Work and Energy

PES 1150 General Physics Lab I

Purpose of the experiment

- What is Work and how is it related to Force?
- Learn about different forms of energy.
- Learn how to use the "Conservation of Energy" to solve complicated dynamics problems.
- [FYI]

[FYI] The early bird gets the worm, but the second mouse gets the cheese.

Background Information

Conservation of Energy

It is difficult to precisely define what energy is. A good definition is that energy is the "stuff" in the universe that is capable of doing work. (Energy really is some form of "stuff", just like matter is "stuff". In fact, Einstein's famous equation $E = mc^2$ tells us that mass is really just congealed energy.) Luckily, we don't have to worry about what energy is, but rather how it behaves. The way energy behaves is called *conservation*.

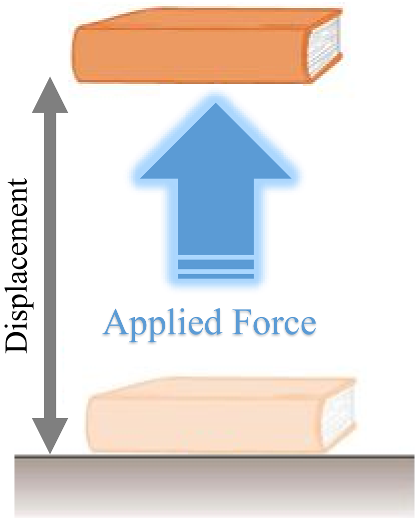
Conservation has a specific meaning in physics. To a physicist, when something is conserved, it means that quantity does not change with time. One quantity that is conserved in physics is energy. In fact, the conservation of energy is a fundamental law of physics. Simply put, the conservation of energy states that:

> For any isolated system (i.e. a system that does not interact with its environment), the energy of the system will remain constant.

Since the universe is an isolated system (as far as we know), the total amount of energy in the universe is constant. Another way of stating the conservation of energy is as follows:

> Energy cannot be created or destroyed. Instead, energy changes between forms.

So, what causes energy to change form? The answer is force. Force is the agent that causes energy to change from one type (such as potential energy) to another (such as kinetic energy or heat). We can divide forces into two types: *conservative forces* that keep the energy with the object that the force is acting on (like gravity, tension, or a spring force), and *non-conservative* forces that cause energy to be exchanged between objects (such as friction or air resistance). The term non-conservative force is a little misleading, however. The energy is still conserved with a force like friction. However, it is usually converted to heat. For this lab, we will look at systems (bouncing ball) in which all the forces that act on the objects in question are conservative in nature, and any non-conservative forces are small or can otherwise be ignored.



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:

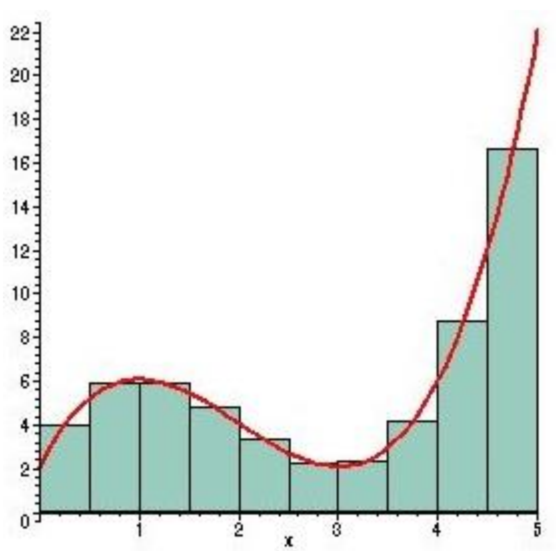
$$W = F \cdot x$$

where F is the constant force and x the displacement of the object.

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, Δx, 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:

$$W = \sum F(x)\Delta x$$

This sum can be determined graphically as the area under the plot of force *vs.* distance.



If you've had calculus, you should recognize this sum as leading to the integral:

$$W = \int_{x_o}^{x_f} F(x)dx$$

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

$$W = \Delta U + \Delta K$$

where W is the work done, ΔU is the change in potential energy, and ΔK the change in kinetic energy, $\Delta K = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$.

Work is the measure of amount of energy being transferred to an object via forces.

Bouncing Ball

When a juggler tosses a ball straight upward, the ball slows down until it reaches the top of its path and then speeds up on its way back down. In terms of energy, when the ball is released it has kinetic energy K. As it rises during its free-fall phase it slows down, loses kinetic energy, and gains gravitational potential energy U. As it starts down, still in free fall, the stored gravitational potential energy is converted back into kinetic energy as the object falls. When the ball bounces off the table, it will lose some of its energy to sound and vibration of the floor. When it leaves the ground again, it will not go quite as high the second time because of the energy lost in the collision with the floor.

If there is no work done by frictional forces while the ball is in the air, the total energy will remain constant. In this experiment, we will see if this works out for the bouncing of a ball by studying these energy changes using a Motion Sensor.

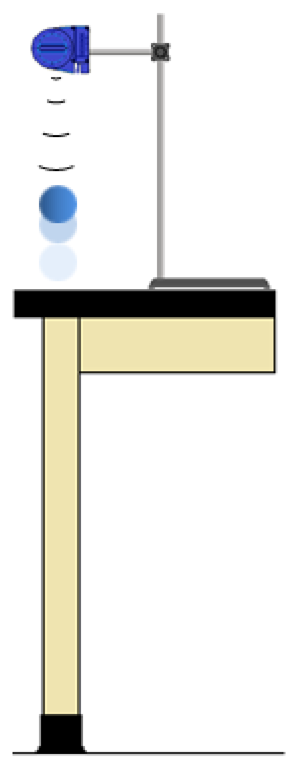


Figure 1: Experimental set up for testing the conservation of energy for a bouncing ball.