



PHYSICS

PHYSICS 20

LAB 03: Free Fall

2 Hours

INTRODUCTION:

All objects, near the surface of the earth falling through a vacuum, have an accepted constant acceleration due to gravity of $g = 9.81 \text{ m/s}^2$.

OBJECTIVES:

- To determine the experimental acceleration due to gravity of a free-falling object.
- To compare the experimental acceleration to the accepted acceleration of 9.81 m/s^2 .

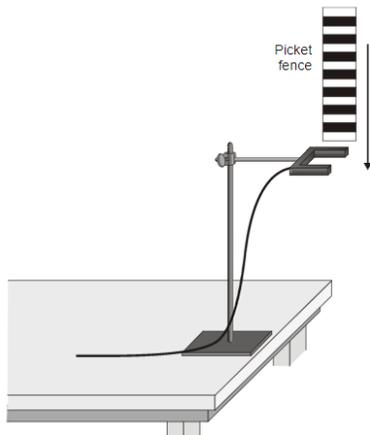
% Error < 10 %

APPARATUS:

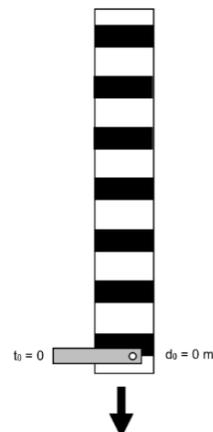
PASCO ME-8930 Smart Timer
PASCO ME-9204B Photogate
AC Adapter
PASCO ME-9377A Picket Fence
Microsoft Excel or similar program
Microsoft Word or similar program
Data Set Number

THEORY:

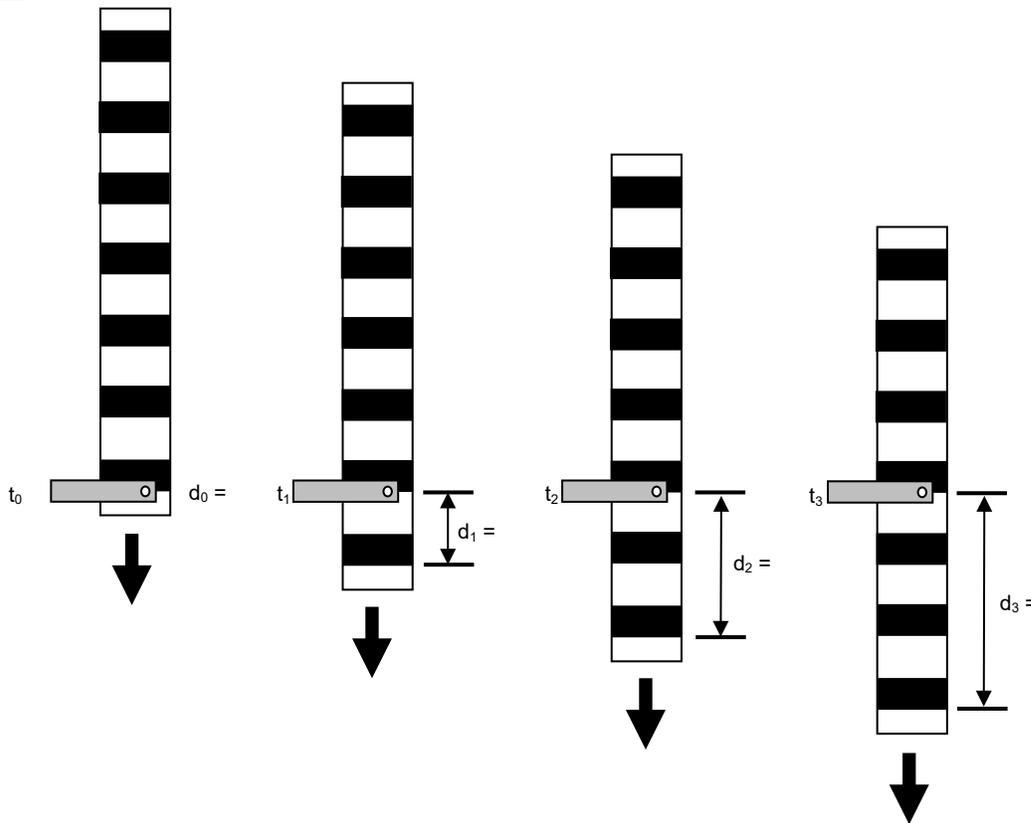
A plastic “picket fence” is a piece of transparent rectangular plastic on which regularly spaced black bars have been placed. The bars are 2 cm wide and are separated by 3 cm gaps. If such a plastic “picket fence” is allowed to fall under the influence of gravity, a photogate timer can record the time at which the leading edge of each black bar cuts the infrared beam and the experimental acceleration due to gravity can be determined. Basically, the photogate timer records how long it takes the leading edge of the lowest bar to fall distances which are multiples of 0.05 m (0.05 m, 0.10 m, 0.15 m, etc)



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Note that because of the experimental setup, the distance traveled in each time interval is always 0.05 m.



