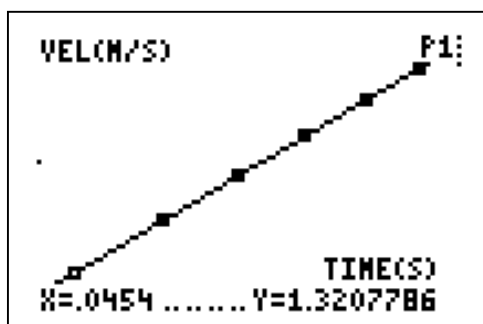


Fig. 1

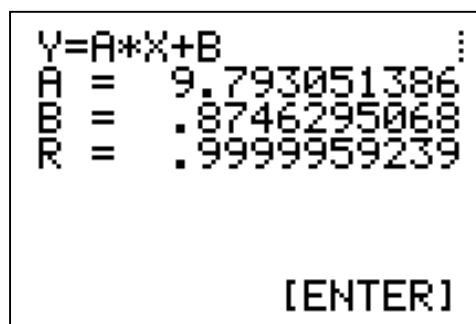


Fig. 2

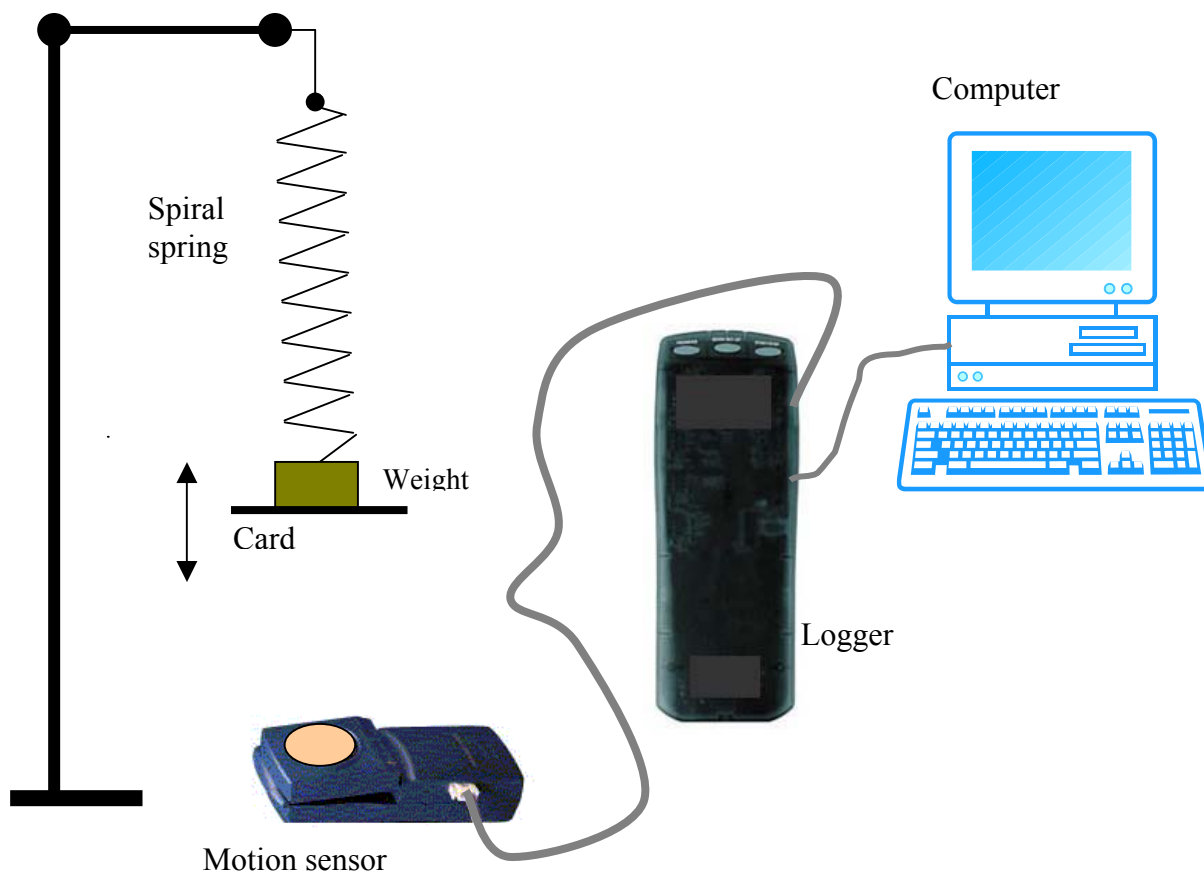
The slope of the velocity versus time graph, i.e. A as given on the screen, is a measure of acceleration due to gravity.

In this case the value of g is found from the graph to be  $9.79 \text{ m s}^{-2}$ .

# INVESTIGATION OF THE MOTION OF A VIBRATING SPRING USING THE COMPUTER

## Apparatus


Computer logger, computer, motion sensor, spiral spring and weight with card attached.

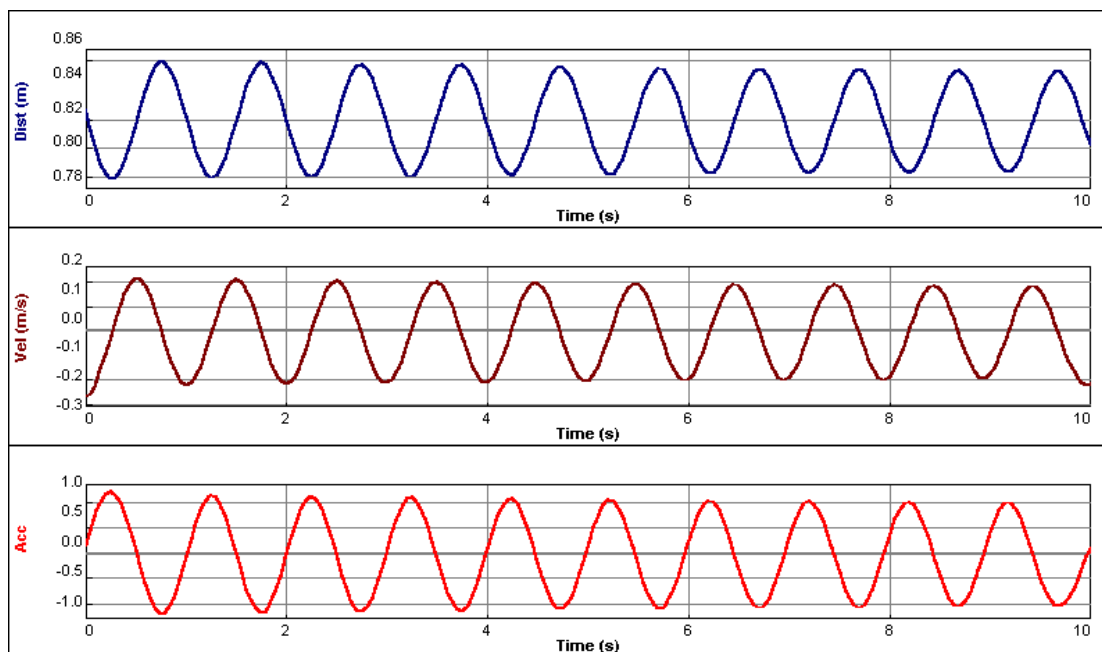


## Arrangement

1. Attach the motion sensor to DIG/SONIC1 of the computer logger.
2. Open the logger program on the computer.
3. Hang the spiral spring from the retort stand.
4. Hang the weight, with a card attached, on the spring.
5. Place the motion sensor 0.50 m under the card.
6. Click on **Set Up**.
7. In **Set Up** menu click on **Data Collection**.
8. In pop-up window click on **Real Time Collect**.
9. Click on **Sampling**
  - set **Experiment Length** at 5 seconds
  - set **Sampling Speed** at 20 samples/second
10. Click on **OK**.

## Procedure

1. Click on View.
2. Click on Graph Layout.
3. Select Three panes.
4. Click on OK.
5. Set the spring oscillating.
6. Click on  - three graphs appear on the screen –displacement, velocity and acceleration versus time.
7. Click on Analyze and use Examine in the discussion on Simple Harmonic Motion.



