Lab 3 - projectile motion part 1

Learning Outcomes

1. Learn how to use kinematics equations to make predictions based on a physical model.
2. Develop skills in creating and performing scientifically sound experiments that make experimental determinations and predictions of unknown quantities.
3. Use statistical methods, including mean, standard deviation of the mean, and standard error, to analyze the results of a set of measurements.

Materials and Apparatus

1. spring gun
2. “projectile”
3. carbon paper
4. plain paper
5. measuring stick
6. Computer, data interface, and photogate sensors

Safety Awareness

Be aware of your surroundings when working with the spring gun and the projectile. The projectile may move extremely fast and cause injury if it strikes someone. Make sure everyone in the vicinity of the launcher is out of the projectile path and aware of each pending launch.

Activity – Determining launch speed.

The purpose of this activity is to determine the launch speed of a projectile. This launch speed may be used for a follow-up activity.

Set-up

1. Mount the spring gun at a vertical distance h above the target that the ball will strike.
2. Set up the computer, sensors, and data interface so that you are able to record the ball’s launch speed.

Acquire the Data

You will be collecting your data in two different ways.

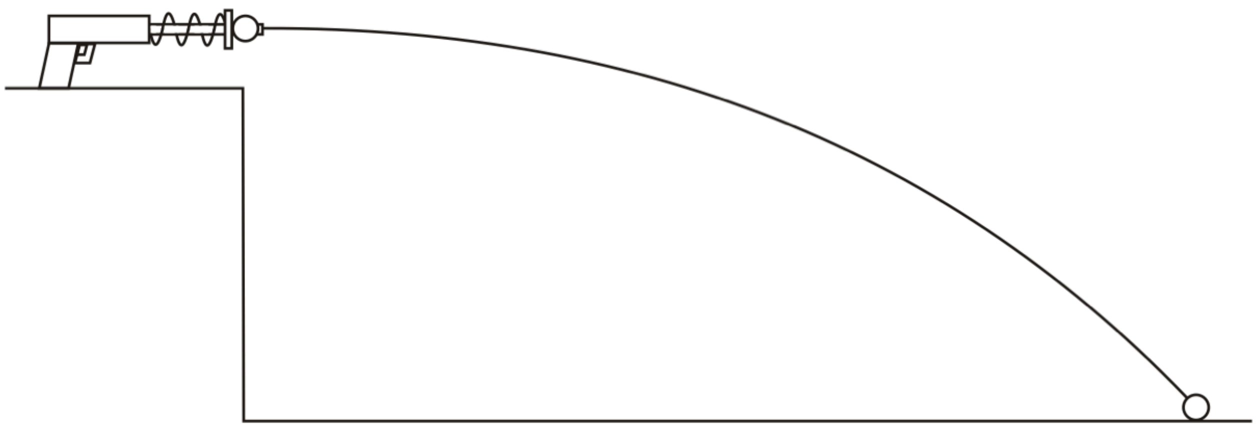
Note: Please read **Method 2** before beginning your data runs. You will need to record data for Method 2 for each shot you make.

Method 1:

Use your data interface and photogate sensors to measure the launch speed for each shot. As directed by the instructor, set up the interface so that you can use the sensor to measure the launch speed for each trial. If the software is able to allow you to measure the launch speed to a variable number of decimal places, then set it to display its data to at least four decimal places (if possible). **Record this data in a data table.**

Method 2:

To determine the launch speed of a cannonball, you will fire a cannonball horizontally from a height h and observe the ball hit the ground R meters away as measured from the base of the cannon.



Find an expression for the cannonball's launch speed v_0 in terms of h, g, and R only.

Measure and record all the data that you need in order to determine the launch speed. The minimum data you need would be one value of h and 10 values of R.

Notes:

- To measure R, you'll need to fire the ball several times and measure the horizontal distance from the launching point to where the ball hits the surface. To do this, In a trial run, fire the ball horizontally, observing the approximate location where the ball hits the surface. Then, place a sheet of carbon paper on top of a sheet of plain paper and center the two sheets on the point where the ball landed during its trial run. You will use these sheets to record and measure the location where the ball hits the surface. (Only the bottom sheet needs to be taped to the surface. DO NOT tape the carbon paper to anything.)

