

corrected (page 3), (8.)

## PICKET FENCE FREE FALL

### LAB MECH 20.COMP

From *Physics with Computers*, Vernier Software and Technology, 2003

### INTRODUCTION

We say an object is in *free fall* when the only force acting on it is the earth's gravitational force. No other forces can be acting; in particular, air resistance must be either absent or so small as to be ignored. When the object in free fall is near the surface of the earth, the gravitational force on it is nearly constant. As a result, an object in free fall accelerates downward at a constant rate. This acceleration is usually represented with the symbol  $g$ .

Physics students measure the acceleration due to gravity using a wide variety of timing methods. In this experiment, you will have the advantage of using a very precise timer connected to the computer and a Photogate. The Photogate has a beam of infrared light that travels from one side to the other. It can detect whenever this beam is blocked. You will drop a piece of clear plastic with evenly spaced black bars on it, called a Picket Fence. As the Picket Fence passes through the Photogate, the computer will measure the time from the leading edge of one bar blocking the beam until the leading edge of the next bar blocks the beam. This timing continues as all eight bars pass through the Photogate. From these measured times, the program will calculate the velocities and accelerations for this motion and graphs will be plotted.

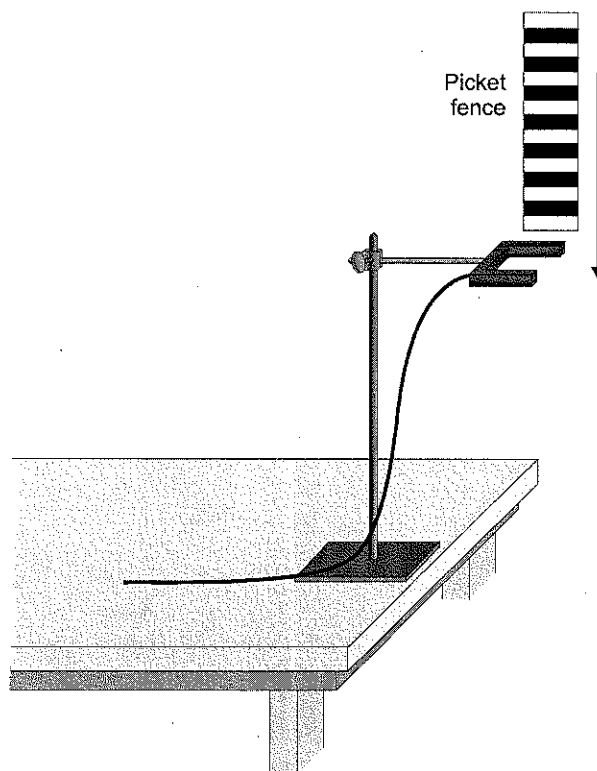


Figure 1

## PURPOSE

The purpose is to measure the acceleration of a freely falling body ( $g$ ) to better than 0.5% precision using a Picket Fence and a Photogate.

## MATERIALS

Power Macintosh or Windows PC  
LabPro or Universal Lab Interface  
Logger *Pro*  
Vernier Photogate

Picket Fence  
Clamp or ring stand to secure Photogate  
Foam for breaking fall

## 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 surface (such as a carpet) to land on.
2. Connect the Photogate to the DIG/SONIC 1 input of the Vernier computer interface.
3. Open the file "05 Picket Fence" in the *Physics with Computers* folder.
4. Observe the reading in the status bar of Logger *Pro* at the top of the screen. Block the Photogate with your hand; note that the GateState is shown as Blocked. Remove your hand and the display should change to Unblocked.
5. Click  to prepare the Photogate. 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. Click  to end data collection.

***Picket Fence Free Fall***

6. Examine your graphs. 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. To do this, click on the velocity graph once to select it, then click the Linear Fit button, , to fit the line  $y = mt + b$  to the data. Record the slope in the Data Table.
7. To establish the reliability of your slope measurement, repeat Steps 5 and 6 five more times. Do not use drops in which the Picket Fence hits or misses the Photogate. Record the slope values in the Data Table.

**DATA TABLE**

Trial	1	2	3	4	5	6
Slope (m/s <sup>2</sup> )						
	Minimum		Maximum		Average	
Acceleration (m/s <sup>2</sup> )						
Acceleration due to gravity, <i>g</i>			±		m/s <sup>2</sup>	
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 position vs. time graph for the free fall.
3. Describe in words the shape of the velocity vs. time graph. How is this related to the shape of the position 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 9.787, 9.757, and 9.815 m/s<sup>2</sup>, express your result as  $g = 9.76 \pm 0.06$  m/s<sup>2</sup>. Record your values in the Data Table.