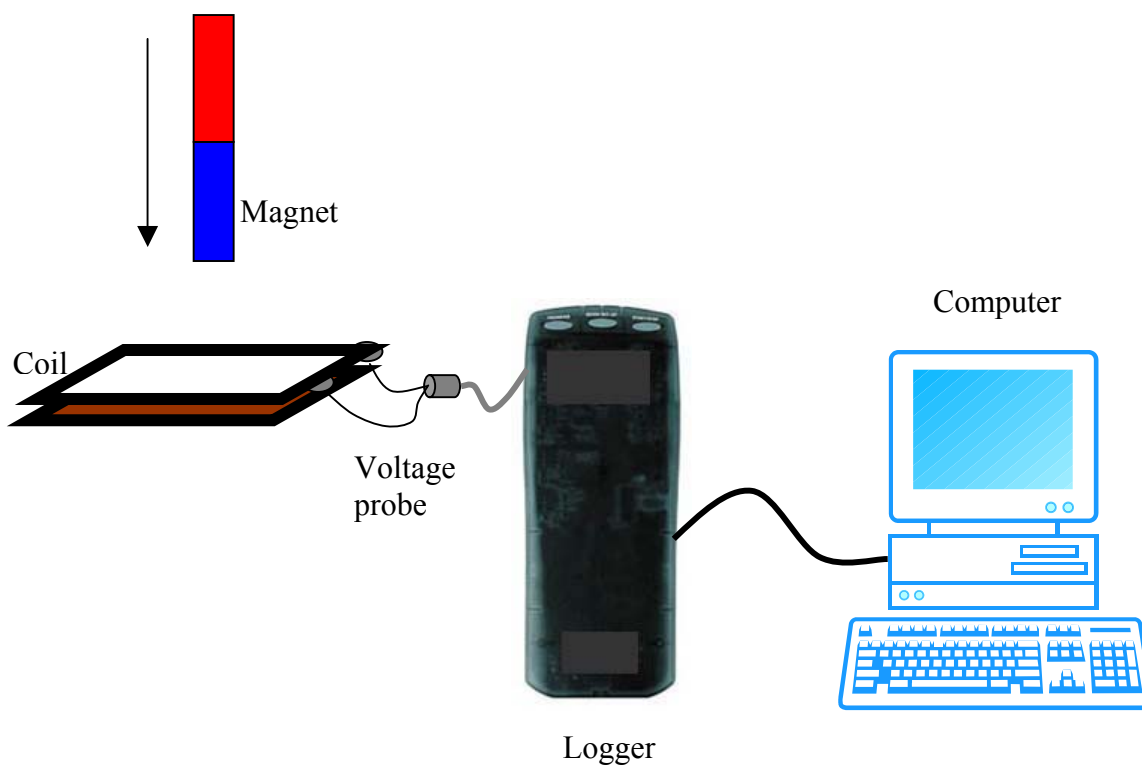
## Note

The card is attached to the weight to give a good reflective surface. It is not needed if the base of the weight is large enough.

# DEMONSTRATION OF ELECTROMAGNETIC INDUCTION USING THE COMPUTER

## Apparatus


Computer logger, voltage sensor, computer, magnet and coil with 1200 turns.



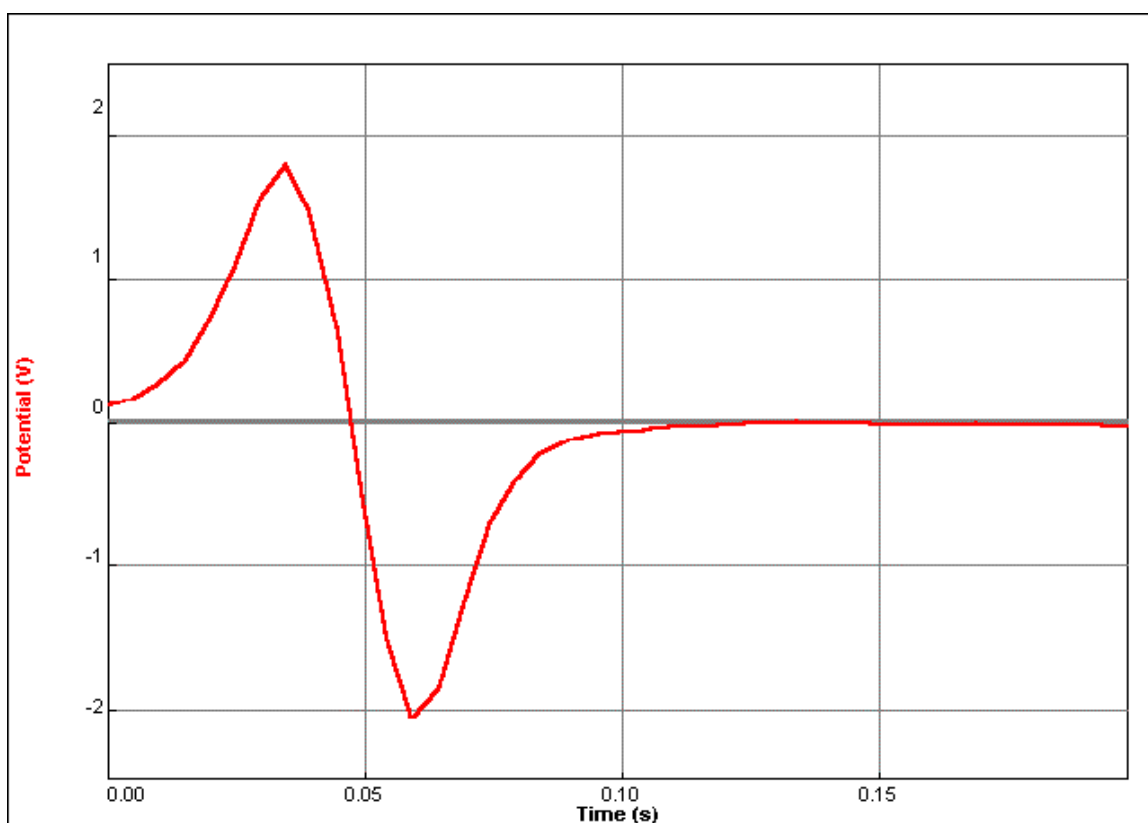
## Arrangement

1. Connect the voltage sensor to the coil.
2. Attach the voltage sensor to CH1 of the logger.
3. Attach the logger to the computer.
4. Open the logger program on the computer.
5. Click on **Set Up**.
6. In the **Set Up** menu click on **Data Collection**.
7. In the pop-up window, click on **Real Time Collect**.
8. Click on **Sampling**
  - set **Experiment Length** at 0.2 s
  - set **Sampling Speed** at 200 per sec
9. Click on **Triggering**
  - set **Enable Triggering**
  - set **Potential** greater than 0.1V OR less than -0.1V
10. Click **OK**.


## Procedure

1. Click on .
2. Drop the magnet into the coil.
3. Observe the pattern on the screen.
4. Repeat with the other pole of the magnet.
5. Repeat for different speeds of the magnet and with coils that have different numbers of turns.

## Sample Result



## Notes

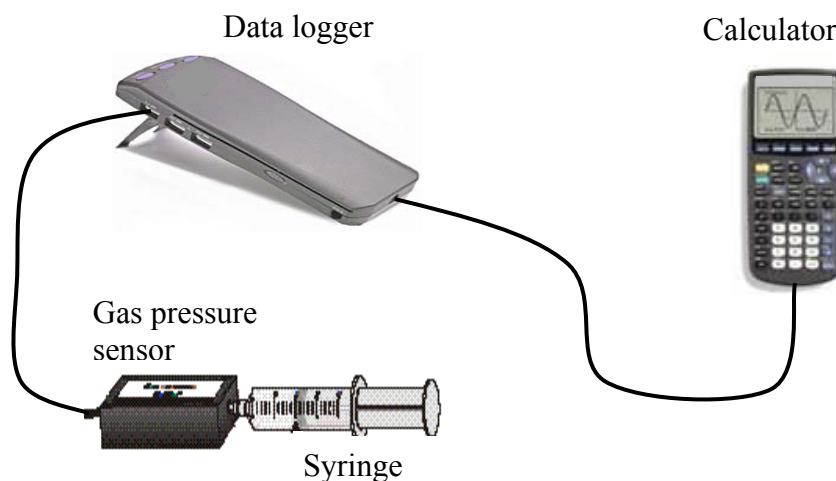
Click on  each time before inserting the magnet into the coil. The computer logger does not start taking readings until the voltage reaches 0.1V in either direction because of the Trigger Set.

