# EXPERIMENT 6: WORK AND ENERGY

**Objective:**

To validate the work-energy theorem and to study the conservation of energy principle.

**Theory:**

The work-energy theorem states that the net (total) work done on a system is equal to its increase in kinetic energy. You will determine the work done on a (nearly) frictionless cart and show that the work done is equal to the increase in kinetic energy of the cart. Furthermore, you will show that the increase in energy of the cart is equal to the decrease in potential energy of the falling weight that supplies the force on the cart.

The apparatus consists of a cart that is accelerated along a linear track by the constant force due to the tension in a cord attached to a falling mass. Three photogate timers spaced along the track measure the time it takes for the photogate flag of the cart to pass through each timer. The speed at that position is the flag width divided by the time measured by the photogate.

**Procedure:**

1. Make sure you understand and have checked the operation of the photogate timers.

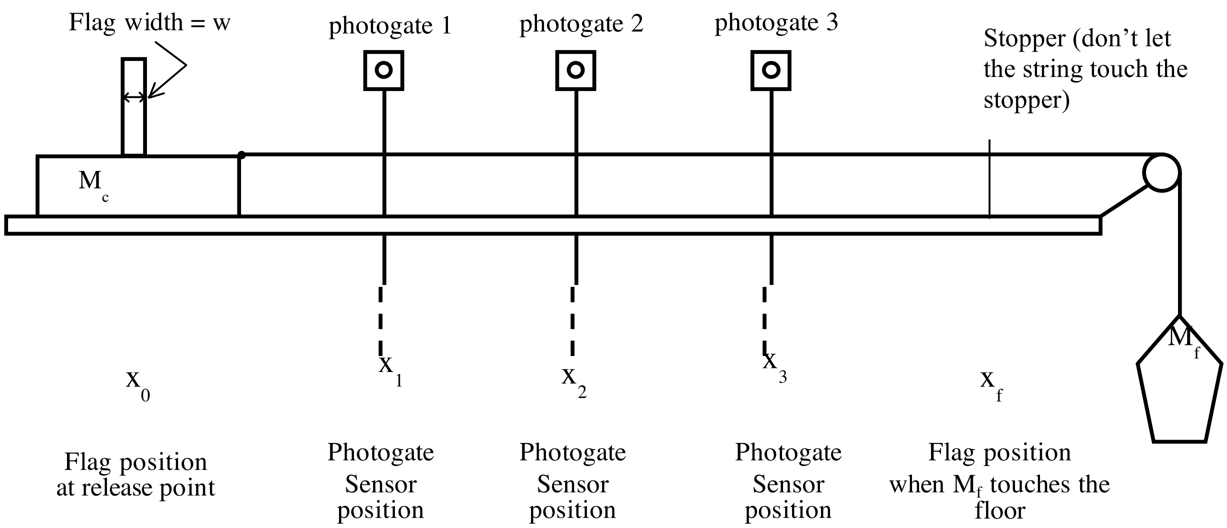
2. To simulate a frictionless system, tip the track until the cart rolls toward the pulley at a constant speed. (No forces should be acting on the cart!)

3. Measure and record the mass of the cart, $M_c$, and the width of the photogate flag.

4. Select a falling mass, $M_f$ between 0.05 kg and 0.20 kg. With the string and weight attached, record $x_f$ the position of the cart's flag on the track when the falling mass hits the floor. After this point the string becomes slack and does no more work. Space the three photogate timers at equal intervals along the portion of the track traveled under the influence of the tension in the string. Record these positions and the corresponding flag position $x_0$ from which you release the cart from rest.

5. With all masses and photogate positions recorded, place the cart at the starting position. Set the photogate timers to "gate" mode; reset the timers; load the string with your particular falling mass, and release the cart. Record the three photogate time intervals in your data table. Repeat this data run at least two more times to check the reproducibility of the apparatus. Use these values to estimate the uncertainty in $\Delta t$.

Each student should record individual data using a different falling weight. Do not share data.




Flag width, w=__________ m ± (      ) m

Mass of cart and load, $M_c$ =_________ kg ± (      ) kg

Falling mass, $M_f$ =_________ kg (where 0.050 kg ≤ $M_f$ ≤ 0.200 kg)

| X(m) ± (    ) m | Δt (s) ± (    ) s | $V = \frac{w}{\Delta t}\left(\frac{m}{s}\right)$ | Kinetic Energy (Joules) | Potential Energy (Joules) | Total Energy (Joules) | Work (Joules) |
|---|---|---|---|---|---|---|
| $X_0$= | | | | | | |
| $X_1$= | | | | | | |
| $X_2$= | | | | | | |
| $X_3$= | | | | | | |
| $X_f$= | | | | | | |

**Analysis:**

1. Calculate the speed of the cart at each photogate position by dividing the flagwidth by the time interval.

2. The kinetic energy of the system is $KE(x) = ½(M_c + M_f) V^2$ where $V$ is the speed at position $x$. Evaluate the kinetic energy at each observation point, including the release position.

3. The work done by gravity is $W(x) = M_f\, g(x\text{-}x_0)$, where $x_0$ is the flag position at the release point. (The mass producing the tension in the string falls the same distance as the cart moves horizontally.) Evaluate the work and record the result for each observation point.

4. The potential energy of the falling mass is $PE(y) = M_f gy = M_f\, g(x_f - x)$, where $(x_f - x)$ is the distance yet to fall and $x_f$ is the flag position when the mass hits the floor. Evaluate the potential energy and record the result for each observation point.

5. Calculate and record for each position the total mechanical energy of the system, kinetic energy plus potential energy.

6. On a single graph plot kinetic energy, work done by gravity, potential energy, and total energy as functions of the position of the cart. Use different symbols for each quantity (identified in a legend) and draw best fit lines for each set of data points.

7. For the values at $x_3$, estimate the experimental uncertainty in your raw data for mass, time, w, and distance. Use these values to determine the uncertainty in your calculation for potential energy and kinetic energy, and then for your value for the total energy at $x_3$

**Report:**

In addition to the standard elements of a well written lab report described in the introduction to this manual, your report must include:

1) A neat, organized data table. If your laboratory instructor agrees, you may use the table given on the previous page.
2) The energy graphs that summarize your analysis.
3) Your statement of observations and conclusions. If the total energy of the system was not constant, is its variance reasonable in light of the experimental uncertainties you estimated for the data you recorded?
4) Include the results obtained in step (7) above.