Within each time interval, the average speed can be calculated. The definition of average speed in a particular time interval is defined as:

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

That is, in the 1st time interval between t_0 and t_1 , the distance = $d_1 - d_0 = 0.05$ m and the time = $t_1 - t_0$. Therefore, the average speed in the 1st interval (v_{avg1}) is given by:

$$v_{\text{avg1}} = \frac{(d_1 - d_0)}{(t_1 - t_0)} = \frac{0.05 \text{ m}}{(t_1 - t_0)}$$

In the 2nd time interval between t_1 and t_2 , the distance = $d_2 - d_1 = 0.05$ m and the time = $t_2 - t_1$. Therefore, the average speed in the 2nd interval (v_{avg2}) is given by:

$$v_{\text{avg2}} = \frac{(d_2 - d_1)}{(t_2 - t_1)} = \frac{0.05 \text{ m}}{(t_2 - t_1)}$$

This pattern can be continued, and the general formula for the average speed (v_{avgn}) in the n^{th} time interval is given by:

$$v_{\text{avgn}} = \frac{0.05 \text{ m}}{(t_n - t_{n-1})} \quad \text{for } n = 1, 2, 3, 4, 5, 6$$

From the properties of uniformly accelerated motion, the average speed for any given time interval is equal to the instantaneous speed at the midway time of that interval. The midway time for any interval is defined as the average of the initial and final times for that interval.

That is, in the 1st time interval between t_0 and t_1 :

The midway time (t_{mid1}) is given by $t_{\text{mid1}} = \frac{(t_0 + t_1)}{2}$ and the instantaneous speed (v_1) at that time is equal to the average speed (v_{avg1}) for that interval and is given by $v_1 = \frac{0.05 \text{ m}}{(t_1 - t_0)}$.

In the 2nd time interval between t_1 and t_2 :

The midway time (t_{mid2}) is given by $t_{\text{mid2}} = \frac{(t_1 + t_2)}{2}$ and the instantaneous speed (v_2) at that time is equal to the average speed (v_{avg2}) for that interval and is given by $v_2 = \frac{0.05 \text{ m}}{(t_2 - t_1)}$.

This pattern can be continued, and the general formulas for the midway time (t_{midn}) and instantaneous speed (v_n) at that midway time for the n^{th} time interval are given by:

$$t_{\text{midn}} = \frac{(t_{n-1} + t_n)}{2} \quad \text{for } n = 1, 2, 3, 4, 5, 6$$

$$v_n = \frac{0.05 \text{ m}}{(t_n - t_{n-1})} \quad \text{for } n = 1, 2, 3, 4, 5, 6$$

Using these calculations for each interval, gives a set of instantaneous speed versus time data, which can be graphed or plotted and used to determine the experimental acceleration due to gravity.

If a plot is made of instantaneous speed on the y - axis versus time on the x - axis, the data should be fairly linear and the slope of the line of best fit (or Trendline) will be the experimental acceleration due to gravity as predicted by the kinematic formula:

$$v = a \cdot t + v_0$$

Note: the general equation for a line is $y = m \cdot x + b$ where m is the slope of the line.

PROCEDURE:

Note: For the online lab, use the Data Set Number assigned by your instructor to complete the lab and include it in the Initial Data Table, the Final Calculations Table, and the Conclusion! The Data Sets are given near the end section of this lab.