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

# VERIFICATION OF BOYLE'S LAW USING THE GRAPHIC CALCULATOR

## Apparatus

Gas pressure sensor, data logger and graphic calculator.

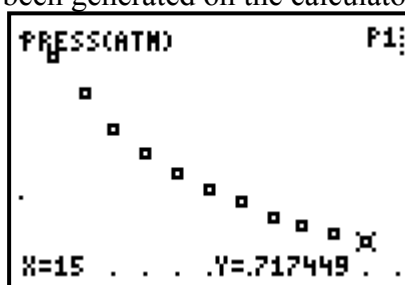


## Arrangement

1. Set the syringe to  $10 \text{ cm}^3$  and attach by screwing onto the Gas Pressure Sensor.
2. Attach the Gas Pressure Sensor to CH1 of the data logger.
3. Attach the data logger to the calculator.
4. Press .
5. Select DataMate.
6. Select SETUP.
7. Using the cursor key  select MODE:TIME GRAPH.
8. Select EVENTS WITH ENTRY and Select OK.

## Procedure

1. Pull out the syringe to  $15 \text{ cm}^3$ . Select START from the main screen to prepare for data collection. Data will be collected only when you later press .
2. Wait for the value displayed on the calculator to stabilize. Press  and enter the volume, 15, on the calculator. Press  to conclude your entry.
3. Release the syringe and hold at  $14 \text{ cm}^3$  and repeat Step 2, this time entering 14 for the volume.
4. Continue adjusting the syringe in  $1 \text{ cm}^3$  decrements until the volume of air is  $5 \text{ cm}^3$ , collecting data as before. After the final data point has been taken, press  to end data collection.
5. A graph of P against V has been generated on the calculator screen, as below.





## Data Manipulation and Analysis Using the Calculator

### To view data

Exit the DataMate programme as follows

- Press **ENTER**
- Select Quit
- Press **ENTER**
- Press **□**
- Select Edit

L1	L2	L3	1
<b>FL3</b>	.71745	0	
14	.76901	-----	
13	.82282		
12	.87887		
11	.95958		
10	1.0515		
9	1.1546		
L1(1)=15			

The data appears on the screen with volume in L1 and pressure in L2.  
Further values can be seen by scrolling down.

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

- Select L3 at the top of the screen above using the scroll buttons
- In the formula space at the bottom of the screen, key in L1 followed by the key  $X^{-1}$
- Press **ENTER** and the values of  $\frac{1}{\text{Volume}}$  appear in L3

(The keys L1, L2, etc. are 2<sup>nd</sup> functions on the 1,2, etc. keys)

L1	L2	L3	3
15	.71745	<b>1.40787</b>	
14	.76901	.07143	
13	.82282	.07692	
12	.87887	.08333	
11	.95958	.09091	
10	1.0515	.1	
9	1.1546	.11111	
L3(1)=.0666666666...			

### To calculate values of PV

- Scroll right to select L4 in the screen above
- In the formula space at the bottom of the screen key in L1  $\times$  L2
- Press **ENTER** and values of PV appear in L4

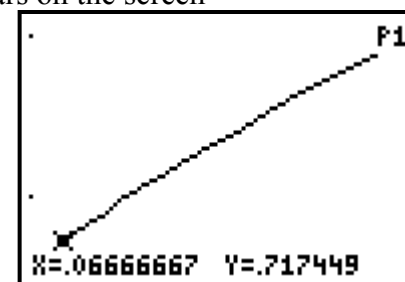
L2	L3	L4	4
.71745	.06667	<b>10.0787</b>	
.76901	.07143	10.766	
.82282	.07692	10.697	
.87887	.08333	10.546	
.95958	.09091	10.555	
1.0515	.1	10.515	
1.1546	.11111	10.392	
L4(1)=10.761735			

### To Plot P against $\frac{1}{V}$ on the calculator

- Press **APPS**
- Select DataMate
- Select GRAPH. A graph of P against V (as above) appears on the screen
- Press **ENTER**
- Select MORE

The values of pressure are in L2 and the values of  $\frac{1}{V}$  are in L3.

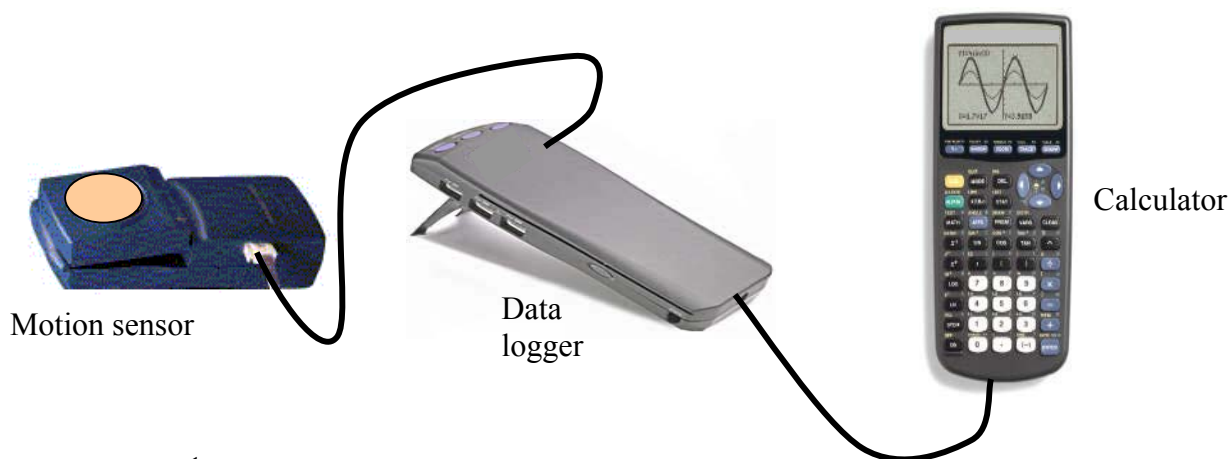
Select the option, L2 VS L3, for a graph of P against  $\frac{1}{V}$ .



# GRAPH MATCHING USING THE GRAPHIC CALCULATOR

## Apparatus

Motion sensor, data logger, graphic calculator and reflective surface.



## Arrangement

1. Connect the calculator to the data logger.
2. Connect the motion sensor to DIG/SONIC port of the data logger.
3. Turn calculator ON.
4. Press .
5. Select CBL/CBR.
6. Press any key to continue.
7. Select RANGER.
8. Press .
9. Select APPLICATIONS.
10. Select METERS.
11. Select DIST MATCH (you could also select velocity match or ball bounce).
12. The instruction "TRY TO MATCH THE GRAPH ON THE NEXT SCREEN" appears, followed by "STUDY THE GRAPH THEN PRESS  TO START".

## Procedure

1. Hold the motion sensor facing a wall, press . Move as you think is necessary to match the graph that appears on the screen.
2. A series of dots appear on the screen depending on how you moved.
3. Press .
4. You now have the option to try to repeat the same graph or match a new graph.
5. If you are feeling more confident you could select VEL MATCH and try a velocity match graph.

## VERIFICATION OF BOYLE'S LAW USING A COMPUTER

Using the supplied software, 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  $0.7 \text{ cm}^3$  added to each volume improves matters considerably. The true volume of air is the syringe reading added to approximately  $0.7 \text{ cm}^3$ . 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

1. Start the logger program.
2. In the File menu click on Open.
3. In the pop-up window, double click on the folder Chemistry with Computers.
4. In the new window double click on Exp 06 Boyle's Law.
5. In the next pop-up window select Gas Pressure Sensor and click on Open.
6. 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 Long Name.
4. Complete the fields as appropriate.
5. Click OK.

### To create a column for Volume

1. Click on Data in the menu bar.
2. In the drop-down menu select New Column, then select Formula.
3. In the pop-up window complete the fields (Volume, V,  $\text{cm}^3$ ).
4. Click the Definition tab. In the Equation field type  $0.7 +$  .
5. In the Variables field click the down arrow, select Syringe Reading and click OK.
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 Column, Formula.
3. In the pop-up window complete the fields (Inverse Volume,  $1/V$ ,  $\text{cm}^{-3}$ ).
4. Click the Definition tab. In the Equation field type  $1/V$ .
5. In the Variables field click the down arrow, select Volume and click OK.
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 Column** and choose **Formula**.
3. In the new window click on the **Definition** tab.
4. Place the cursor in the **Equation** field .
5. In the **Variables** field click the down arrow, select **Pressure**, and type \*
6. In the **Variables** field click the down arrow, select **Volume** and click **OK**.

