Conservation of Energy of a Simple Pendulum

Equipment

	Includes:	
1	Rotary Motion Sensor	PS-2120A
1	Density Set	ME-8569
1	Multi-Clamp	ME-9507
1	Large Table Clamp	ME-9472
1	Rod, 90-cm	ME-8738
1	Rod, 45-cm	ME-8736
1	String	SE-8050
	Required, but not included:	
1	Meter Stick	SE-8827
1	Balance	SE-8723

Introduction

When a pendulum swings, potential energy is transformed into kinetic energy, and then back again to potential energy as the speed and elevation of the pendulum vary during the motion. In this experiment (see Figure 1), the motion of the pendulum is measured by the Rotary Motion Sensor. The height, h, of the pendulum "bob" is calculated using the angle, θ, and the length of the pendulum, L, as shown in Figure 2. Using trig, it can be shown that

$$h = L\,(1 - \cos\theta) \qquad (1)$$

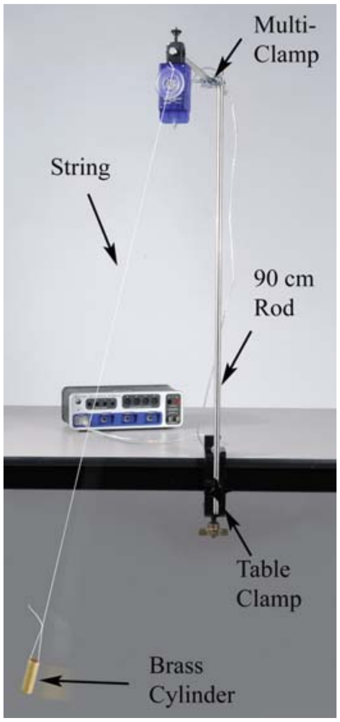

Figure 1: Simple Pendulum

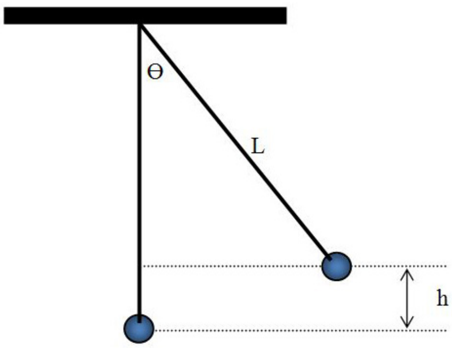

Figure 2: Calculating height, h.

Setup

1. Attach the table clamp and 90 cm rod to the table as shown in Figure 1. Use the multi-clamp and 45 cm rod to suspend the Motion Sensor out over the floor.

2. Use a balance scale to determine the mass of the brass cylinder from the density set.

3. Cut a length of string about 1.5 m long and thread one end through both holes in the Rotary Motion Sensor pulley as shown in Figure 3. Tie a knot at the top to keep the string from pulling back through.

4. Tie the brass mass to the other end of the string. You want the string as long as possible, without the mass touching the floor.

5. As accurately as possible, determine the length, L, of your pendulum. You should measure from the center of rotation down to the center of the cylindrical mass.

6. Plug the Rotary Motion Sensor into Channel P1 on the interface.

7. In PASCO Capstone, set the sample rate to 50 Hz.

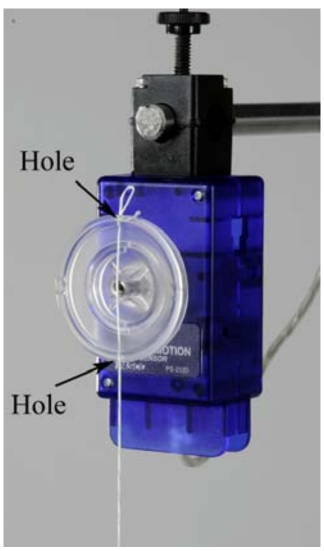

Figure 3. Hanging String

Calculations

1. Open the Capstone Calculator window and create the following calculations:

v = L*derivative(7,[Angle(rad)],[Time])	with units of m/s
L = 1.00	with units of m
KE = 0.5*m*v^2	with units of J
m = 0.300	with units of kg
U = m*g*L (1-cos([Angle (rad)]))	with units of J
g = 9.8	with units of m/s^2
Total=KE+U	with units of J

2. Change the default values for the pendulum mass (m) and length (L) to the values for your pendulum.

3. The calculation for the velocity uses the relationship between tangential speed (v) and the angular rotation speed (ω)

$$v = \omega r \qquad (2)$$

where the radius (r) is equal to L, the length of the pendulum. The angular rotation speed (ω) is calculated by taking the derivative of the angle, θ.

Speed and Kinetic Energy:

1. Create a graph of v vs. t and add a plot area and put KE on the vertical axis of the second plot area.

2. Make sure that the pendulum is absolutely still, then start recording.

3. Immediately pull the pendulum sideways about 30° and smoothly release.

4. You only need two or three oscillations, then click on Stop.

5. The data needs to be completely smooth and free of spikes. If the pendulum is not released smoothly, there will be unwanted secondary oscillations. Repeat until you have one good, smooth run.

6. Use the Multi-Coordinates tool to measure the first maximum speed of the pendulum.

7. Using this speed and the mass of the pendulum, calculate the maximum kinetic energy.

8. Measure the kinetic energy off the graph for the same time and compare.

Potential Energy (U):

9. Create a graph of Angle vs. Time. Then add a plot area and put the potential energy (U) on the vertical axis of the second plot area.

10. Use the Multi-Coordinates tool to measure the first maximum in the angle for the pendulum.

11. Using Eqn. (1), calculate the resulting height, h.

12. Using this height and the mass of the pendulum, calculate the maximum potential energy.

13. Measure the potential energy off the graph for the same time and compare.

14. How does this maximum potential energy compare to the maximum kinetic energy from the previous page? What should they be?

Kinetic Energy and Potential Energy:

15. Create a graph of Potential Energy (U) vs. Time. Then use the Add Similar Measurement to add the Kinetic Energy (KE) to the vertical axis.

16. In general, what can you say about the two curves? For example, as one curve decreases, what is happening to the other?

17. Using annotations on the graph, label where the pendulum is at the top of its swing and where it is at the bottom.

Total Energy:

18. On the energy graph, use the Add Similar Measurement to add the Total Energy (Total = KE + U).

19. What can you conclude about energy transformations and conservation of energy for the motion of a pendulum?

20. In general, does the total energy tend to decrease or increase? What is the reason for this?