- Reset the gun, being careful that it is positioned in a fixed location. Fire the ball horizontally a minimum of ten times. Measure and record the horizontal distance R from the ball's launch point to where it hit the surface for each trial. Record this data in a data table.

Analysis

Please read and review the page on data analysis in module 0.

Method 1

a. Report the initial launch speed, v_0, for each individual trial with 4 decimal places.
b. Use these values to calculate the ball's mean launch speed <vo>.
c. Calculate the standard deviation σ for the ball's mean launch speed. The mean plus its standard deviation gives you an estimate of the range of launch speeds for a "typical" shot. Report the estimate of the typical launch speed of a ball for any trial as v0= <vo> +/- 2σ.

Method 2

a. Using the data you collected for R and h, and your equation relating these to v_o, calculate v_o for each individual launch.
b. Use these values to calculate the ball's mean launch speed <vo>.
c. Calculate the standard deviation σ for the ball's mean launch speed. The mean plus its standard deviation gives you an estimate of the range of launch speeds for a "typical" shot. Report the estimate of the typical launch speed of a ball for any trial as v0= <vo> +/- 2σ.

Compare the two values of the typical launch speed of a fired ball measured with the two different methods by calculating the % difference of the averages. How close do the values match?

Why did I ask you to calculate the percent difference and not the percent error?

Is the typical launch speed calculated by Method 2 within the range of the typical launch speed calculated by Method 1? What about the typical launch speed calculated by Method 1? Is it within the range of the typical launch speed calculated for Method 2? Explain these results.

Using Method 2, compare the launch speed for each of the trials. What is the largest digit where the numbers for v_0 differ? (For example, 3.1415 and 3.1423 differ in the thousandth place.)

Using Method 1, compare the launch speed for each of the trials. What is the largest digit where the numbers for v_0 differ?

Based on your previous answers, what can you say about the precision of Method 1 vs. the precision of Method 2?

Post Lab Questions

1. **Does a measurement with more precision mean that it's more accurate? Explain.**