MAX →

See correction

AV MIN

$$\frac{\text{MAX} - \text{MIN}}{2} = \frac{9.815 - 9.757}{2} = \frac{0.058}{2} = 0.029 \approx 0.03$$

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→ REPORT:  $9.787 \pm 0.03$

$9.779 \pm 0.03$

$\frac{0.06}{2} = 0.03$

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

$$\frac{0.06}{9.76} \times 100\% = 0.6\%$$

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. Now change the upper graph to acceleration vs. time. Do this by clicking on the  $y$ -axis label. Select Acceleration. Comment on any differences. You may want to rescale the graph so that the acceleration axis begins at zero.
8. Using the acceleration vs. time graph on the screen, click on the Statistics button, , to determine the average acceleration. 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 graph and a parabolic fit to determine  $g$ .
2. Would dropping the Picket Fence from higher above the Photogate change any of the parameters you measured? Try it.
3. 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.
4. 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.
5. 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?

# Picket Fence

(5) (1)

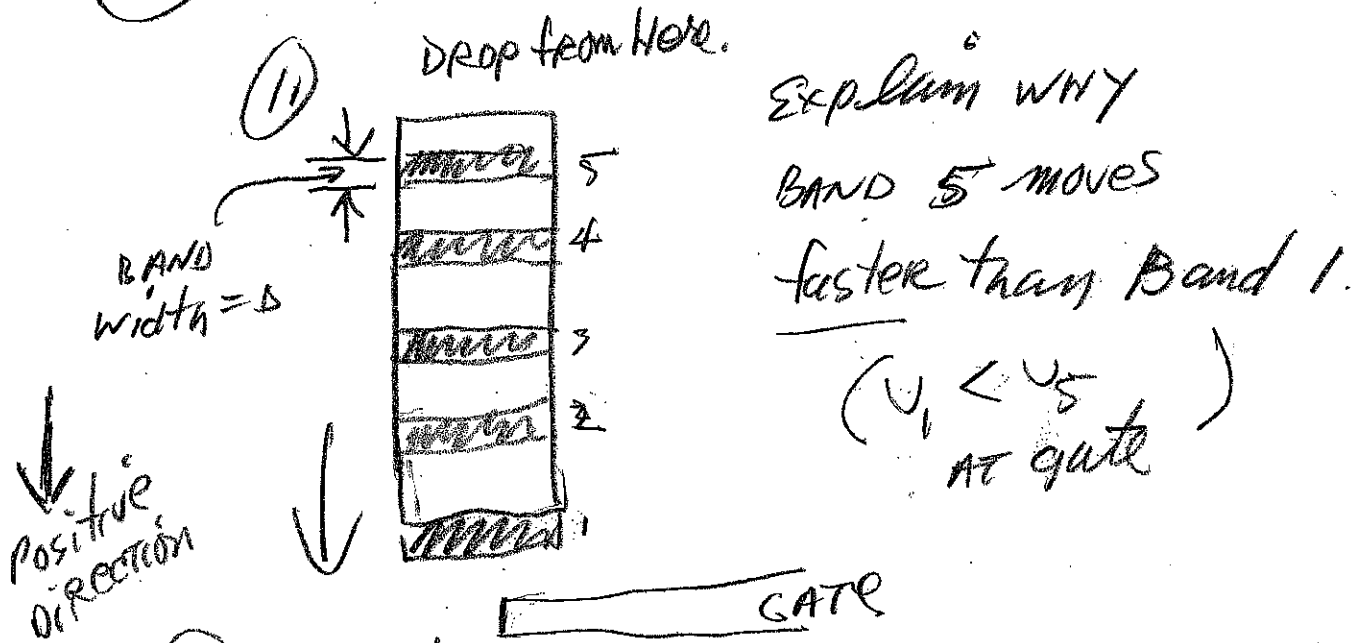
Lab Report : (on formal - DATA sheet + QUESTIONS)

(A) preliminary questions 1, 2, 3.

