MATERIALS

TI-83 Plus or TI-84 Plus graphing calculator
EasyData application
data-collection interface
Vernier Photogate
Picket Fence
clamp or ring stand to secure Photogate

PRELIMINARY QUESTIONS

1. Inspect your Picket Fence. You will be dropping it through a Photogate to measure *g*. The distance, measured from one edge of a black band to the same edge of the next band, is 5.0 cm. What additional information will you need to determine the average speed of the Picket Fence as it moves through the Photogate?

2. If an object is moving with constant acceleration, what is the shape of its velocity *vs.* time graph?

3. Does the initial velocity of an object have anything to do with its acceleration? For example, compared to dropping an object, if you throw it downward would the acceleration be different after you released it?

PROCEDURE

1. Fasten the Photogate rigidly to a ring stand so the arms extend horizontally, as shown in Figure 1. The entire length of the Picket Fence must be able to fall freely through the Photogate. To avoid damaging the Picket Fence, make sure it has a soft landing surface.

2. Turn on the calculator. Connect the Photogate, data-collection interface, and calculator.

3. Set up EasyData for data collection.
   a. Start the EasyData application, if it is not already running.
   b. Select **File** from the Main screen, and then select **New** to reset the application.

4. Now collect your free fall data. To do this, select **Start** from the Main screen. Wait 1 second.

5. Hold the top of the Picket Fence and drop it through the Photogate, releasing it from your grasp completely before it enters the Photogate. Be careful when releasing the Picket Fence. It must not touch the sides of the Photogate as it falls and it needs to remain vertical.

6. When data collection is complete, a graph of distance *vs.* time will be displayed. Sketch the graph on paper for later use.

7. Select **Plots**, then select **Vel(m/s) vs Time**. Examine your velocity *vs.* time graph. The slope of a velocity *vs.* time graph is a measure of acceleration. If the velocity graph is approximately a straight line of constant slope, the acceleration is constant. If the acceleration of your Picket Fence appears constant, fit a straight line to your data.
   a. Select **Anlyz**, and then select **Linear Fit**.
   b. Record the slope of the fitted line in the data table.
   c. Select **OK** to see the fitted line with your data.
   d. Select **Main** to return to the Main screen.

8. To establish the reliability of your slope measurement, repeat Steps 4 through 7 five more times. Do not use drops in which the Picket Fence hits or misses the Photogate. Record the slope values each time. **Note**: After selecting (Start) to begin data collection, select (OK) to overwrite the latest run and start collecting data.

DATA TABLE

Trial	1	2	3	4	5	6
Slope (m/s^2)						

	Minimum	Maximum	Average
Acceleration (m/s^2)			

Acceleration due to gravity, *g*	± m/s^2
Precision	%

ANALYSIS

1. From your six trials, determine the minimum, maximum, and average values for the acceleration of the Picket Fence. Record them in the data table.
2. Describe in words the shape of the distance *vs*. time graph for the free fall of the picket fence.
3. Describe in words the shape of the velocity *vs*. time graph. How is this related to the shape of the distance *vs*. time graph?
4. The average acceleration you determined represents a single best value, derived from all your measurements. The minimum and maximum values give an indication of how much the measurements can vary from trial to trial; that is, they indicate the precision of your measurement. One way of stating the precision is to take half of the difference between the minimum and maximum values and use the result as the uncertainty of the measurement. Express your final experimental result as the average value, ± the uncertainty. Round the uncertainty to just one digit and round the average value to the same decimal place.

   For example, if your minimum, average, and maximum values are 9.12, 9.93, and 10.84 m/s^2, express your result as $g = 9.9 \pm 0.9\ m/s^2$. Record your values.

5. Express the uncertainty as a percentage of the acceleration. This is the precision of your experiment. Enter the value in your data table. Using the example numbers from the last step, the precision would be

$$\frac{0.9}{9.9} \times 100\% = 9\%$$

6. Compare your measurement to the generally accepted value of *g* (from a textbook or other source). Does the accepted value fall within the range of your values? If so, your experiment agrees with the accepted value.

7. Inspect your velocity graph. How would the associated acceleration *vs*. time graph look? Sketch your prediction on paper. From the Main screen, select (Graph), then (Plots), then **Accel(m/s^2) vs Time**. Comment on any differences between the calculator's graph and your prediction. Trace across the acceleration values using your cursor keys. Note that the vertical scale of the graph does not include zero. Is the variation as large as it appears?

8. Find the average acceleration from the trace values. How does this compare with the acceleration value for the same drop, determined from the slope of the velocity graph?

EXTENSIONS

1. Use the distance *vs.* time data and a quadratic fit to determine *g*.

2. Display the acceleration *vs.* time plot and note the apparent variation in acceleration. Trace across the plot with the cursor keys, and read the acceleration values individually. Is the acceleration varying as much as it first appears?

3. Would dropping the Picket Fence from higher above the Photogate change any of the parameters you measured? Try it.

4. Would throwing the Picket Fence downward, but letting go before it enters the Photogate, change any of your measurements? How about throwing the Picket Fence upward? Try performing these experiments.

5. How would adding air resistance change the results? Try adding a loop of clear tape to the upper end of the Picket Fence. Drop the modified Picket Fence through the Photogate and compare the results with your original free fall results.