2. Which of your two measured speeds do you trust more? Why?

Projectile Motion – Initial Speed

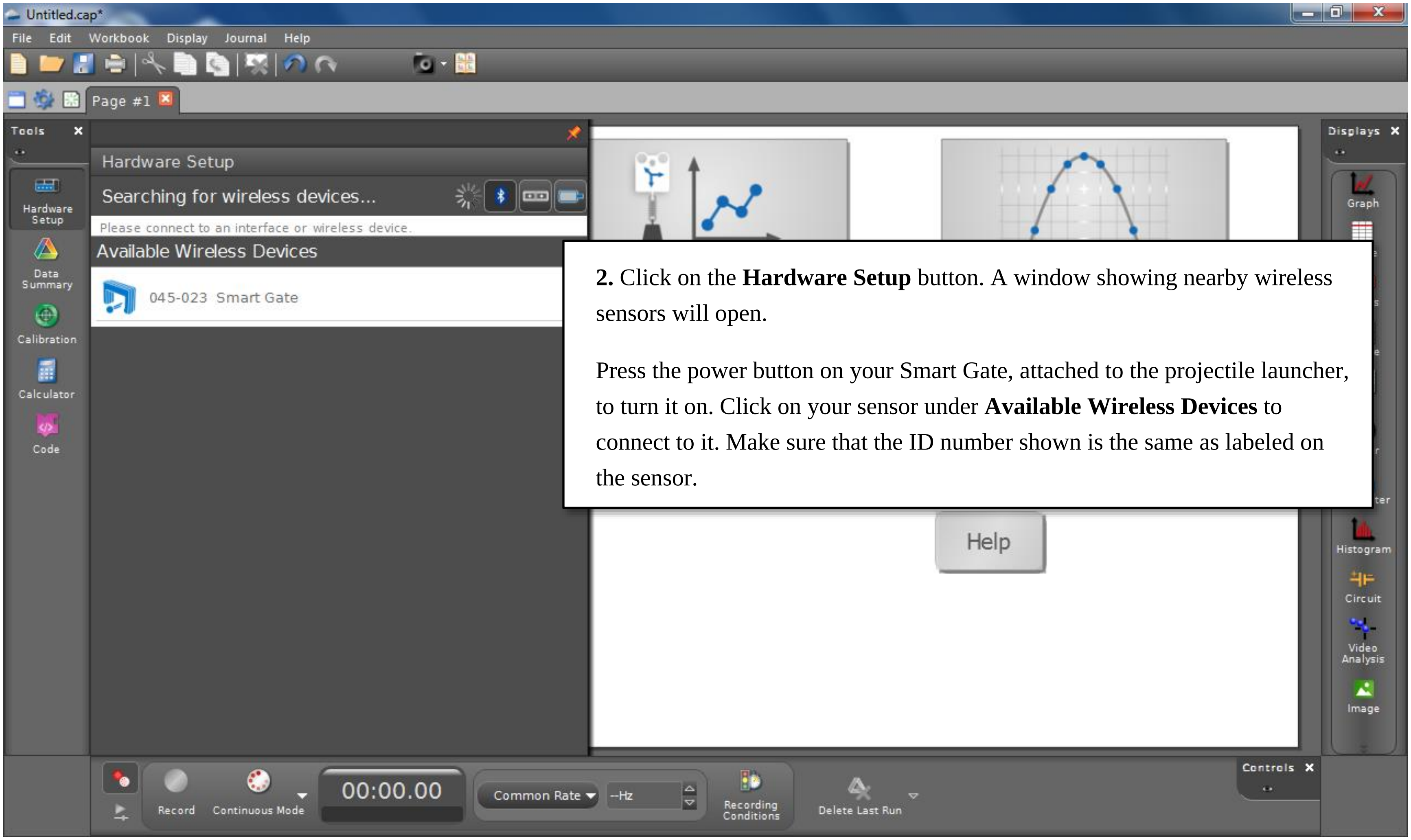
Apparatus

1. Projectile Launcher
2. Smart Gate Bracket
3. Smart Gate
4. Ramrod and Projectile
5. Table Clamp
6. Laptop with Bluetooth

The projectile launchers with the wireless Smart Gate sensors are already set up around the room. Smart Gates are wireless sensors that will be used to measure the speed of the balls launched from the projectile launchers.

