Work & Energy

Pre-Lab Questions Page

Name: _____________________
Class: _____________________
Roster Number: _____________
Instructor: _________________

1. List the equation that represents the relationship between Work and Kinetic Energy.

2. List two possible units for Work and Kinetic Energy.

3. Each little box in the graph below corresponds to the:

\[
\text{Area under the curve} = \text{Work} = (0.05 \text{ N})(0.05 \text{ m}) = 0.0025 \text{ Joules}
\]
Estimate the area under the curve that corresponds to stretching the rubber band to a displacement of 0.5 meters. This is done by estimating the number of rectangles and multiplying by 0.0025 J. **Show your work.**

Enter your estimate here ___________

4. If the glider in #1 has a mass of 250 grams, calculate the final velocity of the glider if it starts from rest. **Hint:** Use the value of work calculated in the previous question. **Show your work.**

Enter your answer here ___________

5. If the final velocity of the same 250gram glider was measured to be 0.5 m/s - estimate how far the rubber band launcher was stretched using the graph. **Show your work.**

Enter your answer here ___________
WORK AND ENERGY

OBJECTIVE: Explore the relationship between work, kinetic energy and potential energy. Verify the Work-Energy theorem by experimentally determining the work done on a glider by a launcher.

APPARATUS:
- Air track with ULI timer (photo gate)
- Glider
- Balance
- Cord
- Mass holder (5 g)
- Masses (slotted)
- Logger Pro timer software

INTRODUCTION:

The work done in stretching the rubber band launcher is found by computing the area under the graph when the stretching force is plotted against the resulting displacement. Known forces are applied to the rubber band by means of a cord attached to it as shown in the figure 1. The displacement of the rubber band from its undisturbed position is measured. The area under the graph is computed to determine the potential energy changes for various displacements by using the Graphical Analysis software options.

The work done by a variable force, such as that exerted by a spring or rubber band must be computed as the area under the curve given by the Force as a function of position that is:
\[ W = \int_{\text{start}}^{\text{finish}} F(x) \, dx \]

In the first part of this lab you will determine the force \( F \) exerted by a rubber band as a function of the amount of its stretch \( \Delta x \). Where, \( F = mg \) and measured in Newtons and the stretch is \( \Delta x = x_f - x_i \) in units of meters.

This will result in a graph that looks something like this:

![Force vs displacement graph]

In part two of this lab you will launch a glider from chosen displacements of the rubber band and measure the resulting kinetic energy of the glider. You will then use your graph to compute the work done by the rubber band by finding the area under the curve for each launch. The work-energy theorem says these two should be equal. You will find the percent difference between the two values. Remember:

\[
\text{%difference} = \left| \frac{V_2 - V_1}{V_2} \right| \times 200
\]

The glider is launched from the positions used to determine the potential energies from part 1 of the experiment and its speed and mass are determined. From this data the kinetic energy imparted to it can be computed from the equation:

\[
\text{K.E.} = \frac{1}{2} m v^2 \quad \text{equation 1}
\]

The kinetic energy is compared to the work done to stretch the rubber band through this same displacement.
**PROCEDURE A:** Potential Energy (Finding the force curve)

1. Level the air track by observing a non-moving glider on the track.

2. Determine the equilibrium position of the un-stretched rubber band by placing the glider with the 5.0 g mass holder only in minimal contact with the rubber band and observing the initial position of the glider using the ruler mounted on the air track. Record this initial position.

3. Apply a 20gram mass to the 5gram mass holder attached to the glider, as in the figure above, to stretch the launcher. Record the position of the rubber band with the added mass and also record the amount of mass added. Remember to include the mass of the holder. Therefore, the total mass in this case is 25 g.

4. Repeat procedure 3 at least 9 times using masses in increments of 20 grams.

5. Remove the mass holder and string from the apparatus.

**PROCEDURE B:** Kinetic Energy

1. (Check out the Vernier Caliper from the instructor.) Measure and record the flag length. Measure and record the mass of the glider. *Place the photo gate about 15 cm from the front of the glider.*

2. Turn on the computer and then click on the Physics Lab folder and select the **Work-Energy** template. Reading the instructions in the text window-click on the **<Set up>** menu, then select **<data collection>,** and **<sampling>**. Enter the flag length in the appropriate units. Now click **<OK>**.

3. Click on the **<COLLECT>** button and then release the glider from the second of nine displacements, from Procedure A. When the glider passes through the photo gate, a table of your data should appear on the screen. Record the displacement of the glider prior to the launch.

4. Launch the glider from eight significantly different rubber band displacements. (These should be eight of the ten previously determined displacements in procedure A.) Record the displacements.

5. After all nine runs have been completed, click the **STOP** button. Save this data if it looks reasonable. Remember to save it as a “.mbl”.

6. Measure and record the mass of the glider with the attached flag fence.

**CALCULATIONS:**

1. **From Procedure A:** Graph the stretch, x in meters, and the associated stretching force, F in Newtons, using the spreadsheet part of the Graphical Analysis program. The initial applied force is zero when the stretch is zero. **This is an essential data point and must be entered as the first point.**
2. Adjust the axis labels to obtain a graph of the stretching force vs the stretch. This graph is NOT linear therefore the Regression line should not be used. Make sure the point protectors and connecting line is selected. Recall: \( F = mg \) and 1 kg = 1000 g and 1 m = 100 cm.

3. For five of the launch displacements find the area under the curve using the Integral option in the Analysis menu.

To integrate, drag the mouse from point (0,0) over the first region for which you want the area, then go to the <analysis> menu and select integral. These area values are the potential energy stored in the rubber band before launch. This is similar to procedure for getting the regression line.

4. Print out a copy of your graph and data column. See below for an example of the graph.

5. From Procedure B: Compute the kinetic energy acquired by the glider for the same five launch positions and coordinating speeds used in calculations steps 3. Recall: \( KE = \frac{1}{2} mv^2 \)

6. Calculate the percent difference between the acquired kinetic energy(KE) and the potential energy(PE) of the rubber band launcher.

\[
\%\text{difference} = \left( \frac{|KE - PE|}{KE + PE} \right) \times 100
\]
QUESTIONS:

1. What is the pattern between your calculated values for %difference and launch position used in procedure B?

2. What role does friction play in your comparison of kinetic energy and potential energy?

3. Calculate the average force, from your data, exerted by the rubber band on the glider using the definition of work and potential energy: \( W = Fd \) and \( PE = mgd \).

   \[
   F_{ave} = \frac{\text{Potential Energy}}{\text{Displacement}}
   \]

4. Calculate the time during which this average force would act to produce the observed momentum change from:

   \[
   F_{ave} \Delta t = m\Delta v
   \]