(B) analysis questions 1, 2, 3, 4, 5, 6, 7, 8

(C) Extensions: 1. only for now

(A) prelim. questions (hints)



(2)

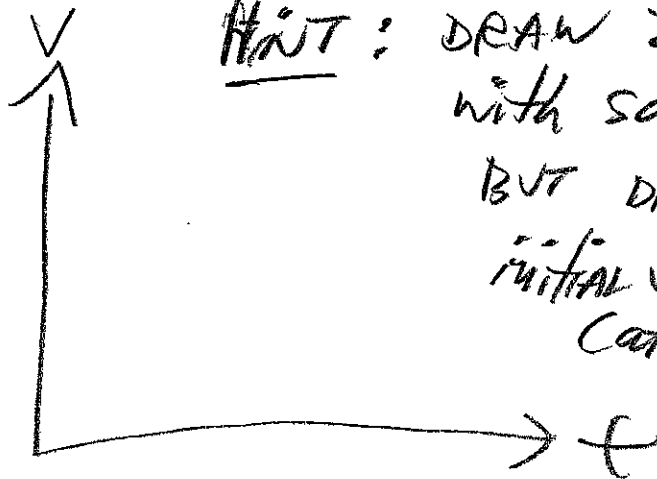
MAKE SKETCH OF SHARP. DESCRIBE SHARP

→ t

prelim. questions (cont's)

HINT: DRAW 2 SHAPES  
with same acceleration  
BUT different  
initial velocities  
(at  $t=0$ ).

(3)



(4)

(2)

(5) more shapes (as we learn!)

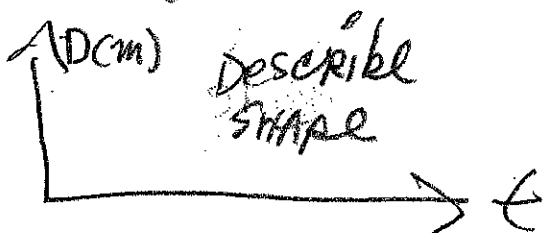
(B) analysis:

(1) six values of "g".  
identify MAX, MIN.

SHOW calculation of AVERAGE

$$= \frac{\sum_{i=1}^6 g_i}{6} = g_{AV}$$

(2)

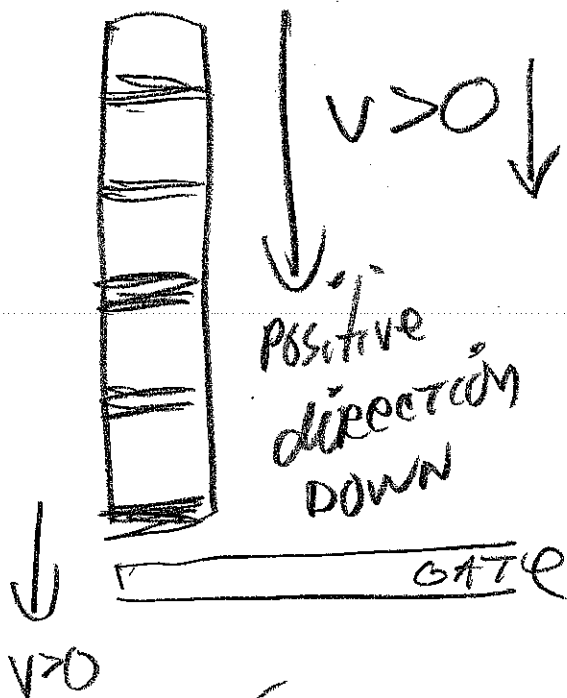
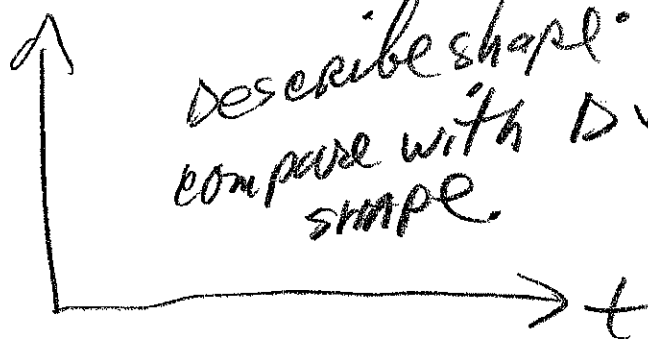


3.

v (velocity)

7.1 (3)

Describe shape.  
compare with D vs t  
SHAPE.



