PHYSICS 133 EXPERIMENT NO. 4
CONSERVATION OF ENERGY

Introduction

In this week's lab, we will study the vector nature of force and energy conservation using a glider on an air track. A vector can be expressed as the sum of its components along a conveniently chosen coordinate system. In the first part of this experiment, we will study the component of the gravitational force, $mg \sin\theta$, by using a tilted air track, where θ is the tilt angle. For an isolated non-dissipative (e.g., frictionless) system, the total mechanical energy must be conserved. In the second part of the experiment, we will examine the law of energy conservation by observing the transfer of gravitational potential energy to kinetic energy.

Equipment

- 1 air track,
- 1 glider with photogate,
- 1 light sensor,
- 1 interface box,
- 1 computer with timing program,
- 2 wood blocks,
- 10 and 20 gram masses,
- low-friction pulley and thread.

Method

A battery-powered photogate is mounted on the glider. When activated with the small push-button on the side of the glider, the photogate turns on a bright, light emitting diode (LED) whenever the picket fence over the air track blocks the photogate. A light sensor at the end of the air track receives the LED signals and a timing program in the computer measures and records the time intervals between successive lightings of the LED. In the first part of the experiment, we release the glider from rest on a tilted air track. The acceleration a of the glider can be measured and the component of gravitational force along the air track, $mg \sin\theta$, can be obtained. In the second part, a small mass is attached to the glider via a thread that passes over a low-friction pulley at the end of a level air track. The small mass is then released, causing it to accelerate the glider as it falls. The change in the height of the small mass is measured, as is the velocity of the glider/mass system. This will allow us to keep track of the kinetic and potential energy as the small mass falls, enabling us to test for energy conservation.

Procedure

Measurement of $g \sin\theta$

1. Level the air track by carefully adjusting the single leveling screw at one end of the track. When the track is level, the glider should remain nearly stationary at any point on the track. Be sure to tighten the wing nut on the leveling screw when the track is level.
2. Tilt the track by placing one of the blocks flat on the table under the leveling screw. Determine the track's tilt angle θ.
3. Set the computer up to take data in the MOTION TIMER mode. When you are ready to begin a run, push the small button on the side of the glider. (This will activate the photogate for about one minute, after which it will turn itself off automatically to save the batteries.) Hold the glider in a position where the photogate is not blocked (LED off). Push the SET button on the grey interface box, then push ENTER on the keyboard. After you let the glider go, data will start recording when the photogate is first blocked. Hit the ENTER key again before the glider rebounds from the end of the air track.
4. As in an earlier lab, the distances from one "picket" to the next must be measured and entered in the computer. Plot the velocity data in your lab book. You may use a limited number of the data points. Superimpose the expected velocity curve for an object accelerated at $g \sin\theta$, where θ is the angle of tilt of the air track. Compare the curves. Repeat the experiment for different values of θ. Simply read the slope and uncertainty of the line calculated by the computer program for the velocity data. (Enable the STATISTICS function) Calculate $g \sin\theta$ and compare with the experimental result.

Test for Conservation of Mechanical Energy

1. Remove the blocks and make sure that the air track is leveled.
2. Attach a 20 gram mass to the glider with a length of thread and pass the thread over the pulley at the end of the air track, so that the mass hangs over the edge of the table and can fall without hitting anything on the way down. Release the glider and record data in the usual way. Make two plots in your lab book: velocity vs. time and displacement vs. time, in such a way that you can read the velocity and displacement of the glider at the same moment; i.e. one plot directly above the other. Take the velocity and displacement of the glider at 6 different time points on the graphs and compute the changes in kinetic and potential energies of the glider/mass system between adjacent points. Note that the horizontal displacement of the glider is the same as that of the small mass's vertical displacement, and the mass and glider are moving at the same speed. Discuss your calculations. Do your results verify conservation of mechanical energy for this system?

This experiment can also be viewed as a test of Newton's second law, $\boldsymbol{F} = m\boldsymbol{a}$. Compare the acceleration of the glider with the theoretical expression (that you should derive)

$$a = gm/(m + M) \tag{1}$$

where a is the acceleration of the glider, m is the small mass, and M is the mass of the glider, which the TA will provide.