### 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.

### Arrangement

1. Set the syringe to  $10 \text{ cm}^3$  and attach by screwing onto the **gas pressure sensor**.
2. Attach the **gas pressure sensor** to CH 1 of the logger.
3. Attach the logger to the computer.
4. Start the computer logger program.
5. In the **File** menu click on **Open**.
6. In the pop-up window, double click on the folder **Physics with Computers**.
7. In the new window double click on **Boyle's Law Amended**.
8. The **Graph Window** now has appropriate labels and the correct sampling mode has been set.
9. If necessary, set the horizontal axis to volume and the vertical axis to pressure by clicking on the axes labels.

### Procedure

1. With the syringe set at  $15 \text{ cm}^3$  press  at the top of the screen.
2. When the Pressure reading is stable press .
3. In the pop-up window, enter **15** for volume and click **OK**.
4. Change the syringe volume to  $14 \text{ cm}^3$  and repeat Steps 2 and 3, this time entering **14** for the volume.
5. Continue changing the syringe volume in  $1 \text{ cm}^3$  decrements down to  $5 \text{ cm}^3$ , 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

- Click on the label of the horizontal axis
- In the window click the button 1/V

### To see the origin

- Click on View in the menu bar.
- In the menu select Graph Options and click on the Axis Options tab
- Set both axes to Autoscale from 0

### To draw a line of best fit

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

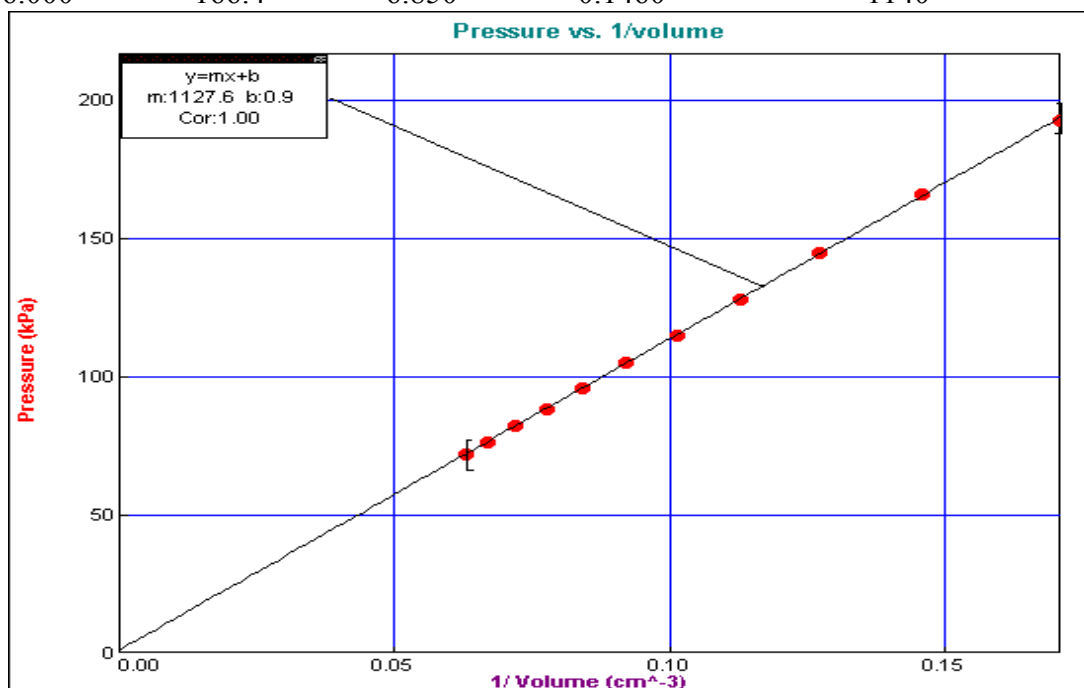
A line of best fit appears in the graph window. A floating box gives numerical details.

### To view column for PV

Select the Table Window. To see values of PV either maximise the window, or scroll to the right.

## Sample Data

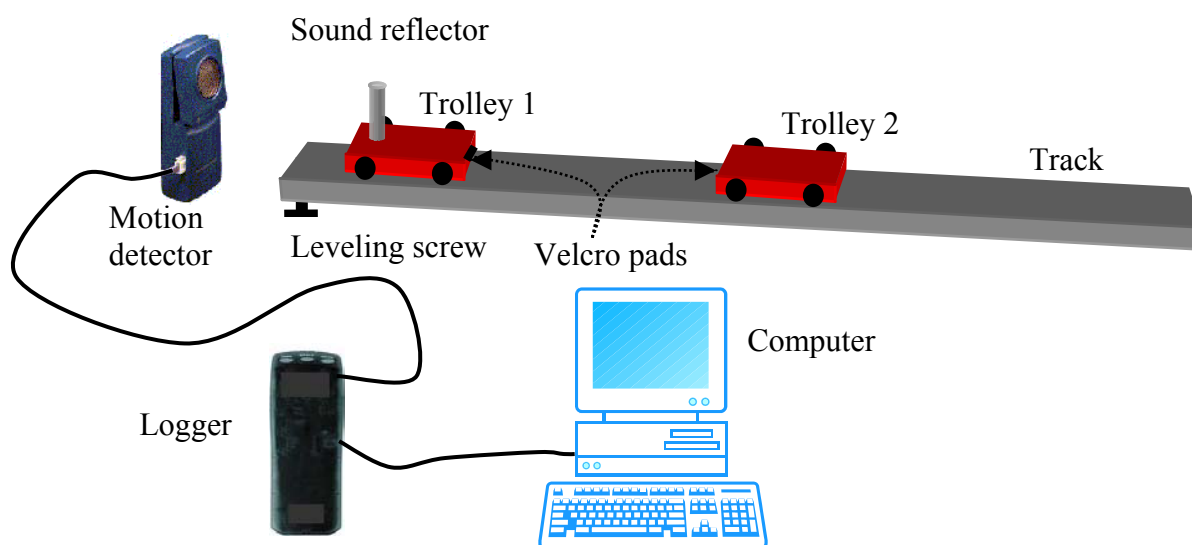
Syringe/cm <sup>3</sup>	Pressure/kPa	Volume/cm <sup>3</sup>	1/Volume/cm <sup>-3</sup>	PV/kPa cm <sup>3</sup>
15.00	72.00	15.85	0.06309	1141
14.00	76.66	14.85	0.06734	1138
13.00	82.33	13.85	0.07220	1140
12.00	88.57	12.85	0.07782	1138
11.00	95.72	11.85	0.08439	1134
10.00	105.5	10.85	0.09217	1144
9.000	115.3	9.850	0.1015	1136
8.000	128.3	8.850	0.1130	1135
7.000	144.9	7.850	0.1274	1138
6.000	166.4	6.850	0.1460	1140



# VERIFICATION OF THE PRINCIPLE OF CONSERVATION OF MOMENTUM USING THE COMPUTER

## Apparatus


Track, trolleys, computer logger, motion detector and computer.



## Arrangement

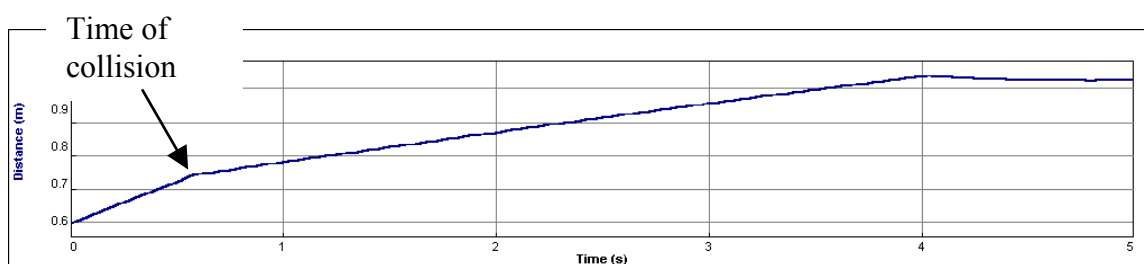
1. Arrange the apparatus as shown in the diagram.
2. Adjust the slope of the track with the levelling screw to compensate for the effects of friction on the motion of the trolleys.
3. Place trolley 2 stationary two-thirds of the way down along the track.
4. Place an object on trolley 1 to improve the reflection the ultra-sound.
5. Place trolley 1 at the end of the track nearest the motion detector.
6. Use Velcro, or other means, to ensure that both trolleys remain together after the collision.
7. Connect the motion detector to the logger.
8. Place the motion detector at the start of the track, about 0.5 m from the first trolley.
9. Connect the logger to the computer.
10. Start the computer logger program.
11. Click on View.
12. Click on Graph Layout.
13. Select One Pane.
14. Click on OK.

