

Lab Connections

YOUR CONNECTION FOR QUALITY SCIENTIFIC EDUCATIONAL LABORATORY EQUIPMENT

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WARNING: ADULT SUPERVISION REQUIRED. PRODUCT IS NOT A TOY. THEY ARE FOR EDUCATIONAL / LABORATORY USE ONLY. THEY ARE NOT FOR USE BY CHILDREN 12 & UNDER.

#638-21 The Deluxe Free Fall Apparatus



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Method 1: Using $y_0 = 0$

The reason the steel ball begins to fall (at its displacement and velocity both equal 0). Therefore, the last equation (2) can be simplified and rearranged to solve for g .

$$y = \frac{1}{2}gt^2 + v_0t + y_0$$

$$y = \frac{1}{2}gt^2$$

$$g = \frac{2y}{t^2}$$

Method 2: Measuring time

The "Measuring" feature on the Smart Timer measures the amount of time the light is each photogate is blocked by an object. This information can be used to calculate the velocity and gravitational acceleration of the steel ball if $v_0 = 0$ and the diameter of the steel ball is known.

$$v = \frac{d}{t_1}$$

$$v = \frac{d}{t_2}$$

$$g = \frac{2(y_2 - y_1)}{t_2^2 - t_1^2}$$

v = velocity of free falling object over time

t = amount of time the ball falls

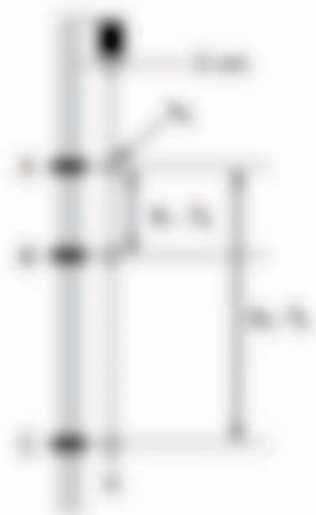
d = amount of time the ball blocks the photogate

d = diameter of ball = 0.025m

g = gravitational acceleration (9.81 m/s²) over the height

Method 3: Interval time

g can also be calculated by using the amount of time it takes for the steel ball to travel between the photogates. Consider the diagram where the photogates are positioned at points A, B and C on the free fall stand. The distance between points A and B is y_1 and the time the ball travels between A and B is t_1 . The distance between points B and C is y_2 and the time the ball travels between B and C is t_2 . If the steel ball starts to fall at an initial velocity of 0, then we can use the following equations to solve for g .



$$y = \frac{1}{2}gt^2 + v_0t + y_0$$

$$y = \frac{1}{2}gt^2$$

$$g = \frac{2(y_2 - y_1)}{t_2^2 - t_1^2}$$

Calculating Gravitational Acceleration and Initial Velocity

Objectives:

1. Calculate the gravitational acceleration of Earth and compare to the accepted value using multiple methods.
2. Create a displacement vs. time graph to show how the amount of displacement of a free falling object varies with time.
3. Develop and perform a procedure to calculate the velocity of the steel ball as it travels through each of the photogates.
4. Create a velocity vs. time graph to show how the velocity of a free falling object changes through time.

Materials:

1. Science First Fall apparatus and all included parts
2. Calculator
3. Additional writing paper and graph paper if needed

Procedure Part 1: Calculating the Gravitational Acceleration using v_0 and $y_0 = 0$

1. Assemble the Science First Fall apparatus according to the assembly instructions.
2. Place the electromagnet so that the steel ball is positioned at 0 cm.
3. Place the photogates at positions of your choice. Do not place the photogates very close to each other or very close to the electromagnet. Record these positions in table 1 for trial 1. Proceed through steps 4-7 for trial 1.
4. Turn on the Smart Timer and electromagnet. Put a steel ball on the electromagnet. Make sure that the Smart Timer is in "Timing" mode.
5. When you are ready to perform a trial, turn the switch on the Smart Timer to the "Release" position. The timer will start immediately. Record the time when the the steel ball is caught each of the photogates in table 1. (Remember to include the units, s or ms).
6. Calculate the gravitational acceleration using the times for each photogate and record in table 1.
7. Calculate the percent error of gravitational acceleration from the accepted value, 9.81 m/s². Record in table 1.
8. Move all three photogates to different positions on the stand. Repeat steps 4-7 for trial 2. Fill in table 1.
9. Create a displacement vs. time graph for a free falling object using all the data from both trials. The graph must include at least 10 data points. Describe the graph's trend.

