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BOUNCING BALL

OBJECTIVE

To collect and interpret motion data of a bouncing ball using a motion probe and Data Studio software; to predict, observe, and explain the position, velocity, and acceleration graphs of data from a bouncing ball; Calculate the acceleration of gravity from the motion graphs

ACTIVITY 1 OBSERVE AND PREDICT

1. **Drop a tennis (or other) ball and observe the motion as it bounces.**
2. **Draw a graph of the motion for 2 bounces (*y vs. t*). Explain it.**
3. When are forces acting on the ball**?** How can you tell there are forces **from observing the motion? Don't forget that the directions of the forces are just as important as their size.**
4. Draw a graph **of the velocity of the ball for 2 bounces.** How do forces affect this graph? **Describe both direction and magnitude.**

ACTIVITY 2 SET-UP

5 **Attach a crossbar (horizontal rod) to a lab stand and position it at the edge of your table with the crossbar as low as possible.**

6 **Attach the Motion Probe to the crossbar so the sensor is pointing directly down toward the floor. Secure the probe to the crossbar by tightening the black knob on the side of the probe.**

7 **Set the switch on the side of the probe to "people" rather than "cart."**

8 **Open the Data Studio icon named Bouncing Ball. Connect the motion probe to the laptop via the USB link. You are now ready to begin collecting data.**

ACTIVITY 3 TAKING DATA

9 **Measure the distance from the sensor on the probe to the floor with your meter stick.** Record this measurement.

10. **Let one partner hold the ball directly under the probe (at least 15 cm from sensor). The other partner should measure and** record the distance **between the sensor and the ball.**
11. **Press START in Data Studio to begin recording data. Release the ball and allow it to drop to the floor. Remove your hand quickly.**
12. **Allow the ball to continue bouncing until it comes to rest. Press STOP.**

ACTIVITY 4 GRAPHS

13. **Observe the graph of position vs. time. Explain how and why this graph differs from your predicted graph.**
14. **Find RUN #1 under the VELOCITY icon in the DATA MENU and drag it in your graph. A new velocity vs. time graph should appear below the position vs. time graph with matching time scales.**
15. **If the time scales (*x*-axis) are not matched, click the ALIGN MATCHING X-SCALES button on the graph toolbar.**
16. **Observe the graph of velocity vs. time.**

ACTIVITY 5 ANALYSIS

17. Calculate by hand the slope of the velocity *vs.* time graph **in the region where the ball is dropping to the floor. Show your calculation.**
18. **Use the LINEAR FIT tool in Data Studio to produce a computer-generated slope of the region of the velocity vs. time graph where the ball is dropping to the floor.** Record the value of the slope generated by the computer.
19. **Repeat STEPS 11 – 18 two more times.** Record your data. **You should have 3 data sets. (You may want to display RUN #2 and RUN #3 data in their own graphs, and delete these runs from your RUN #1 graph.)**

ACTIVITY 6

20. **Find the initial height of the ball from the position vs. time graph for each trial.** Record these values.
21. **Subtract the distance between ball and sensor measurement from the distance between floor and sensor. This is the measured initial height.** Does it match the initial height generated by the graph?
22. **For each trial, determine from the position vs. time graph the maximum heights of the first 2 bounces.** Record these values.

Compare your results in each trial. Did the ball reach the same maximum heights after the first and second bounces for each trial?

23. **Analyze the position vs. time graphs. Did it appear that the ball reached the same maximum distance from the probe (the point where the ball hit the floor) for each bounce? If this distance changed, what might be the reason? Think carefully.**

ACTIVITY 7

24. **Compare your position vs. time graph with the velocity vs. time graph for each trial.** How did the velocity vs. time graph change **in relation to the position vs. time graph?**

25. **At what points was the velocity maximum?**

26. **At what points was the velocity zero?**

27. **At what points did velocity change direction?**

ACTIVITY 8

28. **In steps 17 and 18, you were asked to calculate the slope of the velocity *vs.* time graph for each trial.** What is the significance of this slope?

29. **Compare your results in 17 to your results in 18.** What is the percent difference for each trial? ***Hint:***

$$\text{percent difference } = \left|\frac{g_1 - g_2}{\frac{1}{2}\left(g_1 + g_2\right)}\right| \times 100\%.$$

30. **The accepted value for the acceleration of gravity near the surface of the earth is 9.81 m/s². Compare your LINEAR FIT results for the acceleration of gravity with the accepted value for each trial.** What is the percent error for each trial? ***Hint:***

$$\text{percent error } = \left|\frac{g_{\text{measured}} - g_{\text{accepted}}}{g_{\text{accepted}}}\right| \times 100\%$$