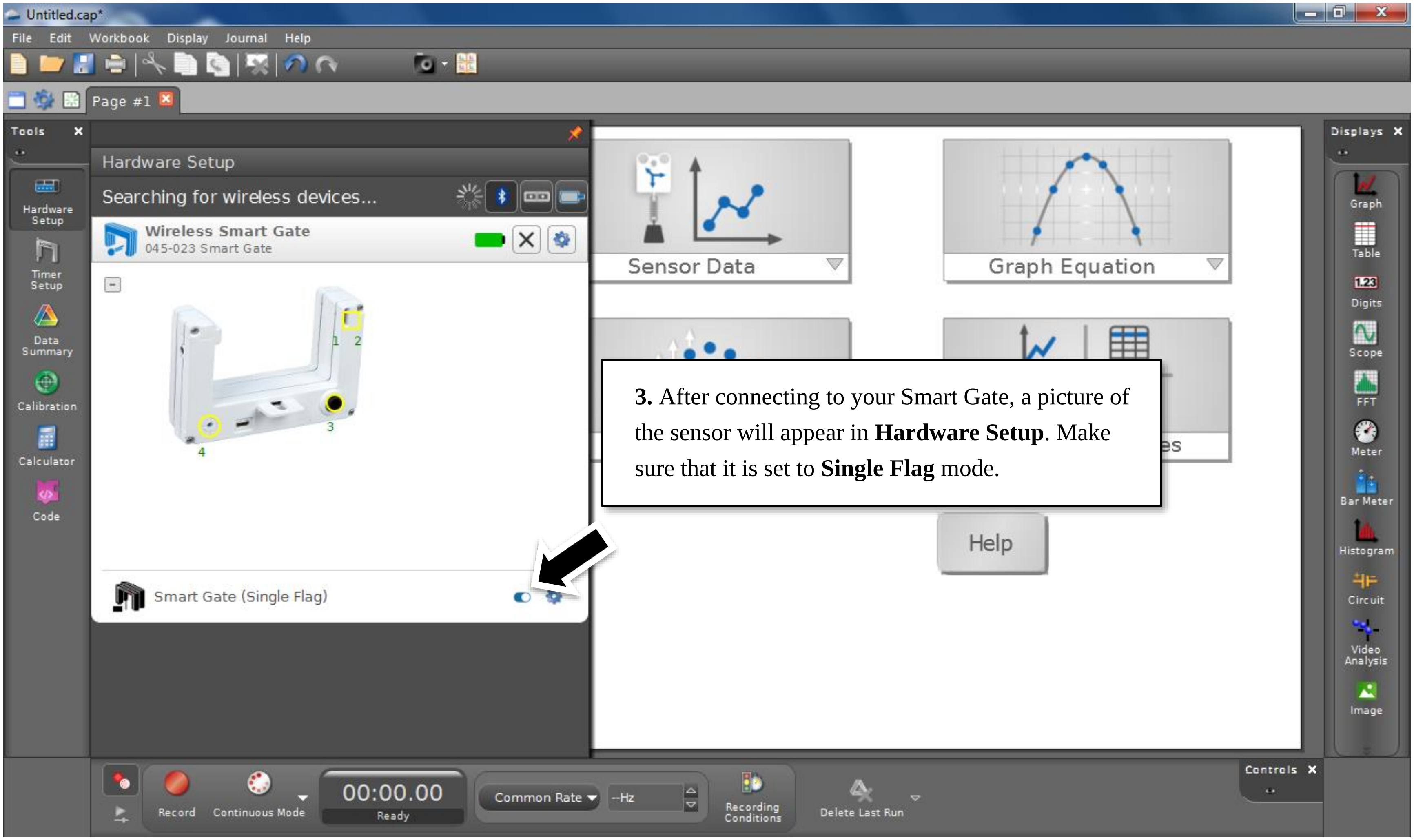
Procedure

1. Make sure a Bluetooth adapter is plugged into one of the USB ports on the laptop that you are using. These are small dongles that have a piece of red tape attached to them. Boot the laptop up in Windows and open the Capstone software. A shortcut should be located on the desktop. If the software comes up with a window prompting you to install an update, click on the **Remind Me Later** button.