Procedure Part 2: Calculating the Gravitational Acceleration using intervals

1. Place the electromagnet so that the steel ball is positioned at 0 cm.

- Place the photogates at positions of your choice. Do not place the photogates very close to each other or very close to the electromagnet. Record these positions in table 2 under trial 1. Proceed through steps 1 - 4 for trial 1.
- Turn on the Smart Timer and electromagnet. Put a steel ball on the electromagnet. Make sure that the Smart Timer is in "Interval" mode.
- When you are ready to perform a trial, turn the switch on the Smart Timer to the "Release" position. The timer will start immediately. Record the time when the the steel ball is seen through the intervals between the 1st and 2nd photogates and 1st and 3rd photogates in table 1 for the appropriate trial. (Remember to include the units, s or ms.)
- Calculate the gravitational acceleration and record in table 1.
- Calculate the percent error of gravitational acceleration from the accepted value, 9.81 m/s². Record in table 1.
- Place all three photogates in different positions on the stand. Record these new positions in table 2 under trial 2. Repeat steps 1 - 4 for trial 2.

Procedure Part 3: Calculating Velocity and Gravitational Acceleration using blocking time

Create a procedure that:

- Calculates the velocity and gravitational acceleration using the "Blocking time" mode on the Smart Timer.
- Allows data needed to create a velocity vs. time graph.

Perform the procedure and create a velocity vs. time graph. Describe the graph's trend. What does the slope of the graph represent? Calculate the percent error of gravitational acceleration from the accepted value. Create data tables and use additional pages if needed.

Procedure Part 1: Calculating the Gravitational Acceleration using v_0 and $y_0 = 0$

Table 1

Trial	Photogates	Photogate Position (m)	Time (s)	Calculated g (m/s ²)	Percent Error
1	1				
2	2				

Teacher Notes: Calculating Gravitational Acceleration and Initial Velocity

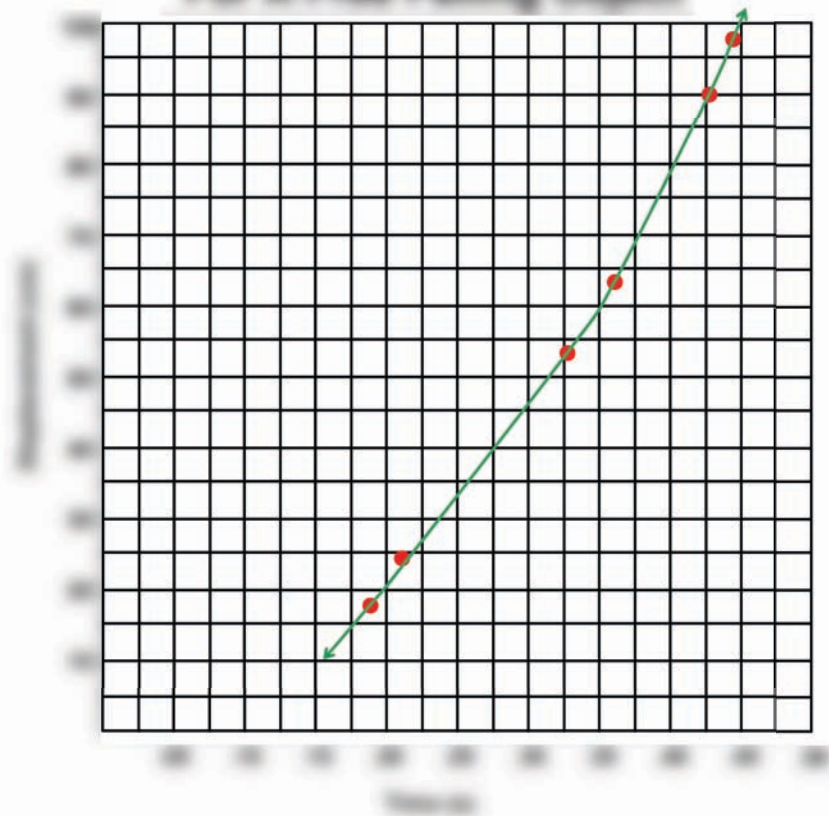
Procedure Part 1: Calculating the Gravitational Acceleration using v_0 and $y_0 = 0$

Sample Data:

Table 1

Run	Height	Height Feet m	Time s	Time s	Time s
1	1	0.30	0.25	0.25	0.25
	2	0.60	0.35	0.35	0.35
	3	0.90	0.45	0.45	0.45
2	1	0.30	0.25	0.25	0.25
	2	0.60	0.35	0.35	0.35
	3	0.90	0.45	0.45	0.45

**Displacement vs. Time
For A Free Falling Object**



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The graph shows a positive trend in displacement as time increases. There is a slight positive curvature to the data which means that displacement is increasing at an increasing rate. In other words, the free falling object is accelerating.

