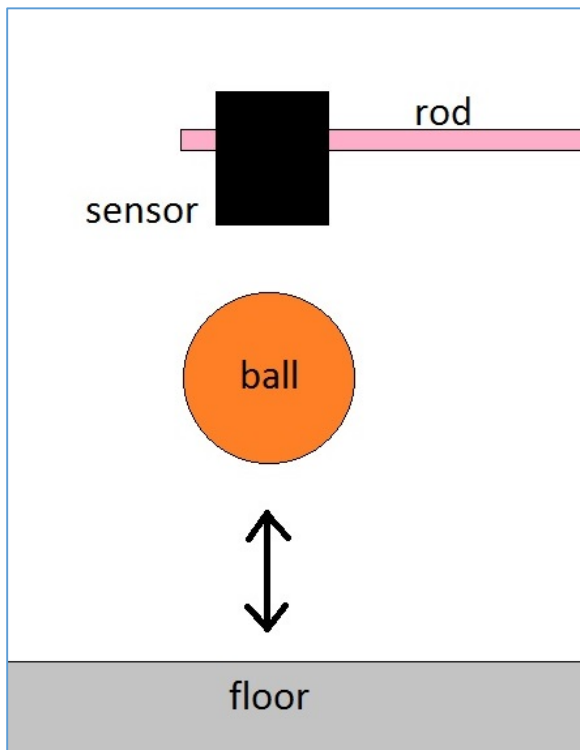


Uniformly Accelerated Motion: Bouncing Ball

Equipment	Quan
ball	1
motion sensor	1
3-legged stand and rod	1
	1
double V clamp	1
Small rod	1
Capstone on the computer	1

When you throw a basketball up, its acceleration after leaving your hands and before touching another object is constant. It's 9.81 m/s^2 straight down. This is true at every point along the trajectory, even if the ball is thrown straight up so that it's motionless for a moment at the trajectory peak.



Instead of throwing the ball straight up, we'll release it just below the motion sensor. It will fall to the floor and bounce back toward the sensor several times. One hundred times per

second, the sensor will continually measure the distance to the ball over several bounces. From these many successive distance measurements, the computer will calculate the speed of the ball throughout its motion, and will plot speed as a function of time on the screen. When the ball is traveling toward the sensor, the speed graph will have a negative value, and when the ball is traveling away from the sensor, it'll have a positive value. The graph should look something like this.

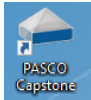





The graph crosses the horizontal axis when the ball's speed is zero, at the trajectory peak and during a bounce. During the bounce, the graph jumps from positive to negative, as the ball quickly changes direction and heads back toward the sensor.

Since the slope of the speed graph is the acceleration, it's clear from the figure above that the acceleration is constant between bounces (it's a straight line in this region),

including at the peak of the bounce, where the graph crosses the horizontal axis and the speed is zero.

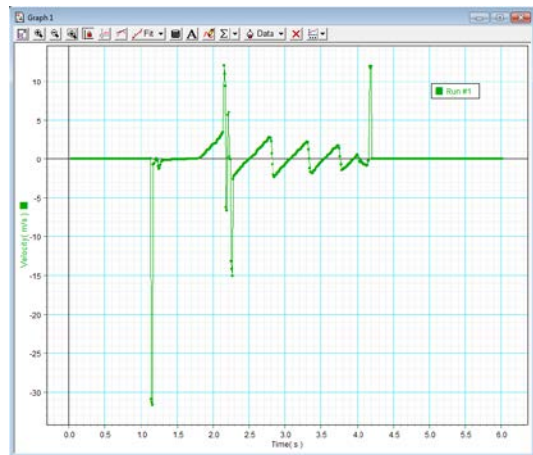
Procedure



1. Place the 3-legged stand and rod on the floor and mount the double-V clamp on the rod.
2. Mount the small rod in the double V clamp so that it's horizontal and stretches out over the floor.
3. Mount the motion sensor onto the small rod so that it points straight downward toward the floor.
4. Plug the yellow and black jack plugs of the motion sensor into ports 1 and 2 of the "DIGITAL INPUTS" on the 850 data collection box.
5. Double click the PASCO Capstone icon to start the software. 
6. Click on the "Hardware Setup" icon. 
7. You should see an image of the 850 box. Click on the port 1 plug in "Digital Inputs." Choose "Motion Sensor II." If you don't see an image of the 850 box, ask the instructor for help.
8. Click again on "Hardware Setup" to dismiss it.
9. The "Record" button should now be red, indicating that the Motion Sensor can collect data. 
10. Double click on the graph icon (on the right-hand side of the window) to bring up graph in the main page. 
11. Click <Select Measurement> on the vertical axis label and select "Velocity."
12. Click the Start button.