1. Plug the photogate cable into the socket marked “1” on the Pasco SMART TIMER. Set up the photogate head such that the u-shaped head is level with the ground and the picket fence can fall freely through the beam.
2. Plug in the AC adapter to the wall plug and to the Pasco SMART TIMER. Turn on the unit and press the red “1” button until the selected measurement is “Time”.
3. Press the blue “2” button until the mode selected is “Fence”
4. Hold the picket fence above the photogate head such that the bottom of the lowest black bar is just slightly above the top of the u-shaped photogate head.
5. Press the black “3” button to arm the SMART TIMER.
6. Let the picket fence drop and fall through the photogate. If the fence contacts the side of the photogate during the run, ignore the run and start over.
7. Once the fence has fallen through the photogate, press the black “3” button again.
8. Record the measured times on the data sheet provided with the lab. To step through the recorded values, press the blue “2” button repeatedly. There should be 6 non-zero readings.
9. Record the measured times in the Initial Data Table provided. Note: a Microsoft Word document with an Initial Data Table has been provided, so you can enter the values on your computer.
10. Calculate the quantities asked for and record them in the Final Calculations Table. State the quantities precise to four decimal places each. **Given the variable name and units are given in the header of table, only the number values should be entered in the table.** Note: a Microsoft Word document with a Final Calculations Table has been provided so you can type the values using your computer.
11. **Using the last two columns of the Final Calculations Table**, create a Scatter Plot Chart of Instantaneous Speed vs Midway Time using Microsoft Excel (or similar program). Add a Linear Trendline and Display the Equation on the chart. Once completed, copy and paste the chart into a Word document and include it your submission. **See sample chart provided for the format required.** If needed, find an educational video online that shows the steps needed to accomplish this.
12. Using the slope of the Trendline, state the Experimental Acceleration precise to three significant digits in the Final Calculations Table provided. Ensure to include the units of m/s^2 .

13. **Using the Experimental Acceleration and the Accepted Acceleration, calculate the % Error and state it in the Final Calculations Table provided. Ensure to use the proper significant digit rules when determining the final answer and include the unit of %.**
14. **Write a conclusion.**
15. **Compile your completed lab and submit it to your lab instructor by the due date.**

Your submitted lab should include:

**Initial Data Table
Calculations
Chart
Final Calculations Table
Conclusion**

See your lab instructor for a more detailed format for the completed lab submission.



INITIAL DATA TABLE

Date Set Number =

Measured Time	Distance
$t_0 = 0.0000$ s	$d_0 = 0.000$ m
$t_1 =$	$d_1 = 0.050$ m
$t_2 =$	$d_2 = 0.100$ m
$t_3 =$	$d_3 = 0.150$ m
$t_4 =$	$d_4 = 0.200$ m
$t_5 =$	$d_5 = 0.250$ m
$t_6 =$	$d_6 = 0.300$ m

Accepted Acceleration =

Allowable % Error <

CALCULATIONS:

Create a title section named Calculations and show a “sample calculation” for each of the following calculations. For each calculation, ensure to include:

Title

Formula

**Substitution into formula using values and units from first interval only as a “sample calculation”.
(Note: The calculations for the other intervals should be done on your calculator but not shown!)**

Final answer

Determining Midway Time

$$t_{\text{midn}} = \frac{(t_{n-1} + t_n)}{2} \quad \text{for } n = 1, 2, 3, 4, 5, 6$$

Determining Instantaneous Speed

$$v_n = \frac{0.05 \text{ m}}{(t_n - t_{n-1})} \quad \text{for } n = 1, 2, 3, 4, 5, 6$$

Determining % Error

$$\% \text{ Error} = \frac{|\text{Experimental Acceleration} - \text{Accepted Acceleration}|}{\text{Accepted Acceleration}}$$



FINAL CALCULATIONS TABLE

Date Set Number =

Measured Time	Distance (m)	Midway Time (s)	Instantaneous Speed (m/s)
$t_0 = 0.0000$ s	$d_0 = 0.000$ m		
$t_1 =$	$d_1 = 0.050$ m		
$t_2 =$	$d_2 = 0.100$ m		
$t_3 =$	$d_3 = 0.150$ m		
$t_4 =$	$d_4 = 0.200$ m		
$t_5 =$	$d_5 = 0.250$ m		
$t_6 =$	$d_6 = 0.300$ m		

Accepted Acceleration =

Experimental Acceleration =

% Error =

CONCLUSION:

Create a titled section named Conclusion. This section will briefly sum up the lab and should contain five main points (objectives, data set used, expectations, results, and possible sources of error).

The conclusion should be written in the third person, past tense and use complete sentences in paragraph form.

Possible sources of error should include possible errors due to the instruments being used to obtain the measurements and air friction.

If needed, see the sample conclusion provided in Lab 1.