## Procedure

1. Click on  and give trolley 1 a gentle push. After collision the two trolleys coalesce and move off together.
2. Measure the mass of each vehicle  $m_1$  and  $m_2$ , including attachments such as the sound reflector on the first trolley, using an electronic balance.
3. Measure the initial velocity ( $u$ ) of trolley 1 before collision and the final velocity ( $v$ ) after the collision by analysis of the collected data as described below.
4. Calculate the momentum before the collision  $p_{\text{BEFORE}} = m_1 u$  and the momentum after the collision  $p_{\text{AFTER}} = (m_1 + m_2) v$ .
5. Record results as shown.
6. Repeat the experiment several times with different masses or velocities.


## Data Manipulation and Analysis

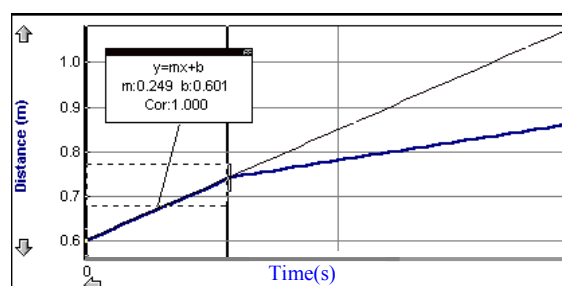
When the data has been collected the distance/time graph should look similar to the one shown below.



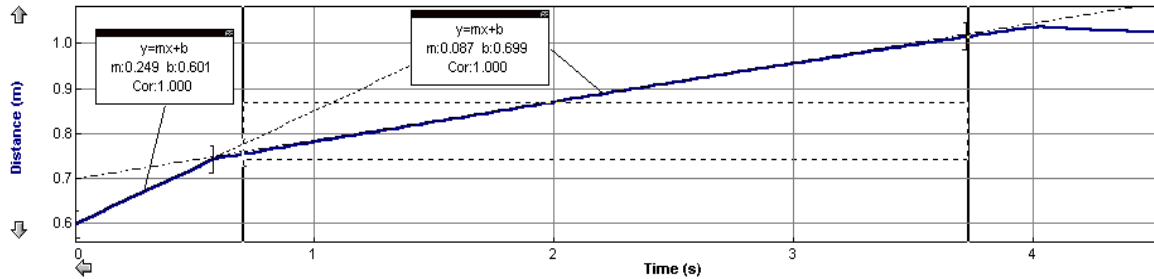
The change in the velocity of the first trolley when it collides with the second trolley can be seen by the change in the slope of the graph.

## To Find the Velocity of the First Trolley Before Impact

1. Select the region of the distance/time graph corresponding to this velocity (the steeper slope at the start of the graph) by holding down the left mouse button and drag the mouse across the area of the graph required.
2. Press the linear regression button, , which is located on the toolbar. This gives the best-fit line and its equation.



- The slope of the line is the average velocity  $u$  of the first trolley before the impact. The velocity of the second trolley is 0 (zero) as it was not initially moving in this experimental arrangement.
- Repeat the above procedure on the graph to find the velocity  $v$  after the collision.



Enter the readings in the results table below and calculate the momentum before and after the collision.

## Results

Mass of vehicle 1,  $m_1 = \dots\dots$  kg

Mass of vehicle 2,  $m_2 = \dots\dots$  kg

$u/\text{m s}^{-1}$	$p_{\text{BEFORE}}/\text{kg m s}^{-1}$	$v/\text{m s}^{-1}$	$p_{\text{AFTER}}/\text{kg m s}^{-1}$

## Notes

To see what the distance/time graph looks like and to practice data manipulation, use just one trolley before starting on the full experiment.

Velocity values may also be collected by viewing the velocity/time graph. Click on the label of the y-axis of the graph. Choose **Velocity** in **Y-Axis Selection** by placing a tick in the appropriate box. Remove the tick from **Distance**. Click **OK**.

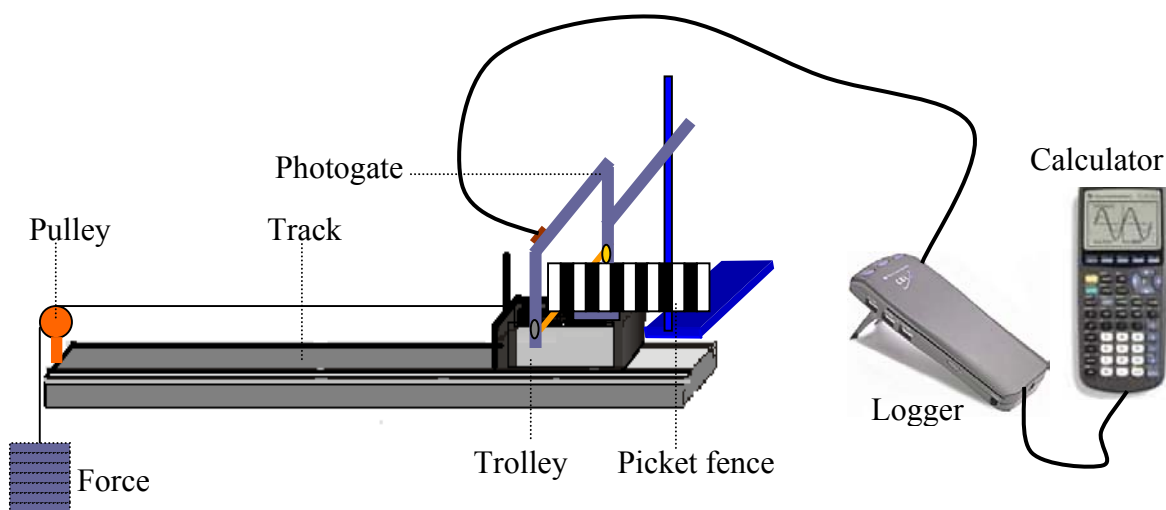
Next click on **Analyze** on the toolbar. This gives a drop down menu. Select **Examine**. The velocities before and after may then be recorded for different points by placing the cursor along the graph.



# MEASUREMENT OF ACCELERATION USING THE GRAPHIC CALCULATOR

## Apparatus

Picket fence, retort stand with clamp, photogate, data logger and graphic calculator with DATAGATE program installed.



## Arrangement

1. Attach the picket fence to the trolley using bluetack, with its 'bands' vertical as shown.
2. Arrange the photogate so that its light beam is intercepted when the picket fence riding on the trolley passes through.
3. Connect the calculator to the data logger.
4. Connect the photogate to DIG/SONIC port of the data logger.
5. Turn calculator ON.
6. Press **PRGM**.
7. Select DATAGATE.
8. Press **ENTER**.
9. Select SETUP.
10. Select MOTION.
11. Select VERNIER PICKET FENCE.
12. Select OK.
13. Attach the set of slotted masses to the trolley with a thread passing over a smooth pulley.

## Procedure

1. Select START.
2. Release the trolley so that it, together with its picket fence rider, it passes through the light beam.
3. Using the cursor (▼) select VELOCITY and press **[ENTER]**.
4. Examine the VELOCITY VS TIME graph (see Fig. 1). The slope of the graph is a measure of acceleration (see Fig. 2).
5. Press **[ENTER]**
6. Select RETURN TO MAIN SCREEN.
7. Select ANALYZE.
8. Select CURVE FIT.
9. Select LINEAR (VELOCITY VS TIME).
10. The screen now shows the equation of the line  $v = at + u$  (see Fig 2).
11. Record the slope.
12. Press **[ENTER]** to see the fitted line with your data.
13. Press **[ENTER]**.
14. Select RETURN TO ANALYZE SCREEN.
15. Select RETURN TO MAIN SCREEN.
16. Repeat procedure steps 1, 2 and 3 to obtain additional acceleration values if required.