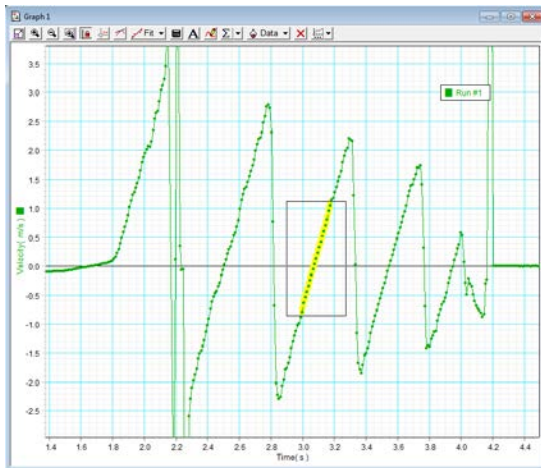
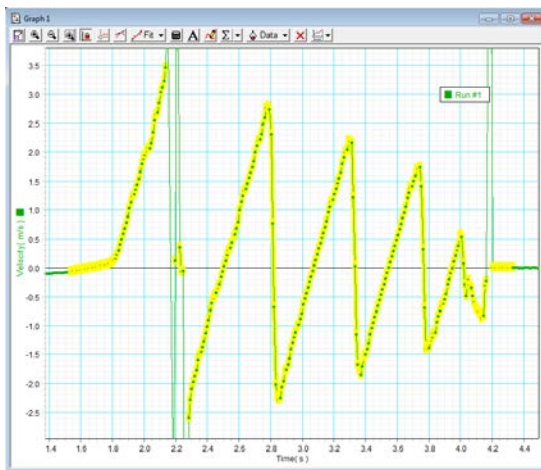
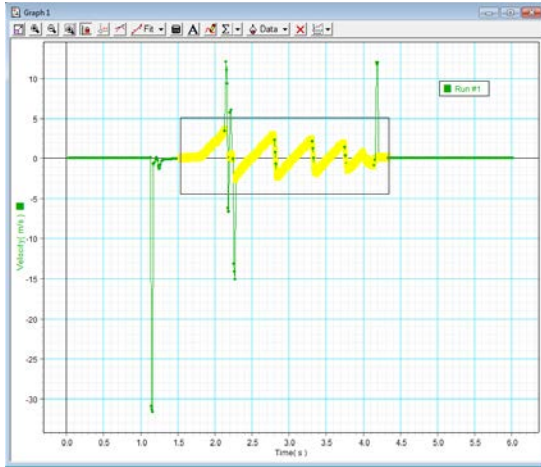
13. Hold the basketball just underneath the motion sensor and drop it. Allow it to bounce at least twice.


The ball's mass distribution is not spherically symmetric, and this can cause it to bounce away from a straight vertical line below the sensor. In order to make it bounce in a straighter line, put the ball on the table top and allow it to roll to a stable position. The ball's orientation will then be such that its center of mass is directly below its physical center. Dropping it in this orientation will cause it to bounce along a fairly vertical line.

14. Click the Stop button.
15. The graph will contain spurious data (unrelated to the motion of the ball), but you can identify the regions of the graph with useful data.

