LAB SECTION: ______________________________ NAME: ______________________________

EXPERIMENT 5: CONSERVATION OF ENERGY

Introduction: In this lab, you will test conservation of mechanical energy by analyzing the motion diagram of a swinging pendulum.

IMPORTANT: Special concerns for swinging pendulum and ink-jet timer

1. The aluminum pendulum rod is easily bent. If you must stop the swinging pendulum, gently slow the pendulum by light contact with the insulated part at the top, or with the bob itself; DO NOT grab the aluminum rod.
2. Timer voltage is 30,000 volts - although not lethal, a shock from the timer is quite uncomfortable. Do not touch any metal parts of the pendulum assembly when the timer is active (on). Turn the timer off between runs.

You will use an ink-jet timer to create a motion diagram (a series of dots) for a pendulum bob as it swings. The time between dots will be known, so by measuring the distance between dots, it will be easy to calculate the average speed v_i between two selected dots. The kinetic energy at location i, approximately midway between the two selected dots, can then be gotten by

$$KE_i = \frac{1}{2}mv_i^2,$$

where m is the mass of the swinging bob. The kinetic energy will be in joules when the mass is in kilograms and the speed is in m/s. You will also measure the height h_i of location i with respect to the lowest possible point in the swing. The potential energy of the bob with respect to zero potential energy at the lowest possible point in the swing can then be gotten by

$$PE_i = mgh_i.$$

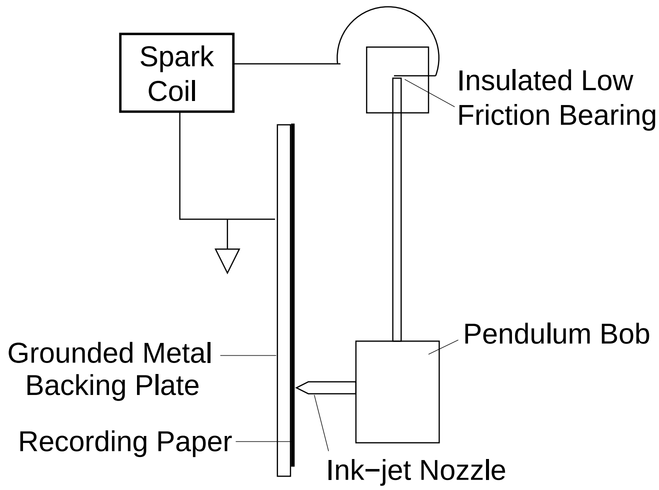
The potential energy will be in joules when the mass is in kilograms, the height is in meters, and the gravitational acceleration is in m/s^2. By checking the sum of KE_i plus PE_i at many different locations, it will be a simple matter to see if the total mechanical energy

$$ME_i = KE_i + PE_i$$

is really constant for this swinging pendulum.

Procedure

A side view of the apparatus is shown below (not to scale).



1. The top edge of the metal backing plate will be aligned with the horizontal. Carefully tape your recording paper to the backing plate, making sure that the top edge of the paper is aligned with the top edge of the plate. Set the ink-jet timer for 60 sparks/sec.
2. Mark the bottom point of the pendulum swing by making a short spark while the pendulum is hanging vertically at rest. Put a square around this dot so that you don't confuse it with the dots in your motion diagram.
3. Practice a few pendulum swings without operating the timer. It is easy to tear the paper, so you must take care to launch the pendulum in the plane of the backing plate. Use the fine nylon string pulled over the marked bolt to get good launches. If your recording paper is taped flat against the plate, there should be no contact between the ink-jet nozzle and the paper during the swing.
4. You will want to make sparks for only one direction of swing, not across and back. You do not have to start the timer during the first swing after release; you may start it near the beginning of any downswing. You only need one ink-jet record. BE SURE TO NOTE, on your recording paper, in which direction the pendulum is swinging during your recorded swing.
5. Make sure the spark timer is off. Remove your recording paper from the backing plate for analysis. Pick a dot, not too close to the beginning (where the dots might be very close together). Circle that dot, and also EVERY OTHER DOT in your motion diagram after the first selected dot. Then go back and label the "in-between" dots as dot #1, #2, etc.
6. Measure d_i, the distance between each pair of successive circled dots. Record each d_i in Data Table 5.1.

7. On your recording paper, draw a line which is parallel to the top edge of the paper and which passes through the dot with the square around it. Be very careful to insure that this line is parallel to the top edge of the paper. Measure h_i, the altitude of each labeled point with respect to this line, and record that value in Data Table 5.1.

Results

1. Calculate the average speed v_i of the bob in each interval i for which the labeled dots mark the timewise midpoints. In each case, this is just d_i divided by $1/30^{th}$ of a second (because there is $1/60^{th}$ of a second between each two dots and we took every other dot). Enter these values in Data Table 5.1. These calculated speeds are only approximately the bob speeds at the labeled locations, because the path of the bob is not a straight line between two successive circled dots, and because the bob is always speeding up or slowing down (except exactly at the lowest point in the swing). However, you should find that this approximation is sufficiently accurate for our purposes. Show a sample calculation of one selected v_i in the space below.

2. Calculate the kinetic energy of the bob (in mJ) at each labeled point. The mass of the bob is 592 g (0.592 kg). Enter these values of KE_i in Data Table 5.1. Make a graph of these values, placing the energy on the y-axis of your graph and the point numbers on the x-axis. Show a sample calculation of one selected KE_i in the space below; get a value in joules and convert to mJ.

3. Calculate the potential energy of the bob (in mJ) at each labeled point. Use 9.8 m/s^2 for the acceleration due to gravity. Enter these values of PE_i in Data Table 5.1. Also enter these values on your graph. If possible, for values of PE_i, use a different color ink or pencil than you used for values of KE_i. Show a sample calculation of one selected PE_i at the top of the next page; get a value in joules and convert to mJ.

4. Calculate the total mechanical energy of the bob at each labeled point. Enter these values in Data Table 5.1 and also on your graph. Is this graph a flat line? If not, give a reasonable explanation for the deviation from a flat line.

Going Further

1. Make a force diagram for the bob at some general location (not the starting point and not near the lowest point in the swing). Identify all forces acting on the swinging bob.

2. Conservation of Mechanical Energy for the swinging bob turns out to be exactly the same as for a falling ball. Yet your force diagram for the swinging bob should include one force besides gravity. Why does that force not affect the mechanical energy?

Data Table 5.1

i	d_i (cm)	h_i (cm)	v_i (cm/s)	KE_i (mJ)	PE_i (mJ)	ME_i (mJ)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						