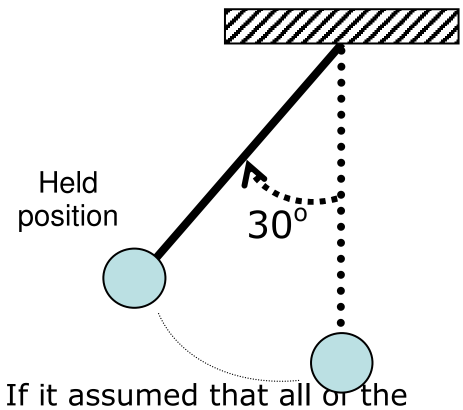
Laboratory: Conservation of Energy for a Simple Pendulum (Video)

Purpose: (1) To investigate the properties of energy conservation (i.e. the relationship between potential and kinetic energy) associated with the motion of a simple pendulum. (2) To calculate the potential and kinetic energy associated with a simple pendulum. (3) To use video analysis to study the energy PE to KE transfer for a simple pendulum.

Part A: Calculation of Kinetic and Potential Energy



a) A simple pendulum (mass = 2 kg and r = 0.5 m), secured at a position 0.8 m above the tabletop, is held in an elevated (taut) position. What is the mechanical potential energy of the pendulum?

b) The mass is then let go and the pendulum swings downward. If it assumed that all of the pendulum's mechanical energy is conserved, what is the pendulum's potential energy at the moment when the angle of the mass reaches 10^o relative to its lowest position? What is the kinetic energy at this moment?

c) The pendulum then reaches its lowest position. What is the pendulum's potential energy at this lowest point? What is the pendulum's kinetic energy?

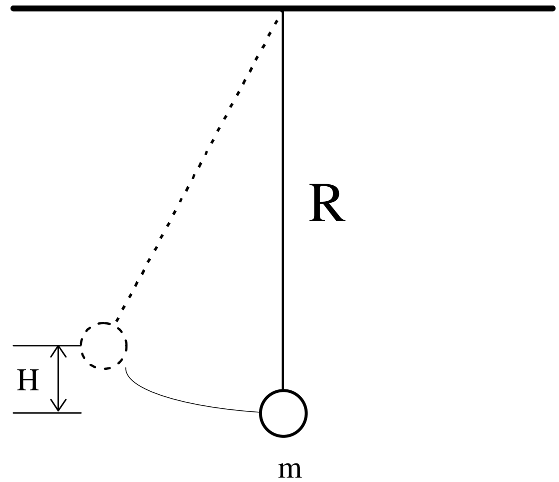
d) What is the pendulum speed when it is at the 10^o position?

e) What is the pendulum speed when it is at the lowest position?

f) Determine the Work performed by the gravitational force as the pendulum swings from 30^o to 0^o by calculating the area under the force vs displacement curve: area = $\int \vec{F} \cdot d\vec{r}$

g) Estimate the average rate of energy transfer (power) for the pendulum during the downswing.

Part B: Investigating a Simple Pendulum



A pendulum consists of a mass attached to a string that is fastened so that the assembly can swing in a plane. For a simple or ideal pendulum, all of the mass is considered to be concentrated at a point at the center of the mass.

When the mass is pulled in one direction, the height of the mass (H) is elevated relative to its height when the mass is freely hanging. Since the mass has been raised it has acquired potential energy relative to when it is freely hanging (i.e. at its lowest point!). When the mass is released, it swings during which time it loses potential energy but gains kinetic energy (since the mass gains speed during the downward phase of the swing). At its lowest point, the kinetic energy of the mass should be the same as potential energy the mass had at its highest point. This is because the energy of the mass is conserved, as long as there are negligible frictional forces, which might "suck" energy from the system.

Using a hanging mass or plumb bob, some string, and a ring stand we will construct a simple pendulum and test this hypothesis.

1. Weigh the mass/plumb bob using an electronic gram scale.
2. Construct a simple pendulum using the mass according to the directions of the instructor.
3. Obtain a webcam and connect to a USB port.
4. Start the LoggerPro software.
5. Insert "Video Capture" then record the motion of several swings of the pendulum. Be sure to include a "reference object" such as a meter stick in the field of view for scaling the movie.
6. Review the movie in LoggerPro. If it is not acceptable then record a new movie. When you have an acceptable video you are ready to begin the video analysis.
7. Resize and move the video analysis field (if necessary) for viewability and convenience
8. Create a new calculated data column named "Potential Energy" (don't forget to assign the appropriate units to the column). In the equation field, define the equation to calculate the potential energy of the pendulum.
9. Create a 2nd new calculated data column named "Kinetic Energy" (don't forget to assign the appropriate units to the column). In the equation field, define the equation to calculate the kinetic energy for the pendulum. ***Note:*** *the equation will need to use the magnitude of the velocity not just the vertical velocity in this calculation.*
10. Create a 3rd new calculated data column named "Total Energy". In the equation field, define the equation to calculate the sum of potential and kinetic energies (from steps 8 and 9) for the pendulum.
11. Select pendulum position in each frame (for 3 or more complete swing cycles)
12. Scale movie (using "reference" object) & set origin to the bottom of the pendulum swing

13. Use the "Examine" tool to determine the maximum K & U during 1st swing.

K_{max}=______ **U_{max}=______**

14. Calculate % error between these values (use the smallest value as the denominator). Do they appear to obey Law of Conservation of Energy? What is the basis for your answer? Be sure to consider the precision limits of the video itself.

$$\% \text{ Error } = \left| \frac{K_{max} - U_{max}}{(\text{smallest of the 2 values})} \right| \times 100\%$$

15. Describe the transfer of energy between U and K during the pendulum swings. What is the shape of the U and K vs. time graphs?

16. Describe what happens (over time) to the maximum U and K as the pendulum swings.

17. Describe the general "shape" of the Total Energy graph? As the swings progress, does the Total Energy remain constant? Does it increase? Decrease? Why?

18. Using the Line tool, calculate a linear fit for the Total Energy graph and determine the slope and y-intercept for the fit.

Slope: __________

Y-Intercept: __________

Note: If the slope is zero then the total energy graph is not changing. If the slope is negative the total energy is decreasing with time, whereas a positive slope will indicate the total energy is increasing with time.

19. What are the units of the slope of the total energy graph? What is the significance of these units?

20. Explain the significance of the slope of the total energy graph vs time.

21. Explain how your pendulum data relates to the Law of Conservation of Mechanical Energy.

22. Explain how your pendulum data relates to the Law of Conservation of Energy.