Physics 123
Experiment 4: Conservation of Energy

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One of the most important and useful concepts in mechanics is that of "Conservation of Energy". In this experiment, you will make measurements to demonstrate the conservation of mechanical energy and its transformation between kinetic energy and potential energy.

1 Total Mechanical Energy

The Total Mechanical Energy, E, of a system is defined as the sum of the Kinetic Energy, K, and the Potential Energy, U.

$$E = K + U \tag{1}$$

If the system is isolated, with only conservative forces acting on its parts, the total mechanical energy of the system is a constant. The mechanical energy can, however, be transformed between its kinetic and potential forms. cannot be destroyed. Rather, the energy is transmitted from one form to another. Any change in the kinetic energy will cause a corresponding change in the potential energy, and vice versa.

$$\Delta K + \Delta U = 0 \tag{2}$$

The conservation of energy then dictates that (1) where ?T is the change in the KE, and ?U is the change in PE.

Potential energy is a form of stored energy and is a consequence of the work done by a force. Examples of forces which have an associated potential energy are the gravitational and the electromagnetic fields and, in mechanics, a spring.

For a body moving under the influence of a force F, the change in potential energy is given by

$$\Delta U = -\int_i^f \overrightarrow{F} \cdot \overrightarrow{ds} \tag{3}$$

where i and f represent the initial and final positions of the body, respectively. Hence, from Equation 2 we have what is commonly referred to as the *work-kinetic energy theorem*:

$$\Delta K = \int_i^f \overrightarrow{F} \cdot \overrightarrow{ds} \tag{4}$$

2 Energy Transfer

Consider a body of mass m, being accelerated by a compressed spring. As you verified in the first experiment of the semester, the force exerted by a spring is given by Hooke's Law, F = -kx. Thus, from Equation 3, the change in potential energy as a spring is stretched or compressed is:

$$\Delta U = -\int_{x_i}^{x_f} (-kx)dx = \frac{1}{2}k(x_f^2 - x_i^2) \tag{5}$$

If we let the initial position $x_i = 0$ (the spring's equilibrium position and where its potential energy is defined to be zero) and set $x_f = x$, Equation 5 becomes

$$U = \frac{1}{2}kx^2.$$

Where we have now defined a potential energy *function*, U, for the spring.

The change in kinetic energy of a body (Equation 4) under the acceleration of a force $F = ma$ is given by:

$$\Delta K = \int_{x_i}^{x_f} (ma) dx = \int_{x_i}^{x_f} (m\frac{dv}{dt}) dx = \int_{v_i}^{v_f} m dv = \frac{1}{2} m (v_f^2 - v_i^2) \tag{6}$$

If the initial velocity of the mass is zero, then the KE at any given time is

$$K = \frac{1}{2} m v^2$$

where v is the instantaneous velocity of the body. Note that this derivation is for any general force F, and not just that specific to the spring. You can do the same derivation for the gravitational force/potential.

3 Experimental Objectives

In the laboratory you have an air track, glider, photogate, a spring launcher, a scale, wooden blocks, ruler, and a set of weights that can be placed on the glider. The photogate is connected to a computer data acquisition system and velocity data can be collected using the "Science Workshop" software (see manual or ask your TA about using this software in your experiment). Using this equipment:

- Devise an experimental procedure to observe how the potential energy of the spring launcher is converted to kinetic energy in the motion of the glider for different masses of the glider. Determine if the friction in the system can truly be neglected.
- Devise an experimental procedure to observe the transfer of potential energy from the spring launcher to gravitational potential energy of the glider. Verify energy conservation for this case.