(4)

NOTE: FIND:

$$\Delta = \frac{\text{MAX} - \text{MIN}}{2} \text{ and ROUND TO ONE PLACE.}$$

Then write  $g_{AV} \pm \Delta$

round to same place as  $\Delta$

Example:  $9.2815 \pm 0.02954$

Report  $\rightarrow 9.28 \pm 0.03$





(9)

15

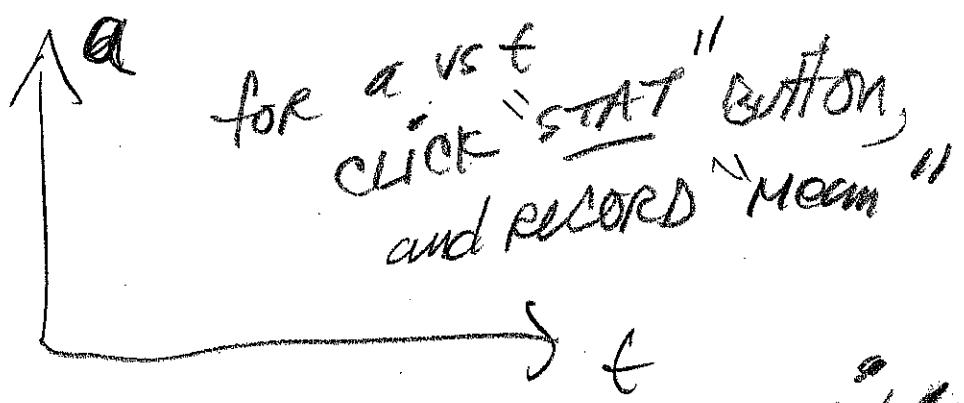
(7) given



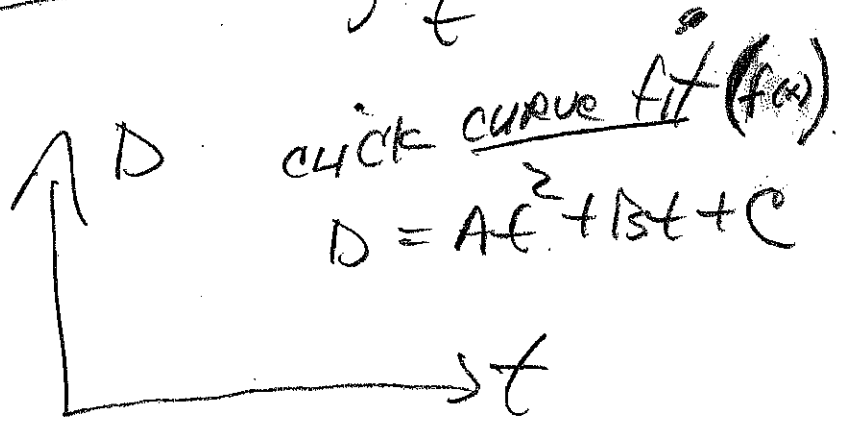
What does  $a$  vs  $t$  look like? (prediction)

confirm: click  $v$  (Y-AXIS)  
select acceleration and see  $a$  vs  $t$  (rescale  $y$ )

(8)



(C) exit



Identify A and compare with  $g$  AV.

# Picket fence!

(10.0) CG

## Picket Fence Free Fall

- Examine your graphs. 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. To do this, click on the velocity graph once to select it, then click the Linear Fit button, , to fit the line  $y = mt + b$  to the data. Record the slope in the Data Table.
- To establish the reliability of your slope measurement, repeat Steps 5 and 6 five more times. Do not use drops in which the Picket Fence hits or misses the Photogate. Record the slope values in the Data Table.

### DATA TABLE

RISE  $\Rightarrow$  0.0006 0.0008

Trial	1	2	3	4	5	6
Slope (m/s <sup>2</sup> )	9.7720	9.7800				

	Minimum	Maximum	Average
Acceleration (m/s <sup>2</sup> )			
Acceleration due to gravity, $g$		$\pm$	m/s <sup>2</sup>
Precision			%

### ANALYSIS

- From your six trials, determine the minimum, maximum, and average values for the acceleration of the Picket Fence. Record them in the Data Table.
- Describe in words the shape of the position vs. time graph for the free fall.
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- 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,  $\pm$  the uncertainty. Round the uncertainty to just one digit and round the average value to the same decimal place.

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