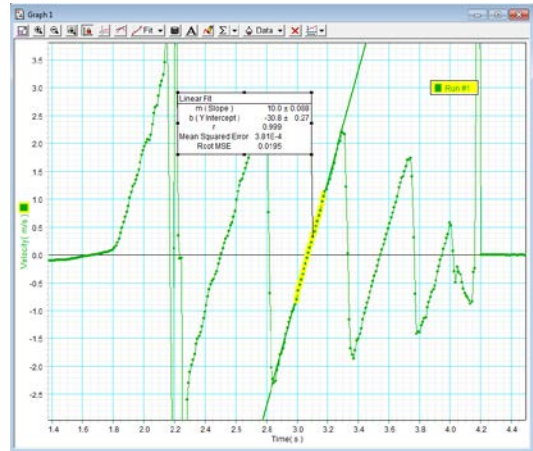


16. You can highlight a subsection of the data graph using a highlight box, which is obtained by clicking on the icon shown. 
17. Then click the  icon. This will expand the highlighted part of the graph (next figure).



18. You can then highlight a portion of the data that represents constant acceleration (next figure).
19. Then fit this part of the data with a straight line. Click the  button to do this.

20. In this case, the slope of the highlighted set of points is 10.0 m/s^2 .



21. Practice this procedure until you can reliably obtain a straight line segment like the ones in the figures above.
22. After learning to obtain good data, repeat the experimental process for a total of 5 successful runs.
23. Find the average of the slopes of your runs.
24. Find the percent error, taking 9.81 m/s^2 as the accepted value for the acceleration due to gravity.

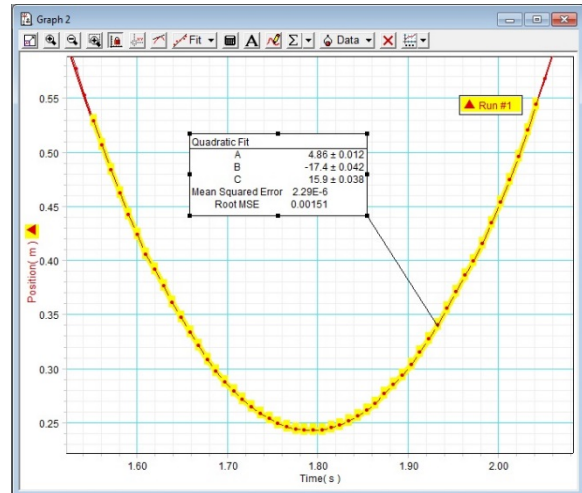
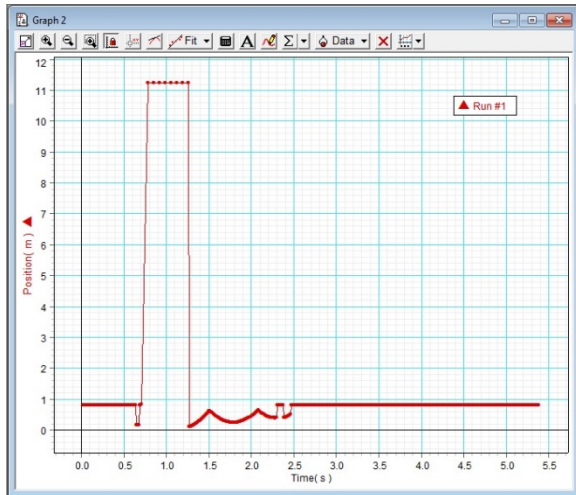
Trial	Slope (m/s^2)
1	
2	
3	
4	
5	
avg	
% error	

25. Print a copy of the data graph from Capstone. On it, mark all points that correspond to the following
 - a. Ball contacts floor.
 - b. Ball loses contact with floor.
 - c. Ball is at peak of bounce.

Plotting & Fitting Position vs Time

Now you'll run the same experiment again, but plot distance (from the sensor) vs time instead of velocity vs time. You can kill the graph window and bring up another one, this time choosing "position" instead of velocity.

26. Run the experiment again. The graph will now look something like the one below.



Trial	t^2 coefficient	acc m/s^2
1		
2		
3		
4		
5		
avg		
% error		

27. Highlight a clean section of parabolic curve, which will correspond to good position data.
28. Fit this curve section with a quadratic (figure below).
29. You'll recall from your study of kinematics that the position of an object with constant acceleration is related to time through:

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

The fit that Capstone just made is of the form:

$$y = At^2 + Bt + C$$

Thus the fit contains the ball's acceleration where $A = \frac{1}{2}a$. This is the acceleration due to gravity.

30. Record the coefficient and calculate the acceleration.