## Sample Results

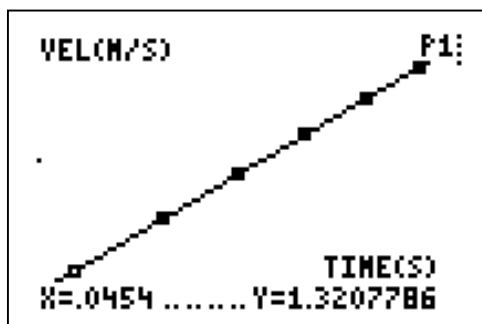


Fig. 1

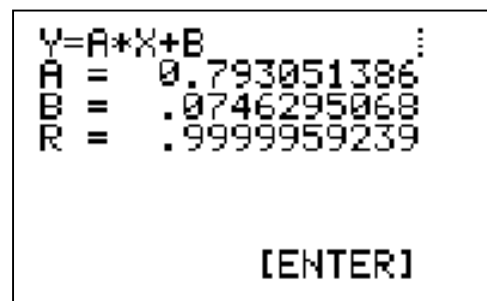


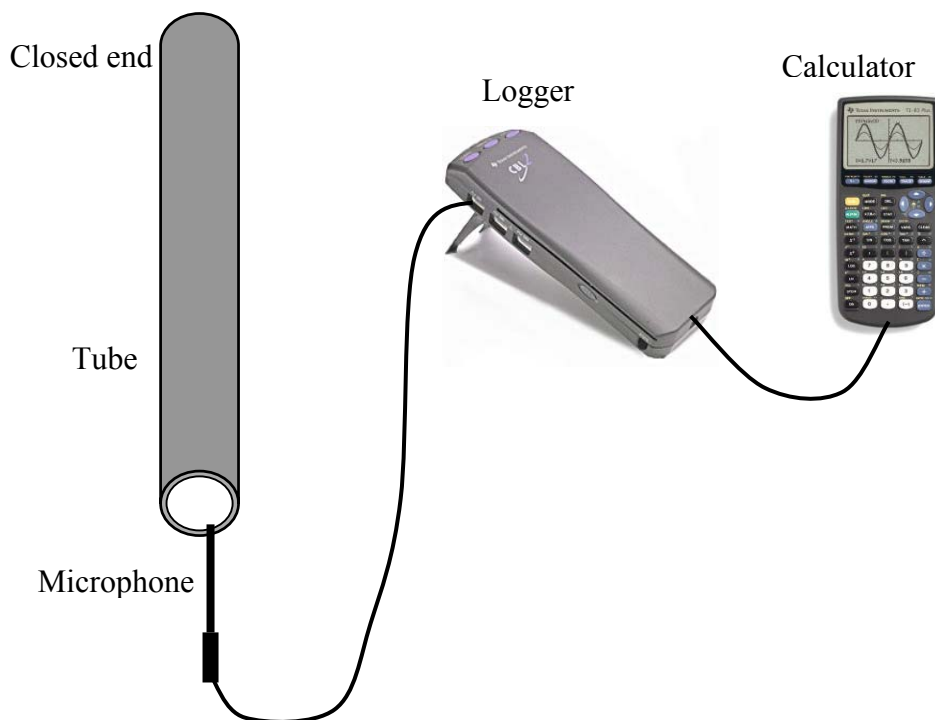
Fig. 2

The slope of the velocity /time graph i.e. the value of A as given on the screen, is the acceleration.

# MEASUREMENT OF THE SPEED OF SOUND IN AIR USING THE GRAPHIC CALCULATOR

## Apparatus

Cardboard or plastic tube, microphone, data logger and graphic calculator.



## 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 data logger.
4. Connect the data logger to the graphic calculator.
5. Switch on the calculator and press **APPS**.
6. Select DataMate.
7. Press **CLEAR** to reset.
8. Select SETUP.
9. Select MODE and press **ENTER**.
10. Select TIME GRAPH.
11. Select ADVANCED.
12. Select CHANGE TRIGGERING.
13. Select CH1 MICROPHONE.
14. Select INCREASING.
15. Enter 0.1 for the TRIGGER THRESHOLD.
16. Enter 0 for the PRESTORE.
17. Select OK three times to return to the main screen.

## Procedure

1. Select START 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 .0033.
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 .0092.
6. Move the cursor to the next reflection and note its time value. The value in the example shown is .0151.

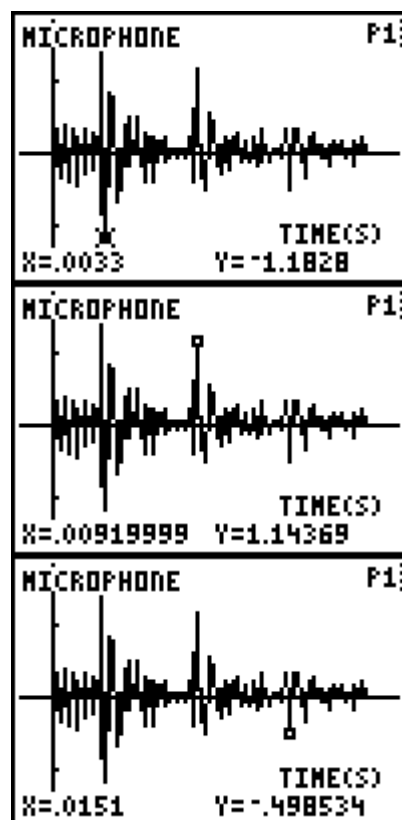
## Data Manipulation and Analysis

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 .0059 s.

The length of the tube is 1m, thus the distance travelled by the pulse between reflections is 2 m.

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

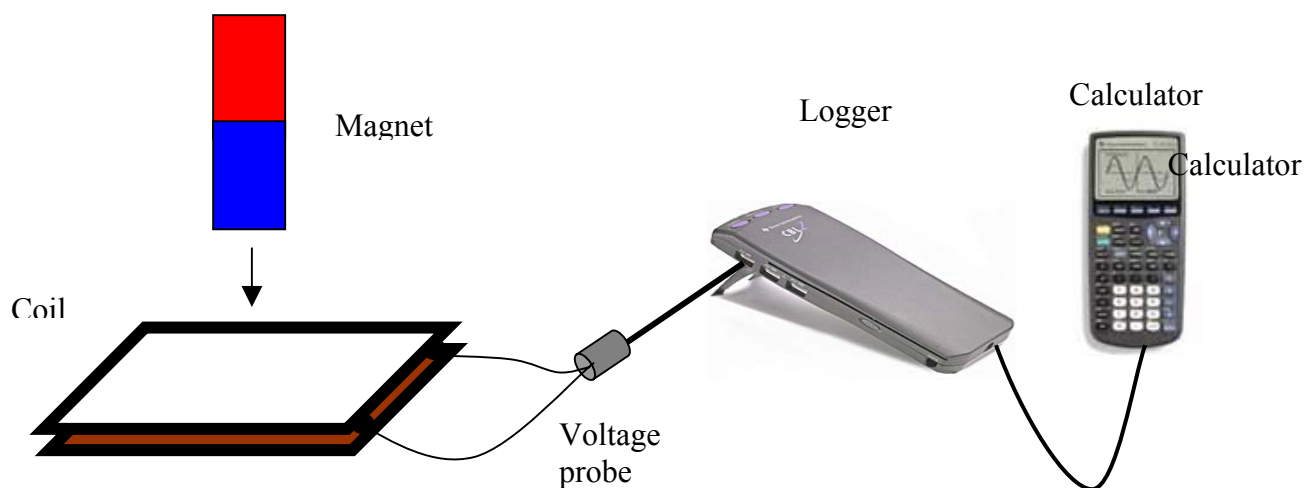
This gives a value for the speed of sound of  $339 \text{ m s}^{-1}$ .



# DEMONSTRATION OF ELECTROMAGNETIC INDUCTION USING THE GRAPHIC CALCULATOR

## Apparatus

Data logger, voltage probe, calculator, magnet and coil with 1200 turns.