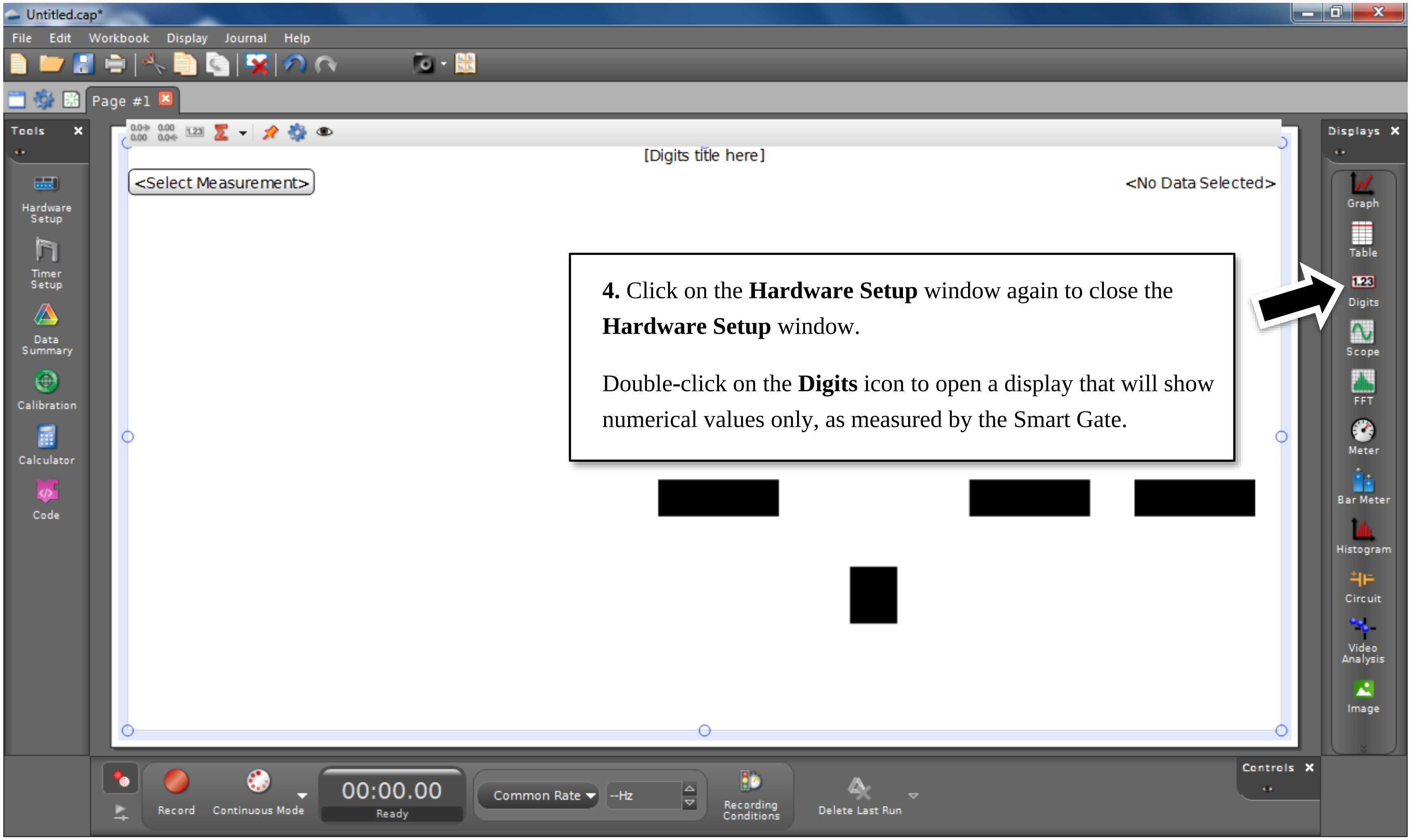


2. Click on the **Hardware Setup** button. A window showing nearby wireless sensors will open.

Press the power button on your Smart Gate, attached to the projectile launcher, to turn it on. Click on your sensor under **Available Wireless Devices** to connect to it. Make sure that the ID number shown is the same as labeled on the sensor.

