

## EXPERIMENT 5B WORK-ENERGY WITH COMPUTERS

### I. THEORY

The purpose of this experiment is to test the Work-Energy Theorem, which states that the net work done on a system is equal to the change in kinetic energy for the system. Sometimes the system contains a single object.

In this experiment, a cart is placed on a level track. A string is attached to the cart and passes over a pulley and a mass is hung from the other end of the string. A sensor (Wireless Dynamics System Sensor =WDSS) attached to the cart measures the force the string exerts on the cart. A motion detector measures the velocity of the cart as it moves along the track.

The cart with the WDSS will be our system. The net work done on the cart will be equal to the work done by the string which pulls the cart. This work will be found using the definition of work.

$$W = \int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot d\vec{r}$$

Since we will have a one-dimensional displacement and the tension will be in the same direction as the displacement, the work will simplify to

$$W = \int_{x_1}^{x_2} F_T dx$$

The kinetic energy of the cart will be  $\frac{1}{2} mv^2$ .

One way to remove the systematic effects of friction is to tilt the track so that the cart will roll with a constant speed toward the pulley when no tension force is applied. If the cart rolls with constant speed, the change in kinetic energy is zero. Thus, the work done by friction plus the work done by gravity add to zero.

### II. LABORATORY PROCEDURE



**WARNING: NEVER PLACE THE CART ON THE LAB BENCH WITH ITS WHEELS IN CONTACT WITH THE BENCH. THE LAB BENCHES ARE NOT LEVEL AND THE CART MAY ROLL OFF AND BREAK ON IMPACT WITH THE FLOOR. WHEN PLACING THE CART ON THE LAB BENCH, ALWAYS PLACE THE CART ON ITS SIDE.**

1. Attach the pulley to the end of the track with the end stop. Attach the motion detector to the motion detector bracket. Slide the motion detector bracket into the bottom groove on

the other end of the track and aim the motion detector parallel to the track. Place the track on the laboratory table so that the pulley extends over the edge of the table.

2. Plug in and power on the Laptop Computer.
3. Level the track lengthwise and crosswise.
4. Turn on the Wireless Sensor (WDSS). Attach the LabPro to one of the USB ports on the back of the laptop. Attach the Motion Detector to the Dig/Sonic 2 port on the LabPro with the provided cable.
5. Open the folder named Physics which you should find on the desktop of the computer. Open the file “WorkEnergy.cmb1” contained in the folder.
6. The WDSS is a Bluetooth device and you must do the following before your computer can get data from it. On the Menu Bar go to:  
Experiment → Connect Interface → Wireless → Scan for Wireless Devices  
Select your WDSS by name by checking the appropriate box and clicking “OK”.
7. You should see three graphs on the screen. The larger graph on the left shows velocity vs position. You want to record the force vs position on this same graph. To do this, click on the velocity label on the graph. Scroll down through the menu that pops up to “more”. In the window that opens the velocity box should be checked. Do not uncheck this box, but do check the force that has the same number as the force from the WDSS which is listed under the menu bar at the top of the screen. Click “ok”. You should return to the three graphs and both Force and Velocity should be labeled on the vertical axis of the graph on the left.
8. Before collecting data, you must zero the force sensor within the WDSS. To do this, place the cart on the track with no string attached. Click the  button which is next to the green  button. Check the force sensor box to zero the force sensor and click “OK”.
9. Run a string from the hook on the WDSS over the pulley and attach a weight hanger. If necessary, adjust the height of the pulley so that the section of the string between the pulley and the cart is parallel to the track. Check that the pulley is vertical to reduce friction on the string. Move the cart toward the far end (away from the pulley) of the track, making sure that no knots will pass over the pulley during the motion. Click the  button and release the cart after you hear clicking from the motion detector.  
**CATCH THE CART BEFORE IT HITS THE ENDSTOP.**
10. You should see data in the three graphs on the screen. One shows position vs. time. One shows velocity vs. time. The other shows velocity and force vs. position. The velocity vs. time graph should contain a region after the release which is linear. For this linear region, the forces on the cart should be approximately constant. Select a time near the beginning of this linear region ( $t_1$ ) and a time near the end of the linear region ( $t_2$ ).

Estimate the position of the cart at these two times ( $x_1$  and  $x_2$ ). Select the region on the velocity and force vs. position graph between  $x_1$  and  $x_2$ .

11. Click the  button. Check the “Latest|Velocity” box and uncheck the “Latest|Force” box and press “OK”. Record the minimum and maximum values of the velocity as the initial and final velocities for the interval.
12. Without changing your selection area, click the  button. Check the “Latest|Force” box and uncheck the “Latest|Velocity” box and press “OK”. Record the “Integral” as the work done by the tension force. Record the hanging mass.
13. Repeat steps 8-11 for the following hanging masses (including the weight hanger):  
70.0 g, 100.0 g, and 150.0 g.
14. Turn off the WDSS sensor. Close all programs on the laptop and shut it down from the “Start” menu.
15. Measure the mass of the cart with the sensor and mass attached. You will need to use a “1000.00 g” mass extender with the balance.

### III. CALCULATIONS AND ANALYSIS

1. Make a table with the following columns: Hanging Mass, Initial Velocity, Initial Kinetic Energy of the Cart, Final Velocity, Final Kinetic Energy of the Cart, Change in Kinetic Energy of the Cart, and Work Done by the Tension Force. Complete the table for your 4 hanging mass values.
2. How does the change in kinetic energy of the cart compare to the work done by the tension force for each run? Compute the percent difference for each case.