ACTIVITY 9

31. **For one of your trials (choose the best position graph), drag RUN # under the ACCELERATION icon in the DATA MENU and drop it in the corresponding position vs. time graph. A new graph of acceleration vs. time should appear with matching time scales. (If the time scales are not matching, click the ALIGN MATCHING X-SCALES tool in the graph toolbar.)**

32. **Click anywhere on the acceleration vs. time graph. Click on the SMART TOOL in the graph toolbar. Place the SMART TOOL on the curve of acceleration vs. time. (The x and y coordinates will turn the same color as the curve when it is properly positioned on the curve. You may need to zoom in to manipulate the tool.)**

33. **Move the SMART TOOL along the curve noting the time. Place the SMART TOOL on a section of the curve where the ball is experiencing free fall. Read the y-coordinate to determine the graph's values for acceleration.** Record these measurements**. How do these values compare with your calculations?**

34. Explain the sharp negative peaks **(spikes) in the observed acceleration data.**

ACTIVITY 10

35. **What are the sources of error in this experiment?**

SUMMARY

In this experiment, you should have accomplished the following goals:

Predict position *vs.* time, velocity *vs.* time, and acceleration *vs.* time graphs of a bouncing object.

Understand the relationship between these three graphs for a single moving object.

Calculate Percent Difference and Percent Error for your measurements.

Calculate the acceleration of the ball from the velocity *vs.* time graph.

Data sheets to hand in. Name ____________________

BOUNCING BALL

DATA AND WORK SHEETS

ACTIVITY 1

Draw a graph of the motion for 2 bounces (*y vs. t*) and explain it.

When are forces acting on the ball and how you can tell there are forces from observing the motion? **Don't forget that the directions of the forces are just as important as their size.**

Draw a graph of the velocity of the ball for 2 bounces. Explain how the forces affect this graph. **Make sure you describe the direction as well as the magnitude of the velocity.**

ACTIVITY 3

Measure the distance from the sensor probe to the floor with your meter stick. Record this measurement.

Hold the ball directly under the probe (at least 15 cm from sensor.) Measure and record the distance between the sensor and the ball.

Sensor to Floor (m)	Sensor to Ball (m)	Ball to Floor (m)

ACTIVITY 4

Explain how and why the computer graph differs from your predicted graph.

ACTIVITY 5

Calculate by hand the slope of the velocity vs. time graph **in the region where the ball is dropping to the floor. Show your calculation.**

Use the LINEAR FIT tool in Data Studio to produce a computer-generated slope of the region of the velocity vs. time graph where the ball is dropping to the floor. Record the values.

Repeat STEPS 13 – 18 two more times. Record your data. **You should have 3 data sets**

Data Set	Calculated Slope (m/s/s)	Linear Fit (m/s/s)
Data Set #1		
Data Set #2		
Data Set #3		

ACTIVITY 6

Find the initial height **of the ball from the position *vs.* time graph.**

Subtract the distance between ball and sensor measurement from the distance between floor and sensor measurement. This is the measured initial height.

Data Set	**Initial Height (graph) (m)**	**Meas. Initial Height (m)**
Data Set #1		
Data Set #2		
Data Set #3		

Do the values for the initial height match?

For each trial, determine the maximum heights of the first 2 bounces.

Data Set	**Height of Bounce 1 (m)**	**Height of Bounce 2 (m)**
Data Set #1		
Data Set #2		
Data Set #3		

Did the ball reach the same maximum heights after the first and second bounces for each trial?

Did the ball reach the same maximum distance from the probe (the point where the ball hit the floor) for each bounce? If this distance changed, what might be the reason?

ACTIVITY 7

How did the velocity *vs.* time graph change **in relation to the position?**

At what points was the velocity maximum?

At what points was the velocity zero?

At what points did velocity change direction?

ACTIVITY 8

In steps 17 & 18, you were asked to find the slope of the velocity vs. time graph for each of your trials. What is the significance of this slope?

Compare your results in step 17 to your results in 18. What is the percent difference for each trial?

Data Set	**Calculated Slope (m/s^2)**	**Linear Fit Slope (m/s^2)**	**Percent Difference**
Data Set #1			
Data Set #2			
Data Set #3			

Compare your LINEAR FIT results for *g* with the accepted value for each trial. What is the percent error for each trial?

Data Set	Measured Value g (m/s^2)	Accepted Value g (m/s^2)	Percent Error
Data Set #1			
Data Set #2			
Data Set #3			

ACTIVITY 9

Place the tool on a section of the curve where the ball is experiencing free fall. Read the y-coordinate to determine the graph's values for acceleration. **How do these values compare with your calculations?**

Data Set	Calculated Values (m/s^2)	Acceleration Graph (m/s^2)
Data Set #1		
Data Set #2		
Data Set #3		

Explain the sharp negative peaks **(spikes) in the observed acceleration data.**

ACTIVITY 10

What are the sources of error in this experiment?