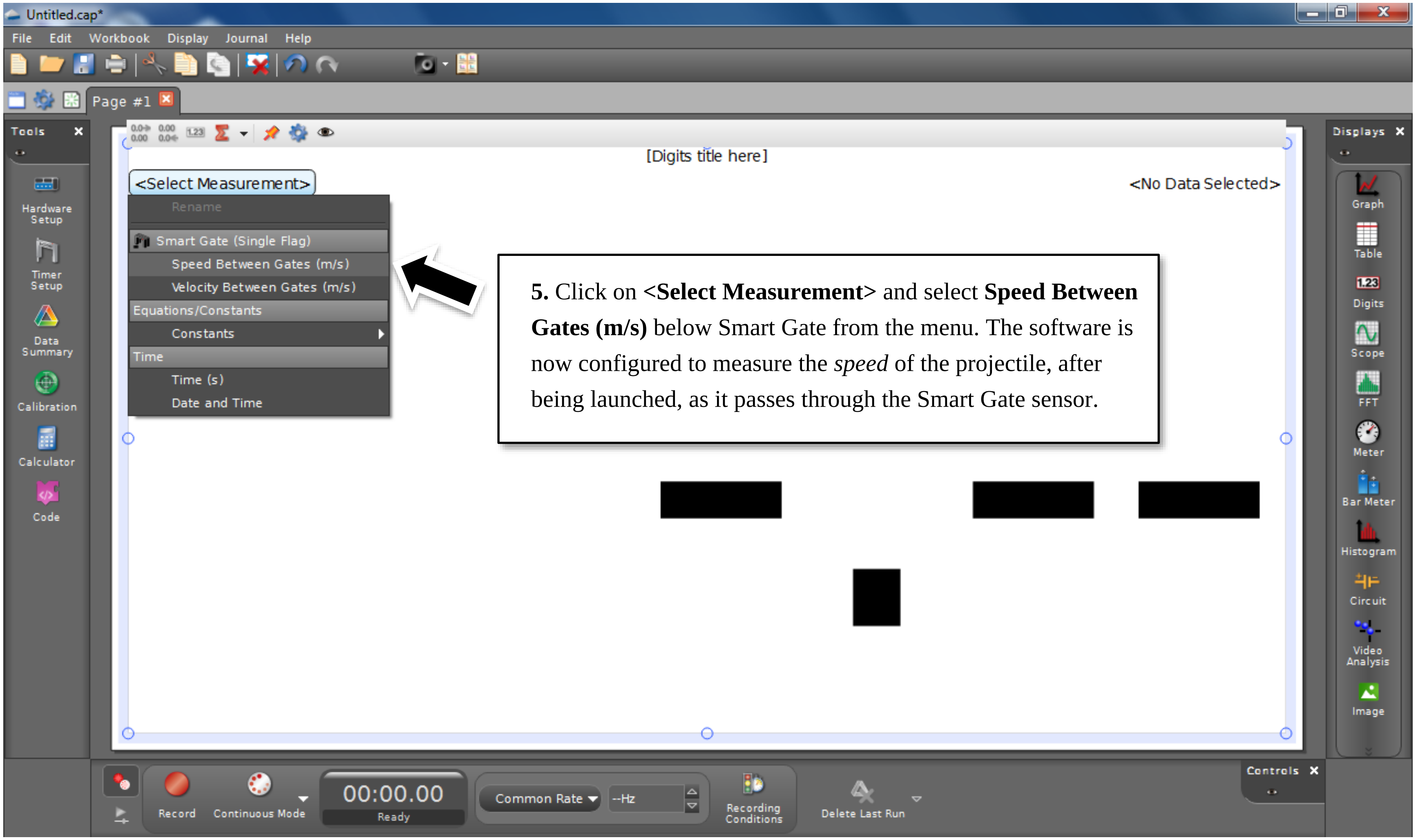


3. After connecting to your Smart Gate, a picture of the sensor will appear in **Hardware Setup**. Make sure that it is set to **Single Flag** mode.