Procedure Part 2: Calculating the Gravitational Acceleration using intervals

Table 2

Trap	Photogate	Photogate Time
1	1	0
	2	0
	3	0
2	1	0
	2	0
	3	0

Table 3

Trap	Photogate Interval	Interval Distance (cm)	Interval Time (s)	Calculated g (m/s ²)	Percent Error
1	1-2	40	0.1742	9.80	1.5
	2-3	75	0.2007		
2	1-2	20	0.08810	9.80	0.20
	2-3	40	0.1406		

Procedure Part 3: Calculating Velocity and Gravitational Acceleration using blocking time**Sample Procedure and Table**

1. Place the electromagnet so that the steel ball is positioned on it.
2. Place each photogate at any position on the free fall stand. Record each photogate's position in the table for trap 1.
3. Turn on the Smart Timer and turn the electromagnet to "Release". Put a steel ball on the electromagnet. Make sure that the Smart Timer is in "Blocking" mode.
4. When you are ready to perform a trial, turn the electromagnet to "Release". Record the blocking time for each photogate in the table.
5. Calculate the velocity of the steel ball as it travels through each photogate given that the diameter of the steel ball is 10mm. Record the velocities in the table below.
6. Do not move the photogates. Switch the mode on the Smart Timer to "Timing" and the electromagnet to "Release". Place the steel ball on the electromagnet.

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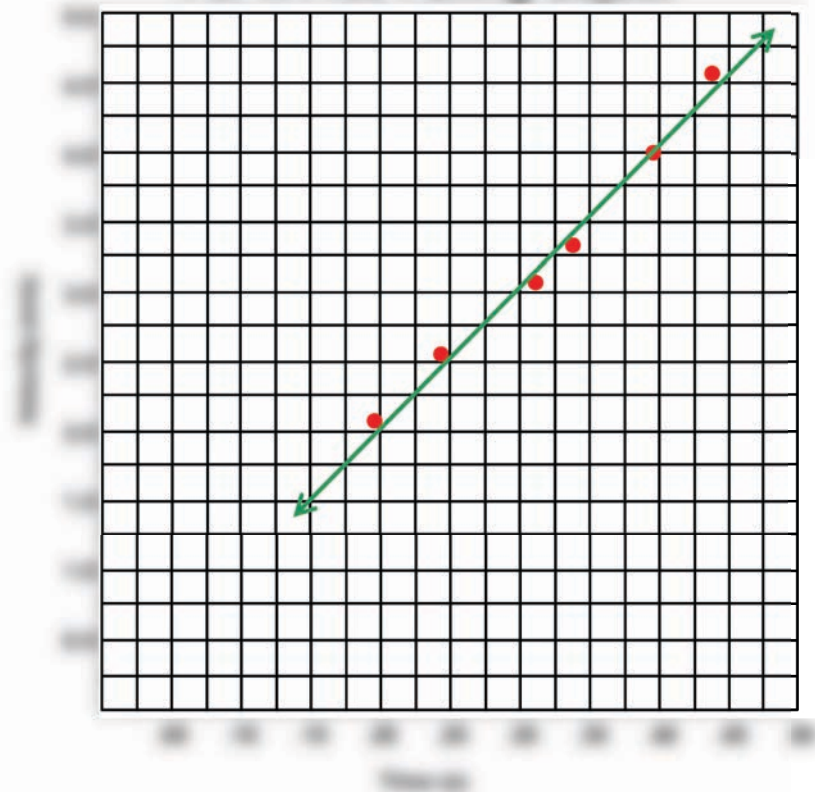
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- When you are ready to perform a trial, turn the video camera on "Release". Record the time it takes for the steel ball to reach each photogate in the table. Record in the table.
- Calculate the gravitational acceleration at each photogate from the table. Record in the table.
- Calculate the percent error of gravitational acceleration from the accepted value (9.81 m/s²). Record in the table.
- Move the position of each photogate and record these new positions in the table for trial 2. Repeat steps 1-3 for trial 2.
- Create a velocity vs. time graph using the 6 data points from the procedure.

Trial	Photogate	Photogate Position (m)	Measuring Time (s)	Velocity (m/s)	Falling Time (s)	Gravitational Acceleration (m/s ²)	Percent Error
1	1	20	1.10	1.80	200.0	15.47	5.7
	2	40	1.40	1.90	150.0	9.80	1.0
	3	70	1.50	1.90	100.0	15.11	5.1
2	1	20	0.90	1.80	180.7	15.50	7.0
	2	40	1.00	1.90	150.0	9.80	1.0
	3	60	1.10	1.90	120.7	15.40	6.6

Velocity vs. Time
For A Free Falling Object



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