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Lab 3 Data Sets

Data Set 1	
$t_0 =$	0.0000 s
$t_1 =$	0.0449 s
$t_2 =$	0.0788 s
$t_3 =$	0.1063 s
$t_4 =$	0.1312 s
$t_5 =$	0.1523 s
$t_6 =$	0.1729 s

Data Set 2	
$t_0 =$	0.0000 s
$t_1 =$	0.0397 s
$t_2 =$	0.0692 s
$t_3 =$	0.0961 s
$t_4 =$	0.1200 s
$t_5 =$	0.1407 s
$t_6 =$	0.1602 s

Data Set 3	
$t_0 =$	0.0000 s
$t_1 =$	0.0454 s
$t_2 =$	0.0788 s
$t_3 =$	0.1067 s
$t_4 =$	0.1312 s
$t_5 =$	0.1524 s
$t_6 =$	0.1728 s



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Lab 3 Data Sets

Data Set 4	
$t_0 =$	0.0000 s
$t_1 =$	0.0417 s
$t_2 =$	0.0736 s
$t_3 =$	0.1005 s
$t_4 =$	0.1245 s
$t_5 =$	0.1467 s
$t_6 =$	0.1669 s

Data Set 5	
$t_0 =$	0.0000 s
$t_1 =$	0.0648 s
$t_2 =$	0.1044 s
$t_3 =$	0.1362 s
$t_4 =$	0.1615 s
$t_5 =$	0.1856 s
$t_6 =$	0.2062 s

Data Set 6	
$t_0 =$	0.0000 s
$t_1 =$	0.0494 s
$t_2 =$	0.0843 s
$t_3 =$	0.1136 s
$t_4 =$	0.1377 s
$t_5 =$	0.1599 s
$t_6 =$	0.1812 s



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Lab 3 Data Sets

Data Set 7	
$t_0 =$	0.0000 s
$t_1 =$	0.1011 s
$t_2 =$	0.1434 s
$t_3 =$	0.1746 s
$t_4 =$	0.2016 s
$t_5 =$	0.2252 s
$t_6 =$	0.2469 s

Data Set 8	
$t_0 =$	0.0000 s
$t_1 =$	0.0654 s
$t_2 =$	0.1045 s
$t_3 =$	0.1362 s
$t_4 =$	0.1611 s
$t_5 =$	0.1851 s
$t_6 =$	0.2065 s

Data Set 9	
$t_0 =$	0.0000 s
$t_1 =$	0.0397 s
$t_2 =$	0.0699 s
$t_3 =$	0.0966 s
$t_4 =$	0.1196 s
$t_5 =$	0.1413 s
$t_6 =$	0.1605 s



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Lab 3 Data Sets

Data Set 10	
$t_0 =$	0.0000 s
$t_1 =$	0.1013 s
$t_2 =$	0.1432 s
$t_3 =$	0.1748 s
$t_4 =$	0.2011 s
$t_5 =$	0.2258 s
$t_6 =$	0.2477 s

Data Set 11	
$t_0 =$	0.0000 s
$t_1 =$	0.0391 s
$t_2 =$	0.0692 s
$t_3 =$	0.0968 s
$t_4 =$	0.1195 s
$t_5 =$	0.1401 s
$t_6 =$	0.1605 s

Data Set 12	
$t_0 =$	0.0000 s
$t_1 =$	0.0426 s
$t_2 =$	0.0746 s
$t_3 =$	0.1006 s
$t_4 =$	0.1249 s
$t_5 =$	0.1458 s
$t_6 =$	0.1659 s



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Lab 3 Data Sets

Data Set 13	
$t_0 =$	0.0000 s
$t_1 =$	0.0648 s
$t_2 =$	0.1042 s
$t_3 =$	0.1356 s
$t_4 =$	0.1621 s
$t_5 =$	0.1848 s
$t_6 =$	0.2067 s

Data Set 14	
$t_0 =$	0.0000 s
$t_1 =$	0.0392 s
$t_2 =$	0.0693 s
$t_3 =$	0.0961 s
$t_4 =$	0.1202 s
$t_5 =$	0.1407 s
$t_6 =$	0.1602 s

Data Set 15	
$t_0 =$	0.0000 s
$t_1 =$	0.0413 s
$t_2 =$	0.0740 s
$t_3 =$	0.1006 s
$t_4 =$	0.1248 s
$t_5 =$	0.1461 s
$t_6 =$	0.1665 s

Sample Chart