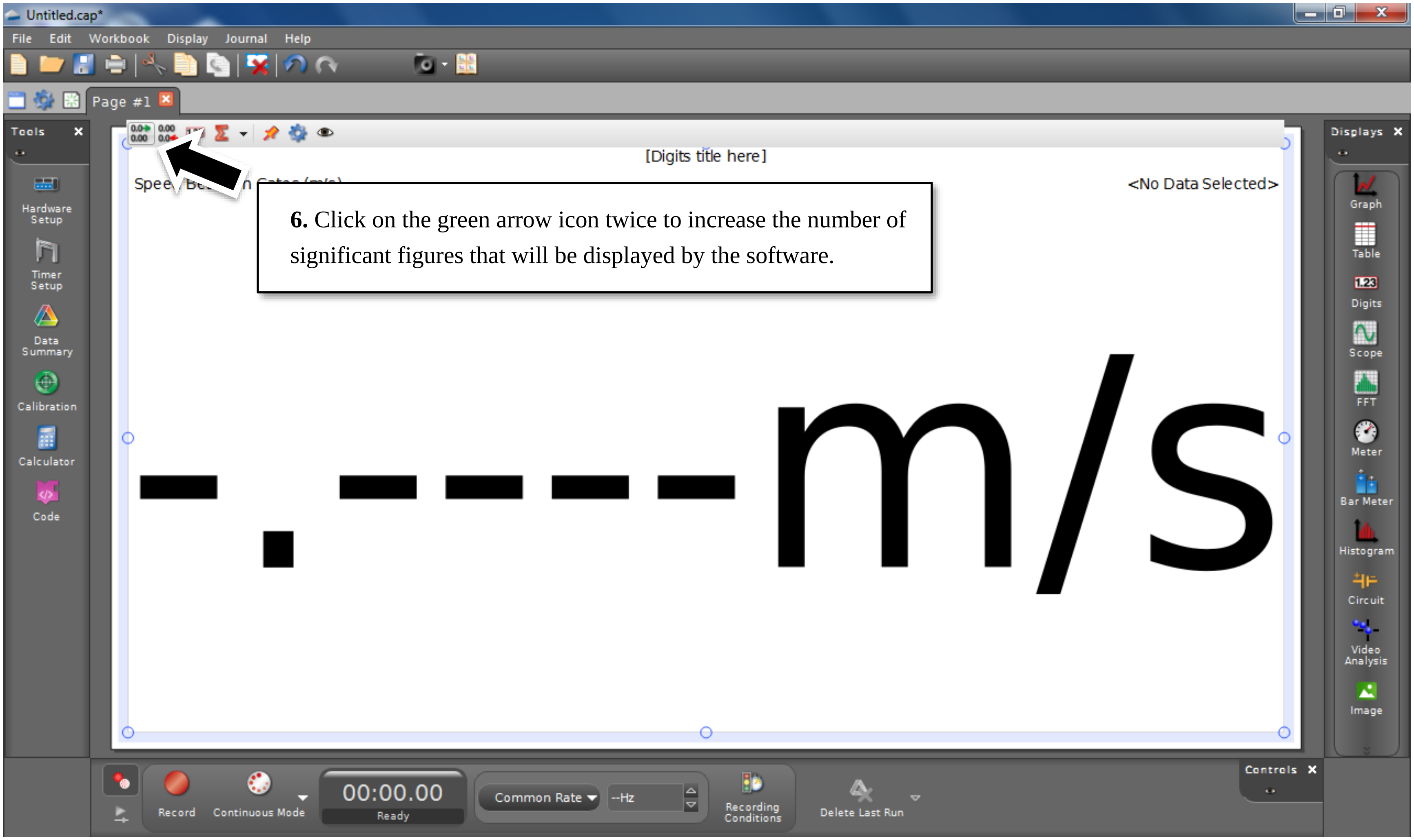


4. Click on the **Hardware Setup** window again to close the **Hardware Setup** window.

Double-click on the **Digits** icon to open a display that will show numerical values only, as measured by the Smart Gate.



5. Click on **<Select Measurement>** and select **Speed Between Gates (m/s)** below Smart Gate from the menu. The software is now configured to measure the *speed* of the projectile, after being launched, as it passes through the Smart Gate sensor.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Timer Setup
Data Summary
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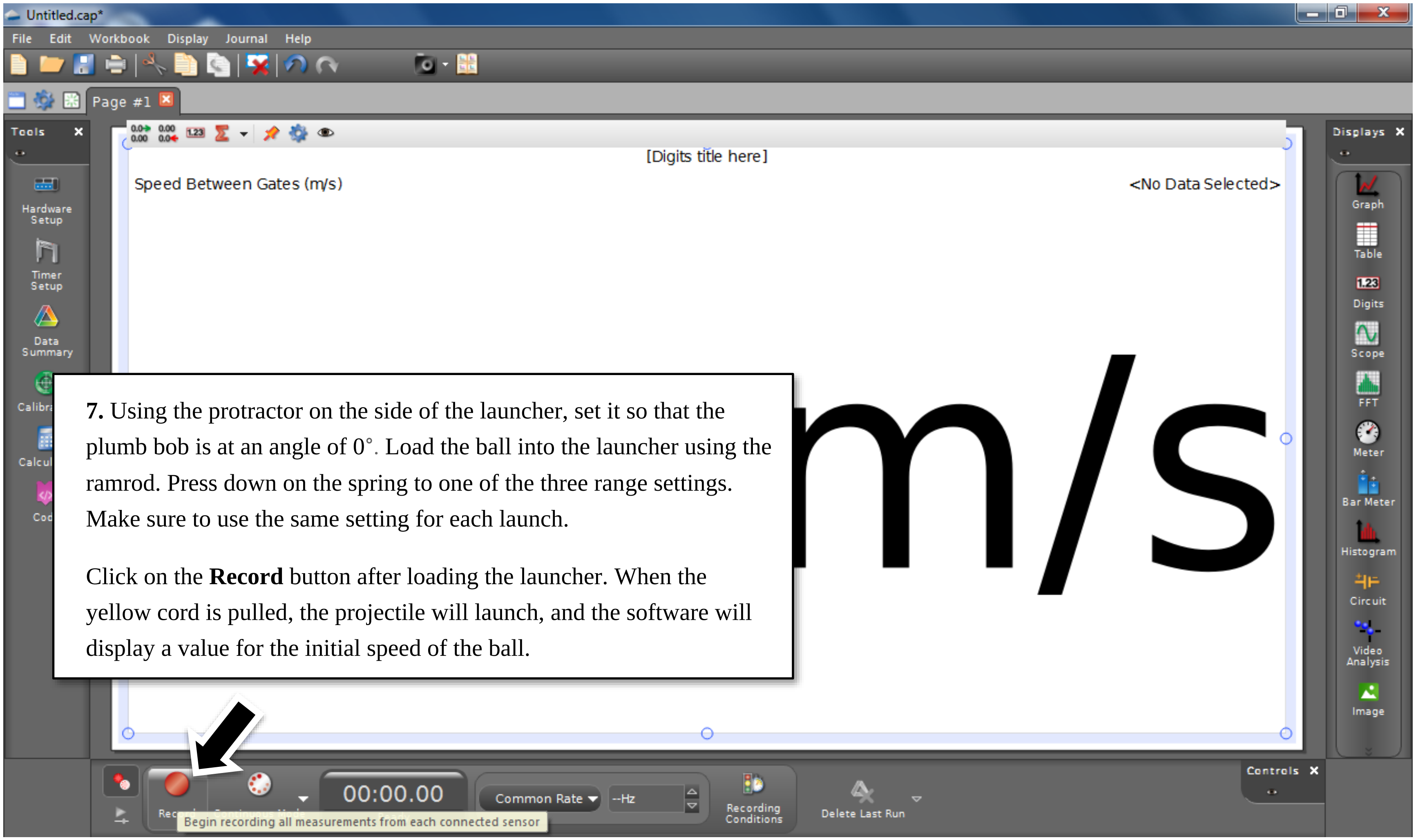