6. Investigate how the value of *g* varies around the world. For example, how does altitude affect the value of *g*? What other factors cause this acceleration to vary at different locations? How much can *g* vary at a location in the mountains compared to a location at sea level?

TEACHER INFORMATION

Experiment
5

Picket Fence Free Fall

1. The student pages with complete instructions for data collection using LabQuest App, Logger *Pro* (computers), EasyData or DataMate (calculators), and DataPro (Palm handhelds) can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. Dirty or scratched Picket Fences may give erratic results.

3. Picket Fences are available from Vernier Software (order code PF). You can make your own Picket Fences using clear plastic and black tape, but the tape tends to stretch as it is placed on the plastic. It is difficult to achieve precise results with a handmade fence. To use the supplied experiment file, the leading edge separation of the bars must be 5.00 cm.

4. It is important that the Picket Fence remain vertical during the fall. If not, the vertical distance between bars gets smaller and the results are off.

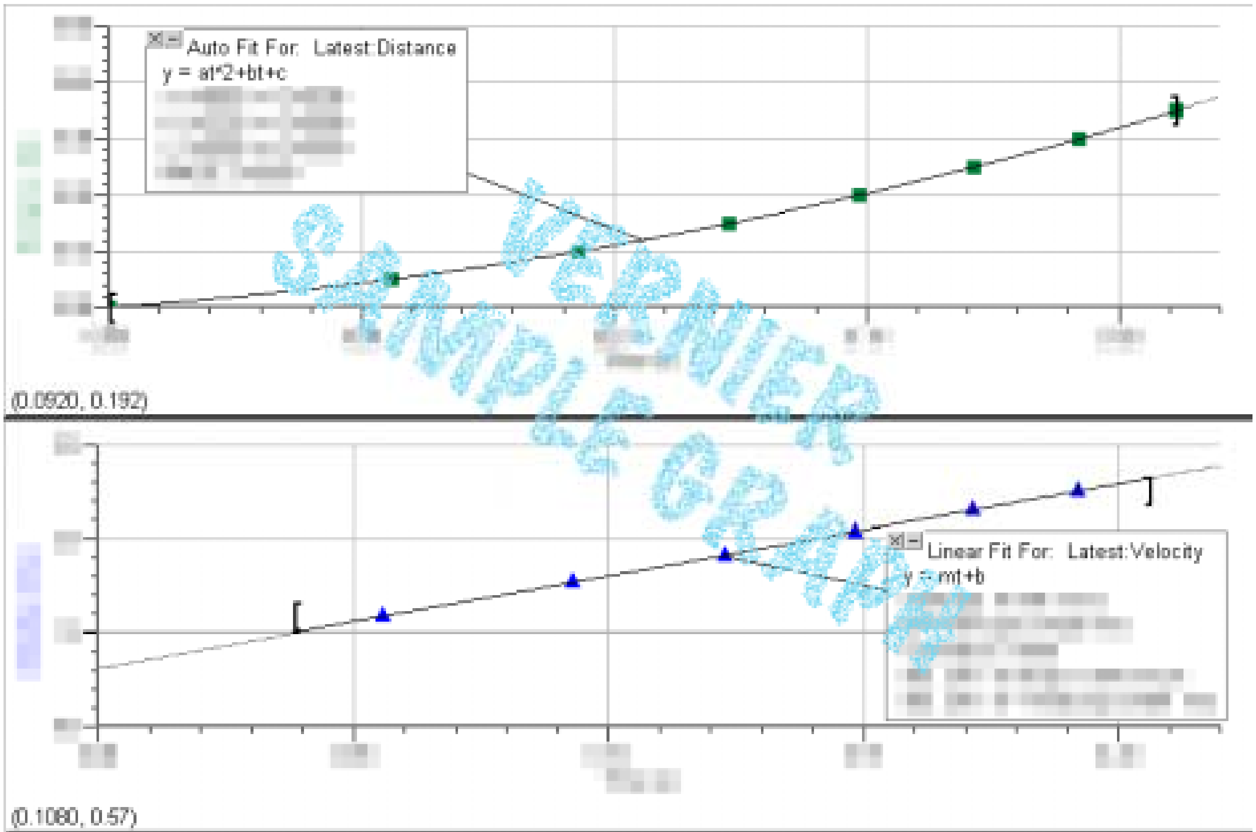
5. The Photogate must be rigidly fixed to avoid noise or systematic errors. In particular, do not hold the Photogate in your hand.

6. You may want to have the students drop the Picket Fence onto a rug so that it does not get scratched or damaged.

7. There is a good discussion of variation in the acceleration due to gravity on the earth's surface in the chapter on gravitation in *Fundamentals of Physics* by Halliday, Resnick, and Walker.

8. Another alternative to the extension in which students put a piece of tape on the end of the Picket Fence to add air resistance is to tape a coffee filter, parachute style, to the top of the picket fence and proceed as instructed.

SAMPLE RESULTS



Trial	1	2	3	4	5	6
Slope (m/s^2)	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx

	Minimum	Maximum	Average
Acceleration (m/s^2)	xxxx	xxxx	xxxx

Acceleration due to gravity, *g*	xxxx
Precision	xxxx

ANSWERS TO PRELIMINARY QUESTIONS

ANSWERS TO ANALYSIS QUESTIONS