**Phys 135A College Physics I**

**Activity 10: Work and Energy Part II**

*Work* is a measure of energy transfer. In the absence of friction, when positive work is done on an object, there will be an increase in its kinetic or potential energy. In order to do work on an object, it is necessary to apply a force along or against the direction of the object’s motion. If the force is constant and parallel to the object’s path, work can be calculated using



where *F* is the constant force and *s* the displacement of the object. (if not parallel then include **cosθ**, as you have seen in the class) If the force is not constant, we can still calculate the work using a graphical technique. If we divide the overall displacement into short segments, *s*, the force is nearly constant during each segment. The work done during that segment can be calculated using the previous expression. The total work for the overall displacement is the sum of the work done over each individual segment:



This sum can be determined graphically as the area under the plot of force *vs.* position.[[1]](#footnote-1)

These equations for work can be easily evaluated using a Force Sensor and a Motion Detector. In either case, the work-energy theorem relates the work done to the change in energy as

W = ΔPE + ΔKE

where W is the work done, PE is the change in potential energy, and KE the change in kinetic energy. For now, we will not involve the potential energy. Hence our equation becomes

W=ΔKE

In this activity you will investigate the relationship between work and kinetic energy.

objectives

* Determine the work done on an object using a force *vs*. position graph.
* Use the Motion Detector to measure velocity and calculate kinetic energy.
* Compare the work done on a cart to its change of mechanical energy.

Materials

|  |  |
| --- | --- |
| Computer | masking tape |
| Vernier computer interface |  |
| Logger *Pro* |  |
| Vernier Motion Detector |  |
| Vernier Force Sensor |  |
| dynamics cart |  |

Preliminary questions

1. Lift a book from the floor to the table. Did you do work? To answer this question, consider whether you applied a force parallel to the displacement of the book.

2. What was the average force acting on the book as it was lifted? Could you lift the book with a constant force? Ignore the very beginning and end of the motion in answering the question.

Procedure

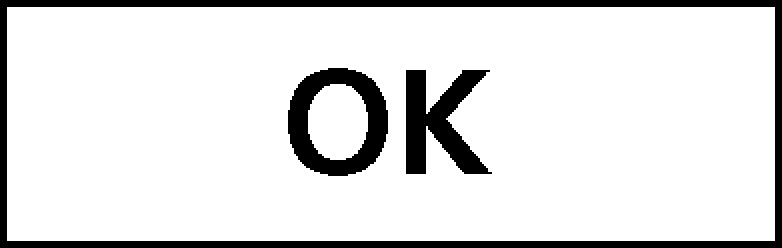
Work Done To Accelerate A Cart

Here you will push on the cart with the Force Sensor, causing the cart to accelerate. The Motion Detector allows you to measure the initial and final velocities; along with the Force Sensor, you can measure the work you do on the cart to accelerate it.

1. Open the file “18c Work Done Cart”. Three graphs will appear on the screen: position *vs.* time, force *vs.* time, and force *vs.* position. Data will be collected for 5 seconds.

2. Remove the spring and support. Determine the mass of the cart. Record in the data table.

3. Place the cart at rest about 1.5 m from the Motion Detector, ready to roll toward the detector.

4. Click ZeroNew. Check to see that both sensors are highlighted in the Zero Sensors Calibration box and click . Logger Pro will now use a coordinate system which is positive towards the Motion Detector with the origin at the cart, and a push on the Force Sensor is positive.

5. Prepare to gently push the cart toward the Motion Detector using the Force Sensor. Hold the Force Sensor so the force it applies to the cart is parallel to the sensitive axis of the sensor.

6. Click CollectNew to begin data collection. When you hear the Motion Detector begin clicking, gently push the cart toward the detector using only the hook of the Force Sensor. The push should last about half a second. Let the cart roll toward the Motion Detector, but catch it before it strikes the detector.

7. Examine the position *vs.* time and force *vs.* time graphs by clicking the Examine button, ExamineNew. Identify when you started to push the cart. Record this time and position in the data table.

8. Examine the position *vs.* time and force *vs.* time graphs and identify when you stopped pushing the cart. Record this time and position in the data table.

9. Determine the velocity of the cart after the push. Use the slope of the position *vs.* time graph, which should be a straight line after the push is complete. Record the slope in the data table.

10. From the force *vs.* position graph, determine the work you did to accelerate the cart. To do this, select the region corresponding to the push (but no more). Click the Integrate button, IntegralNew, to measure the area under the curve. Record the value in the data table.

|  |  |  |
| --- | --- | --- |
| Data Table 1 | | |
|  | Time (s) | Position (m) |
| Start Pushing |  |  |
| Stop Pushing |  |  |
| Integral during push (N•m)  (this is the area under the curve of Force-Distance graph, and it is equal to the work done on the cart) |  | |

|  |  |
| --- | --- |
| Data Table 2 | |
| Mass (kg) |  |
| Final velocity (m/s)  (From the slope of the straight portion of the Distance-Time graph) |  |
| *KE* of cart (J)  (from KEfinal-KEi, where here the initial refers to the cart at rest, and final refers to the cart right after force stops pushing) |  |

Analysis

1. In this activity you did work to accelerate the cart. In this case the work went to changing the kinetic energy. Since no spring was involved and the cart moved along a level surface, there is no change in potential energy. How does the work you did compare to the change in kinetic energy? Here, since the initial velocity is zero, Δ*KE* = ½ *mv*2where *m* is the total mass of the cart and any added weights, and *v* is the final velocity. Record your values in the data table.

Extensions

1. Show that one N•m is equal to one J.

1. If you know calculus you may recognize this sum as leading to the integral . [↑](#footnote-ref-1)