7. Using the protractor on the side of the launcher, set it so that the plumb bob is at an angle of 0°. Load the ball into the launcher using the ramrod. Press down on the spring to one of the three range settings. Make sure to use the same setting for each launch.

Click on the **Record** button after loading the launcher. When the yellow cord is pulled, the projectile will launch, and the software will display a value for the initial speed of the ball.

Error Analysis Formulas

Error Analysis of Single Measurements	
name	***formula***
best estimate, x_{best}	*Determined by estimating the measurement to the nearest reliable value.*
reporting a measured value	$(measured\ value\ of\ x) = x_{best} \pm \sigma_{absolute}$
absolute uncertainty in a single measurement	$\sigma_{absolute} = \pm 0.5 \times (smallest\ unit\ of\ measure)$
fractional uncertainty	$\sigma_{fractional} = \dfrac{\sigma_{absolute}}{\lvert x_{best} \rvert}$
percent uncertainty	$\sigma_{percent} = \dfrac{\sigma_{absolute}}{\lvert x_{best} \rvert} \cdot 100\%$
reported value of measurement, x	$x = x_{best} \pm \sigma_x$
reported value of measurement, y	$y = y_{best} \pm \sigma_y$
sum and difference rule	$x \pm y = (x_{best} \pm y_{best}) \pm (\sigma_x + \sigma_y)$
product rule	$xy = (x_{best} y_{best}) \pm \left(\dfrac{\sigma_x}{\lvert x_{best} \rvert} + \dfrac{\sigma_y}{\lvert y_{best} \rvert} \right) \times 100\%$
power rule	$x^n = x^n_{best} \pm n \left(\dfrac{\sigma_x}{\lvert x_{best} \rvert} \times 100\% \right)$
percent error	$\%\ error = \dfrac{\lvert measured\ value\ -\ accepted\ value \rvert}{accepted\ value} \times 100\%$
percent difference	$\%\ difference\ =\ \dfrac{\lvert measured\ value\ 1\ -\ measured\ value\ 2 \rvert}{\left(\dfrac{measured\ value\ 1\ +\ measured\ value\ 2}{2} \right)} \times 100\%$

Error Analysis of Statistical Samples	
name	***formula***
best estimate, x_{best}	$x_{best} = x_{average} = \langle x_i \rangle \equiv \frac{\sum_{i=1}^{N} x_i}{N}$
standard deviation, uncertainty for a set of N measurements of a single quantity	$\sigma_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(x - \langle x_i \rangle\right)^2}$
best estimate, x	$x_{best} = x_{average}$
best estimate, y	$y_{best} = y_{average}$
sum and difference	$x \pm y = \left(x_{best} \pm y_{best}\right) \pm \sigma_{xy}$
uncertainty, sum and difference	$\sigma_{xy} = \sqrt{\sigma_x^2 + \sigma_y^2}$
product	$xy = \left(x_{best} y_{best}\right) \pm \sigma_{xy}$
product rule, uncertainty	$\sigma_{xy} = \sqrt{\left(\frac{\sigma_x}{x_{best}}\right)^2 + \left(\frac{\sigma_y}{y_{best}}\right)^2}$
confidence intervals	see table below

range	*confidence interval*
1σ	*0.6826895*
2σ	*0.9544997*
3σ	*0.9973002*
4σ	*0.9999366*
5σ	*0.9999994*