## Arrangement

1. Connect the voltage probe across the coil.
2. Connect the voltage probe to CH1 of the data logger.
3. Connect the calculator to the logger.
4. Press the **APPS** button.
5. Select DataMate.
6. Select SETUP from the DataMate menu.
7. Using the cursor **▼** select MODE:TIME GRAPH.
8. Press **ENTER**.
9. Select TIME GRAPH.
10. Select CHANGE TIME SETTINGS.
11. Enter 0.01 for TIME BETWEEN SAMPLES.
12. Press **ENTER**.
13. Enter 20 for NUMBER OF SAMPLES.
14. Press **ENTER**.
15. Select ADVANCED.
16. Select CHANGE TRIGGERING.
17. Select CH1-VOLTAGE.
18. Select INCREASING.
19. Enter 0.1 for TRIGGER THRESHOLD.
20. Press **ENTER**.
21. Enter 0.0 for PRESTORE IN PERCENT.
22. Press **ENTER**.
23. Select OK.
24. Select OK.

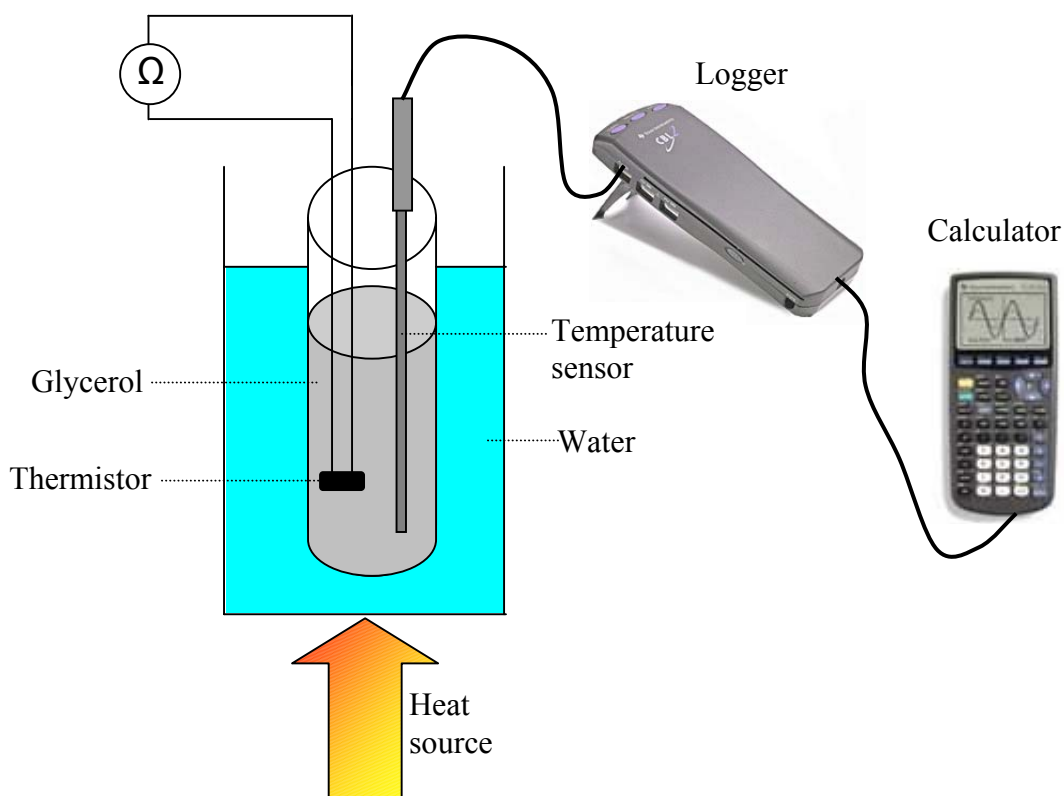
## Procedure

1. Select START – WAITING FOR TRIGGERING appears. The logger will not start to sample until the voltage reaches 0.1V.
2. Drop the magnet into the coil.
3. Observe the graph on the screen.
4. Repeat with the other pole of the magnet.
5. Repeat for different speeds of the magnet and with coils that have different numbers of turns.

# INVESTIGATION OF THE VARIATION OF THE RESISTANCE OF A THERMISTOR WITH TEMPERATURE USING THE GRAPHIC CALCULATOR

## Apparatus

Thermistor, ohmmeter, glycerol, test tube, water bath, temperature sensor, data logger and graphic calculator.



## Setup

1. Connect a multimeter to the thermistor.
2. Place both the thermistor and the temperature probe in a boiling tube of glycerol.
3. Place the tube in a water bath.
4. Connect the temperature sensor to CH1 of the data logger.
5. Connect the calculator to the data logger.
6. Turn the calculator ON.
7. Press .
8. Select DataMate.
9. Select SETUP.
10. Using the cursor  select MODE and press .
11. Select EVENTS WITH ENTRY.
12. Select OK to return to the main screen.

## Procedure

1. Select START from the main screen to prepare for data collection. Data will be collected only when **ENTER** is pressed.
2. Wait for the temperature value displayed on the calculator to stabilize. Press **ENTER** and simultaneously note the value of the resistance.
3. Enter the value of resistance. Press **ENTER** to conclude the entry.
4. Begin heating the water bath and repeat steps 7 and 8, entering the new resistance value at each chosen temperature.
5. Continue to take readings at suitable intervals until you have perhaps ten data points, collecting data as before. After the final data point, press **STO▶** to end data collection.

A graph of temperature against resistance has been generated on the calculator screen.

## Linking to the Computer

1. Connect the calculator to the computer with the Graph-Link cable.
2. Open the Graphical Analysis program on the computer.
3. In the File menu select Import from TI Calculator.
4. Click on Select Port and select Com 1.
5. On the calculator press 2<sup>nd</sup> LINK.
6. Select List.
7. Using the cursor **▼** select L<sub>1</sub>.
8. Press **ENTER**.
9. Using the cursor **▼** select L<sub>2</sub>.
10. Press **ENTER**.
11. Using the cursor key **▶** select Transmit
12. Press **ENTER**.


The data appears in the Data Table on the computer screen and a graph of temperature against resistance appears in the graph window.

## Data Manipulation and Analysis

### To Label Axes

- In the Data Table, double click on L1
- In the “Column Options” pop-up window, type the new name Resistance and new units Ohms
- Similarly rename L2 as Temperature with units °C

### To Create a Column for Temperature in Kelvin

- Click on 
- In the “New Column” window type Temperature (K) for the name and K for the units
- To write the formula type 273.15 + then click on **Columns** **▼**
- From the list select Temperature(°C) and click OK
- The column Temperature(K) immediately appears in the data table window




### To Generate a Graph of Resistance Against Temperature

- Click on the label of the horizontal axis
- In the pop-up X-Axis Setup window, click the radio button for Temperature and click OK
- Similarly place Resistance on the vertical axis

### To See the Origin

- Click on Graph in the menu bar
- Select X-Axis Options
- In the pop-up window, select AutoScale at 0 and click OK
- Repeat for Y-Axis

