**Phys 135A College Physics I**

**Activity 7: Work and Energy**

In dynamics, we have so far dealt with Newton’s three laws of motion. Force played a central role there. Now we will take a different approach in terms of work, energy, and later on momentum. These quantities are conserved quantities so this makes them valuable in solving for unknowns. This approach is good especially for systems with many interacting bodies.

“Work” in physics is a measure of energy transfer. It is because of this that we say “energy” is the ability to do work! 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. How can we calculate the work done on an object?

We first note that doing a net work on an object can either increase or decrease an object’s kinetic energy. This fact goes by the name of a principle called WORK-ENERGY PRINCIPLE.

It states that

Kinetic energy is the energy of motion, and is given by the following formula:

where m is the object’s mass, its speed. If the kinetic energy is increased we say a “positive” net work has been done on the object; if it is decreased, we say a “negative” net work has been done on the object.

Now suppose an object with mass m is moving at a constant velocity along +x axis, and you start applying a net force F on the object along the same direction for a distance of . The change you caused in the kinetic energy of the object is referred to as the “work.” Let us try to calculate an expression for work using our knowledge of kinematics and the definition of kinetic energy and its relationship with work we just learned about. Recall the “timeless” equation:

If we multiply both sides by , we will get an expression for the final kinetic energy and initial kinetic energy:

Since , we have

Here we assumed that both force and displacement are parallel to each other. If they are not parallel to each other, in other words, if there is an angle between them then we rewrite the expression as follows:

The unit of work is N.m which is given the name of joules or J!

Note that the concept of energy, which is the ability to do “work,” is a scalar quantity, and so it will be easier to deal with energy. Furthermore, energy is a conserved quantity, which will give us further insight into the workings of nature!

**Example 1**: Suppose there is toy car that is moving along +x axis with a certain velocity. You begin applying a force F that is perpendicular to the displacement direction (which is +x direction) for a distance of d, what is the work you do on the car?

**Example 2**: What if the force you apply makes with the +x axis?

**Example 3**: What if the force you apply is parallel to the +x axis?

**Example 4**: What if the force you apply is anti-parallel to the +x axis?

**Example 5**: If you push a cart with a force of 30 N for 50 m, how much work will you have done?

**Example 6**: If you carry a box of mass 10 kg at a constant velocity and at a fixed height for a distance of 30 m,

(a) how much work will you have done on the box as you move the box horizontally?

(b) how about the vertical force you apply, does it do any work?

(c) is gravity doing any work during this motion?

**Corollary: Force application does NOT always mean work! To see whether there is any work done by a particular force, use the formula Work = F\*d\*cosθ!**

**If there is more than one force acting on an object, to obtain the net work on the object do either**

**(1) calculate the work done by each force and then add the works algebraically (as work can be + or –)! or**

**(2) calculate the net force on the object and then calculate the net work for the net force.**

**Example 7**: A box is dragged across a rough floor by a constant force of magnitude 50 N. The force makes an angle of 37 above the horizontal. A friction force of 10 N retards the motion, and the box is displaced a distance of 3 m to the right.

(a) Calculate the work done by the 50-N force.

(b) Calculate the work done by the friction force.

(c) Determine the net work done on the box by all forces acting on it.

**Example 8**: A piano of mass 100 kg is pushed up a rough incline which has a slope of by a person who applies a constant force of 1100 N parallel to the incline. The piano is displaced a distance 5 m up the incline.

(a) Calculate the work done by the force of the person

(b) Calculate the work done by the force of gravity

(c) Find the work done by the force of kinetic friction if the coefficient of friction is 0.2

(d) Find the net work done on the block for this displacement.

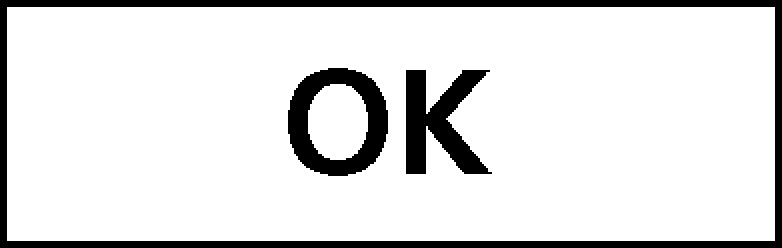
Work Done To Accelerate A Cart

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. Once the sensors are connected, the LoggerPro will open three graphs: position *vs.* time, force *vs.* time, and force *vs.* position. If any one of them is not the correct parameter, right click on the axis title and choose the right one. Adjust sensor settings to make push direction to be positive for both sensors. Adjust the clock setting to collect data for 3 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.

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| 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.

**Example 9**: A 1000-kg car is accelerated from rest to a speed of 10 m/s, what is the work that must have been done on the car to achieve that speed?

**Example 10**: A 1000-kg car is moving at a constant speed of 10 m/s, what is the work that must be done on this car to bring it to a stop?

**Work Done by a Varying Force:**

If a force is not constant during displacement, we cannot use the , formula because F is varying throughout displacement d. Which force are we going to use? The solution to this problem is to graph the force versus distance graph and calculate the net area under that curve. That will give us the net work done by that force on the object.

**Example 11**: Given the following force-distance graph, calculate the net work done on the object between 0 and 15 m.

