

Physics Lab Skill: Finding Speed and Acceleration

Introduction: In physics experiments we are often asked to find the speed, velocity or acceleration of an object. Both speed and velocity are measurements of how fast an object moves. Speed and velocity are calculated using the equation $v=d/t$ where v is speed or velocity, d is the distance covered and t is the time for the distance to be covered. Speeds and velocities measured over a long period of time are called average speed and velocity while those measured during a instant or a short time in are called an instantaneous speeds or velocities. Acceleration is how fast something speeds up, slows down or changes direction. Accelerations can be calculated using the equation $a = (v_f - v_0) / t$ where v_f is the final velocity the object ends with, v_0 is the starting velocity of the object and t is the time it takes for the object to change from one velocity to the other. The velocities v_f and v_0 are instantaneous velocities in this case. The following describe procedures for measuring average velocity and speed, instantaneous velocity and speed and acceleration. The later two involve using electronic timing using the calculator based laboratory (CBL) system.

Finding Average Velocity or Speed

- 1) Measure the distance an object travels with a meter stick, cm ruler or other metric distance-measuring device. This quantity should be in meters or centimeters.
- 2) Measure the time it takes for the object to travel the distance measured above with a stopwatch. This quantity should be in seconds.
- 3) Calculate the average velocity or speed of the object using the equation $v=d/t$. Units for the quantity include m/s and cm/s.

Finding Instantaneous Speed or Velocity

- 1) Obtain the necessary materials. Obtain a TI calculator and have the instructor download the Vernier program Physics on it using a Graphlink and the TI calculator website. Also check out a CBL system with one photogate probe. Calculators that are appropriate include the TI 83 Plus along with any later model of TI that has an Applications button and an input/output port for a link cable. Calculators are also available for checkout.
- 2) Set up the CBL system and photogate. Do this by first plugging in the photogate into the photogate adaptor. Then plug the adaptor cord into input 1 on the CBL. Plug the calculator into the CBL using the link cable to connect the Input/Output jack on the bottom of the calculator to the Input/Output jack on the bottom of the CBL. Place the photogate so that whatever object the velocity is to be found for passes between the ends of the C shaped photogate blocking the light that goes from its transmitter to receiver. You may need to build a stand or use clamps and ring stands for this step.
- 3) Turn on the calculator and CBL and run the Physics application for photogate. Turn on the calculator using the On button on the lower left of the keyboard. Turn on the CBL using the left most key which says On. Access the Physics application program using the Apps button on the calculator, scrolling down using the arrow buttons and hitting enter or run when the Physics app is highlighted. Follow the directions on the calculator screen to set up the probe.

- You should choose 1 probe, photogate, 1 photogate and gate mode when asked in the program. At the end of this process the program will tell you to move your hand through the gate when ready to collect data.
- 4) Collect data using the system. Do this by running your hand through the gate. The CBL screen will then say Sampling. You should now run your experimental trial. The CBL screen will say Done when it has finished sampling. It is always a good idea to do several runs for each trial.
 - 5) Read the time number from the calculator. After the trial the CBL screen should say done. Follow the instructions on the calculator screen to get the time it took your object to move through the gate. This number is in seconds.
 - 6) Measure the length of the object that went through the gate. Use a centimeter ruler to measure the width of the object along the dimension that blocked the light from the gate's transmitter to receiver.
 - 7) Calculate the instantaneous velocity or speed of the object. Do this using the equation $v=d/t$ where d is the length measured in step 6 and t is the time read from the calculator in step 5. Your answer will have units of cm/s or m/s depending on what unit you used to measure the length.

Measuring Acceleration

- 1) Obtain the calculator, Physics Program, CBL and TWO photogates as described in step 1 for finding instantaneous velocity.
- 2) Set the photogates, CBL and calculator as described in step 2 for finding instantaneous velocity. The only variation is that two photo gates should be plugged into the adaptor rather than 1.
- 3) Set up the gates using the same procedure as step 3 for finding instantaneous velocity. The only change is you should choose 2 gates when the calculator asks you how many photogates you have.
- 4) Collect data from the system. Do this as described in step 4 of the finding instantaneous velocity section. You will need to pass your hand through both gates to arm the CBL.
- 5) Read the numbers from the calculator as described in step 5 above. The first number is the time for the first photogate the object passed through. The second number is the time for the second photogate the object passed through. All measurements are in seconds.
- 6) Measure the length of the object passing through the photogates as described in step 6 above.
- 7) Calculate the two instantaneous velocities as described in step 7 of above using the two times you got from the calculator screen.
- 8) Calculate the acceleration of the object. Do this using the equation $a = (v_f - v_0) / t$ where v_0 is the instantaneous speed or velocity from the first photogate, v_f is the instantaneous speed or velocity from the second photogate and t is the time it takes to travel between the gates. The time can be measured either using the pulse mode of the photogate or with a stopwatch. Answers will have units of m/s/s or cm/s/s depending on the length unit chosen.