

PHYSICS 201 LAB: THE CONSERVATION OF ENERGY
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THEORETICAL DISCUSSION

Work and potential energy: When an object subject to a *conservative* force $\vec{F}$ moves from point $\vec{r}_1$ to another point $\vec{r}_2$, the system potential energy changes by an amount ΔU given by

$$\Delta U = - \int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot d\vec{s} \quad (1)$$

The expression on the right (absent the sign) is the work done by the force $\vec{F}$ in this process, and $d\vec{s}$ is the [infinitesimal] displacement along the path. If the force is constant in both direction and magnitude over the entire path, the previous equation reduces to

$$\Delta U = -\vec{F} \cdot \vec{\Delta s} = -F\Delta s \cos \theta \quad (2)$$

where $\vec{\Delta s}$ is the [finite] displacement from the beginning of the path to the end of the path.

Conservation of energy: The “law” of conservation of energy states that in a closed system, the total energy of the system does not change. If only conservative forces do work, this energy is purely in mechanical form, i.e., composed solely of potential and kinetic energy. It follows that any increase in kinetic energy ΔK must be compensated by a matching decrease in potential energy $-\Delta U$ (or vice-versa):

$$\begin{aligned} \Delta E &= \Delta K + \Delta U = 0 \\ &\Downarrow \\ \Delta K &= -\Delta U \end{aligned}$$

The kinetic energy of a mass m moving with speed v is calculated as

$$K = \frac{1}{2}mv^2 \quad (3)$$

while for a constant force, ΔU can be found from Equation 2.

EXPERIMENTAL PROCEDURE

In today’s lab, you will allow a cart to glide down an inclined air track. A photogate timer at the bottom of the track is used to measure the final speed of the cart. The inclination angle of the track is adjustable; for each inclination angle, the increase in kinetic energy of the cart, ΔK , will be compared with the decrease in its potential energy, $-\Delta U$, in an attempt to verify energy conservation. The experimental setup is shown in Figure 1.

The particulars of the experiment are as follows:

1. Measure the mass m of the cart (with sail). Also measure the width w of the sail, using the vernier caliper.
2. Begin with an inclination angle ϕ of approximately 5° . Use the digital protractor to make an accurate measurement of the angle actually used in the experiment.
3. Measure the displacement along the track, Δs . We will assume the cart occupies its final position when the photogate beam interrupts the *midpoint* of the sail (why is this justified?).

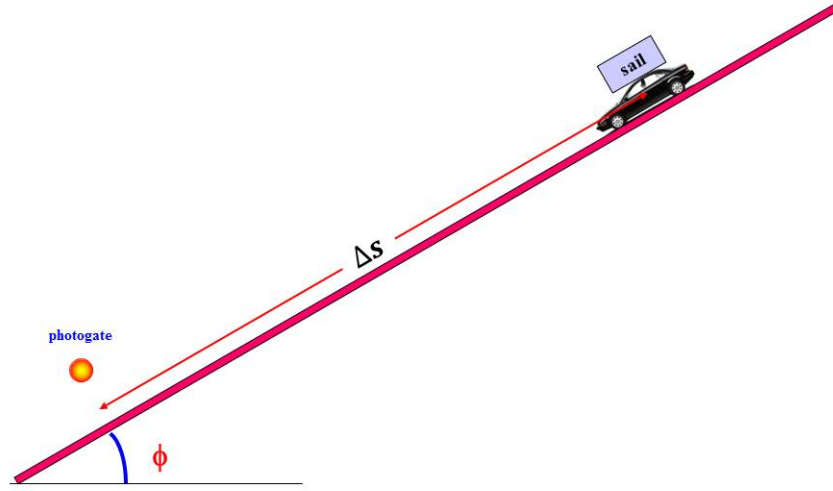


FIG. 1: Experimental setup for measuring kinetic energy on an inclined plane.

4. Release the cart from rest. The speed of the cart at the bottom of the incline is found from the width w of the sail it carries; the photogate timer measures the time τ during which the sail interrupts the photogate beam.[1] It follows that the cart's speed at the photogate location can be calculated as $v = w/\tau$. Use Equation 3 to calculate its kinetic energy; since the cart was released from rest, this is also the increase in kinetic energy ΔK .
5. Calculate the change in potential energy. The constant force in Equation 2 is just the weight of the cart, $F = mg$. For this calculation, use the accepted value for g in our locale (to 4-digit accuracy), 9.797 m/s^2 . Also, since the angle θ between the force and displacement vectors and the incline angle ϕ are complementary angles, we can write $\cos \theta = \sin \phi$ and calculate the *decrease* in potential energy, $-\Delta U$, as

$$-\Delta U = mg\Delta s \sin \phi \quad (4)$$

6. Energy conservation requires $\Delta K = -\Delta U$, so we expect these two energies to be numerically equal. The difference between them is just $\Delta E = \Delta K + \Delta U$, the degree to which mechanical energy is *not* conserved in the experiment. Compute ΔE , and express the result as a percentage of $-\Delta U$, the amount by which the potential energy decreased in the experiment.
7. Repeat the preceding steps for inclination angles of [approximately] $\phi = 10^\circ$ and $\phi = 15^\circ$. Compare ΔE for all three inclination angles studied, and report any trend(s), e.g., ΔE is always negative, or ΔE as a percentage of $(-\Delta U)$ increases with increasing incline angle ϕ , etc.

[1] Prior to initiating each run, you should verify that the function mode of the photogate timer is set to 's1'. The function mode is altered by repeatedly pushing the function button; an LED indicates which function is activated.

A second LED indicator identifies the units in which the result will be output on the display panel. Remember to press the 'clear' button, to clear out any previous results.