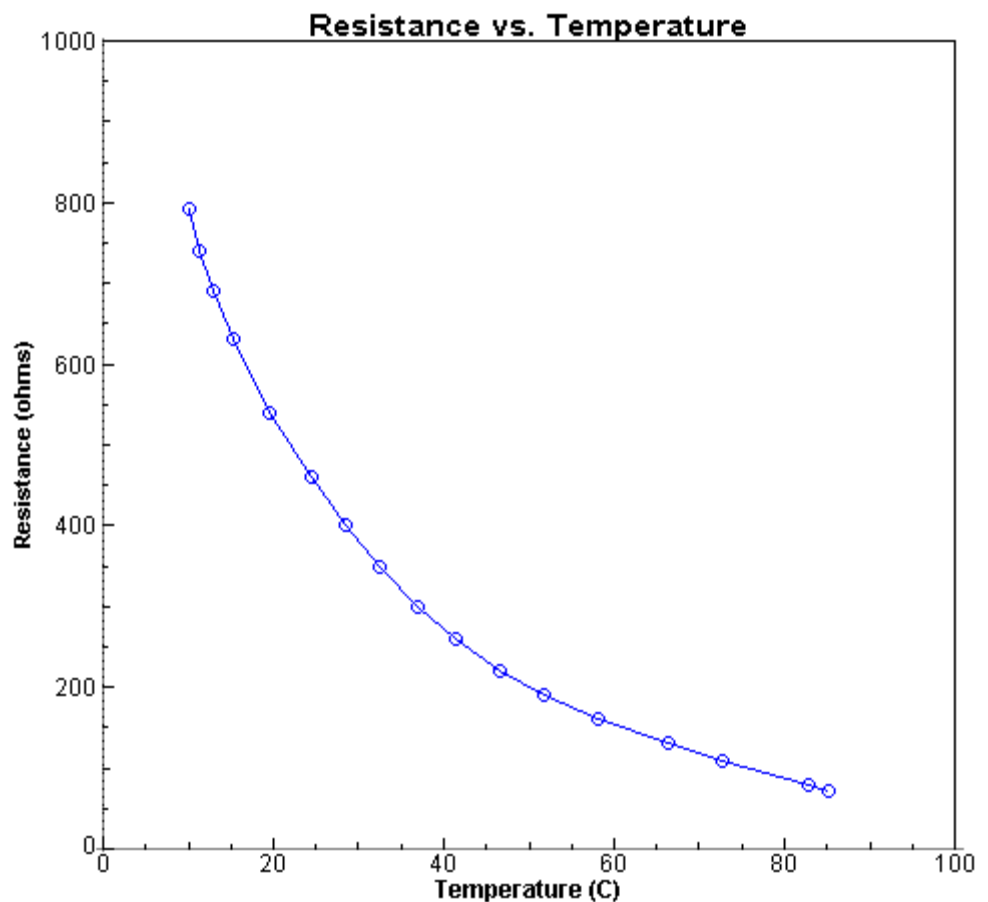
### To Obtain an Automatic Curve Fit

- Select the graph by clicking anywhere on it.
- Click on  in the toolbar.
- In the pop-up window, select  $A * x ^ B$  Power
- Click OK.
- A floating box gives numerical details.

It will be seen that if temperature is in Kelvin  $R \propto T^{-10}$  is a very good approximation to the data obtained.

Sample Data

$R/\Omega$	$\theta/^{\circ}\text{C}$
792	10.2
739	11.4
690	12.8
630	15.2
539	19.5
460	24.4
400	28.5
350	32.5
300	36.9
260	41.3
220	46.7
190	51.7
160	58.0
130	66.3
110	72.7
80.0	82.9
73.0	85.1



## LOADING PROGRAMS ONTO THE CALCULATOR

### To load DATAGATE

1. Connect the TI-GRAPH LINK cable to the serial port of the computer and to the port on the bottom edge of the calculator.
2. Turn on the calculator.
3. Start the TI-GRAPH LINK software on the computer.
4. Load Physics Lab Manuals CD ROM.
5. Open Calculator Programs Folder.
6. Open DATAGATE Folder.
7. Drag DATAGATE .83p into the program window. See Fig 1.
8. Click **Send to RAM**

To confirm that the program is now in the calculator, press **PRGM** on the calculator and you should see DATAGATE listed

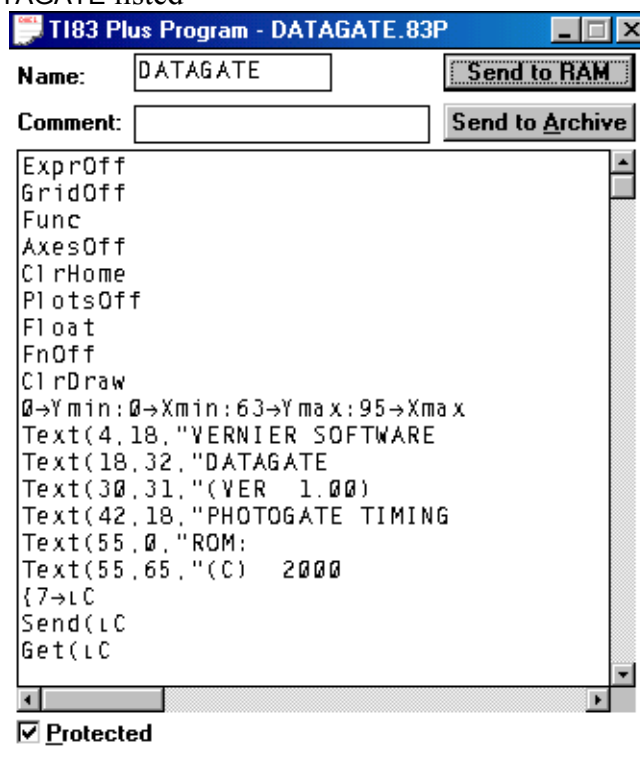


Fig. 1

### To transfer DATAGATE from one graphic calculator to another

1. Link both calculators using the link cable.
2. On the calculator that is to receive the program, press 2<sup>nd</sup> [LINK].
3. Scroll across to RECEIVE.
4. Select RECEIVE. The word WAITING... should appear on the screen.
5. On the calculator that is to send the program press 2<sup>nd</sup> [LINK].
6. Select PGRM.
7. Select DATAGATE PRGM by scrolling down to it and press **ENTER**.
8. Scroll across to TRANSMIT and press **ENTER**. DONE will appear on both screens when finished.

## TROUBLESHOOTING

### Scrolling

When using the graphic calculator, it can be faster to scroll upwards to reach another item lower down on the menu.

### Overhead viewing panel

When using the overhead viewing panel in conjunction with the teacher graphic calculator, it is easier to put the connector into the graphic calculator through the cradle first, before the data logger is attached to the cradle.

### Setting up and clearing

If the calculator has been set-up in the “EVENTS WITH ENTRY” mode in the previous experiment/demo you may encounter difficulty when you attach the light sensor or any other sensor, where you expect automatic recognition. Even after it checks the sensors it may not recognise the new sensor because it has not returned to “TIME-GRAPH” mode. One can get out of the problem by pressing . This should be standard procedure every time you begin a new investigation.

### Checking available memory.

If you want to check or manage the available memory in the graphic calculator, press 2<sup>nd</sup> [MEM]. Select **Mem Mgmt/Del**. This displays the memory management menu. This calculator expresses memory quantities in bytes. Scroll down through menu and select **Apps**. Press ; a list of the amount of free RAM and amount of space taken up by the various applications is shown. If you wish to delete any of the applications, place the cursor next to the item you wish to delete and press DEL. The variable is then deleted from memory.

### Clearing/Resetting the memory.

If the Graphic calculator / data logger gets *hung up*, or you cannot run the DataMate program, or if the same graph keeps being produced on the screen, then clearing/resetting the memory may solve the problem. This can be done as follows. Quit from the program or clear the screen. Press 2<sup>nd</sup> [MEM] and select **Reset**. Next select All RAM and select **Reset**. The screen should now display the message RAM cleared.

**A word of warning:** this procedure will also clear programs from memory including the DATAGATE programme. To eliminate this possibility, programs can be archived.

### Archiving and Unarchiving Programs.

To archive a program, proceed as follows: Press 2<sup>nd</sup> [MEM]. Select **Archive**. Press . Select DATAGATE. Press . Press . **Done** appears on the screen.

When a program is archived it cannot be used or deleted by accident. If you press **PRGM**, any program that is archived will have \* at the left hand side of the program name.

To unarchive a program, proceed as follows. Press 2<sup>nd</sup> **[MEM]**. Select **UnArchive**. Press **PRGM**. Select **DATAGATE**. Press **ENTER**. Press **ENTER**. **Done** appears on the screen.

### **Clearing Data lists.**

If you wish to clear the data from all the lists press 2<sup>nd</sup> **[MEM]**. Select **ClrAllLists**. Press **ENTER**. **Done** will appear on the screen when the lists have been cleared. You can check to see that all the lists are cleared by pressing **STAT**. Then select **Edit**. Empty lists should now appear on the screen.

### **How to transfer DataMate from data logger to calculator.**

Link the data logger and the calculator with a lead. Press 2<sup>nd</sup> **[LINK]** on the graphic calculator and select **RECEIVE**. Press **TRANSFER** on the data logger. This will transfer the DataMate program to the graphic calculator. **Done** will appear on the screen when finished.

### **Checking Battery level of Calculator.**

Press **APPS**. Select **DataMate**. Select **Tools**. Then select **Check Battery**. The screen will come up with a message telling the level of the battery. Press **ENTER** to return to previous panel. Then select **Return To Main Screen**.

If this message appears;   CONTINUE WITH  
                                  1:INTERFACE  
                                  2:NO INTERFACE  
                                  3:QUIT

the batteries are low in the CBL or there is no link between the graphic calculator and the CBL.

### **Note of Caution**

When changing the batteries in the calculator, be sure to check that the RAM and consequently the programs have not also been cleared.