PHYS 1401
General Physics I

EXPERIMENT 7
CONSERVATION OF MECHANICAL ENERGY

I. INTRODUCTION

The objective of this experiment is to measure the total mechanical energy of a system at two arbitrary points on the path of motion of the system and to show that the total mechanical energy remains constant. This will be done by directly measuring the initial height of a mass above a reference level and then measuring the velocity of the mass at that level. This will allow us to calculate the mechanical energy of the system at each point and to check if our data are consistent with the law of **conservation of mechanical energy.**

II. THEORY

The mechanical energy of an object exists in two forms: potential and kinetic. Kinetic energy is the energy of motion and is defined as

$$KE = \frac{1}{2}mv^2 \tag{1}$$

where m is the mass of the object and v is its velocity. Gravitational potential energy is the energy of the object due to its position relative to the earth. The gravitational potential energy of an object of mass m, relative to an arbitrary reference level is

$$PE = mgh \tag{2}$$

where h is the height of the object above the reference level.
The mechanical energy of an object, E, is the sum of its kinetic and potential energies.

$$E = KE + PE. \tag{3}$$

If the work done on an object is due to conservative forces only (gravity, spring force, electric force), then the mechanical energy of the system is constant throughout its motion. This means that the mechanical energy of the object at any point (an initial point) is equal to the mechanical energy of the object at any other point (a final point). Algebraically

$$\begin{aligned} E_i &= E_f \\ KE_i + PE_i &= KE_f + PE_f. \end{aligned} \tag{4}$$

This equation is known as the equation of **conservation of mechanical energy.**

III. APPARATUS

200 g mass (cylinder from the weight set), string, rod and pendulum clamp, meter stick, photogate, computer with Logger Pro software.

IV. EXPERIMENTAL PROCEDURE

1. Assemble the apparatus as shown in figure (1). Place the rod on the table and tighten the clamp near the top. Cut a piece of string long enough such that the mass is hanging from the string with its center (center of mass) $10.0\,\text{cm}(= 0.100)\,\text{m}$ above the table. You can adjust this height as you fasten the string to the clamp.

2. Place a piece of tape on the middle part of the cylinder and mark a horizontal line and vertical line near the middle as if you are marking the middle of the cylinder with a cross. You will measure the height of the cylinder with respect to this point.

3. Measure the diameter of the cylinder using a vernier caliper and enter this number in the computer. Do this by opening the **Logger Pro** folder and the **One Gate Timing** file. Locate the **LabPro** icon on the top left of the screen and click on it. Click on **Dig/Sonic 1** and scroll to **set distance or length**. Enter the diameter of the cylinder in units of meters.

4. Allow the mass to hang vertically down and place the photogate at that location. Adjust the height of the photogate such that it is blocked and unblocked by the middle portion of the mass.

5. Clamp a meter stick to a stand to use in the measurement of the initial height of the mass.

6. 6. Pull the mass to the side until the height of the center (marked by the cross) is $h_i = 20.0\,\text{cm} = 0.200\,\text{m}$. Line up the mass with the middle of the phototgate such that when you release the mass, it goes through the photogate and the computer can measure the velocity. The photogate should be blocked and unblocked by the middle of the mass not the top nor the bottom.

7. Click on **start** and release the mass from that initial height. As the mass goes through the photogate, the computer will give you its speed at that point. Record this speed in the data table. Repeat three times. The velocity for this run will be taken as the average of the three trials.

8. Repeat steps (6) and (7) from initial heights $h_i = 0.300\,\text{m}$ and $h_i = 0.400\,\text{m}$ each time recording the velocity.

9. You are done with experimental procedure. Do not disassemble the apparatus yet. Follow the steps in the analysis section and perform the required calculations to make sure your data are in agreement with the theory.

V. ANALYSIS

1. Calculate the total mechanical energy of the mass at the initial point of release

$$E_i = PE_i + KE_i = mgh_i + \frac{1}{2}mv_i^2. \tag{5}$$

2. Calculate the total mechanical energy of the mass at the point where it goes through the photogate

$$E_f = PE_f + KE_f = mgh_f + \frac{1}{2}mv_f^2. \tag{6}$$

3. Calculate the percent difference between E_i and E_f for the three cases.

$$\%\,\text{difference} = \frac{|E_f - E_i|}{\left(\dfrac{E_f + E_i}{2}\right)} \times 100. \tag{7}$$

4. Write a conclusion summarizing your results. Comment on the success of this experiment. Is your result consistent with the law of conservation of mechanical energy? Explain any percent differences that are larger than 10%. What do you think are the two most important sources of error?

Experiment (6) Data Table				
Mass of cylinder in kilograms, $m =$				
Diameter of cylinder in meters, $d =$				
Initial velocity, $v_\mathrm{i} = 0.00\,\mathrm{m/s}$	Initial Kinetic Energy, $KE_\mathrm{i} = (1/2)mv_\mathrm{i}^2 = 0.00\,\mathrm{J}$			
Height of cylinder at the bottom of the swing, $h_\mathrm{f} = 0.100\,\mathrm{m}$				
Initial Height h_i (m)	Final Velocity v_f (m/s)	Final Velocity v_f (m/s)	Final Velocity v_f (m/s)	Average Final Velocity $v_\mathrm{f,average}$ (m/s)
0.200				
0.300				
0.400				

Initial Height h_i (m)	Average Final Velocity $v_\mathrm{f,average}$ (m/s)	Initial Mechanical Energy $E_\mathrm{i} = KE_\mathrm{i} + PE_\mathrm{i}$ (J)	Final Mechanical Energy $E_\mathrm{f} = KE_\mathrm{f} + PE_\mathrm{f}$ (J)	Percent Difference
0.200				
0.300				
0.400				