**Experiment 3: Conservation of Mechanical Energy**

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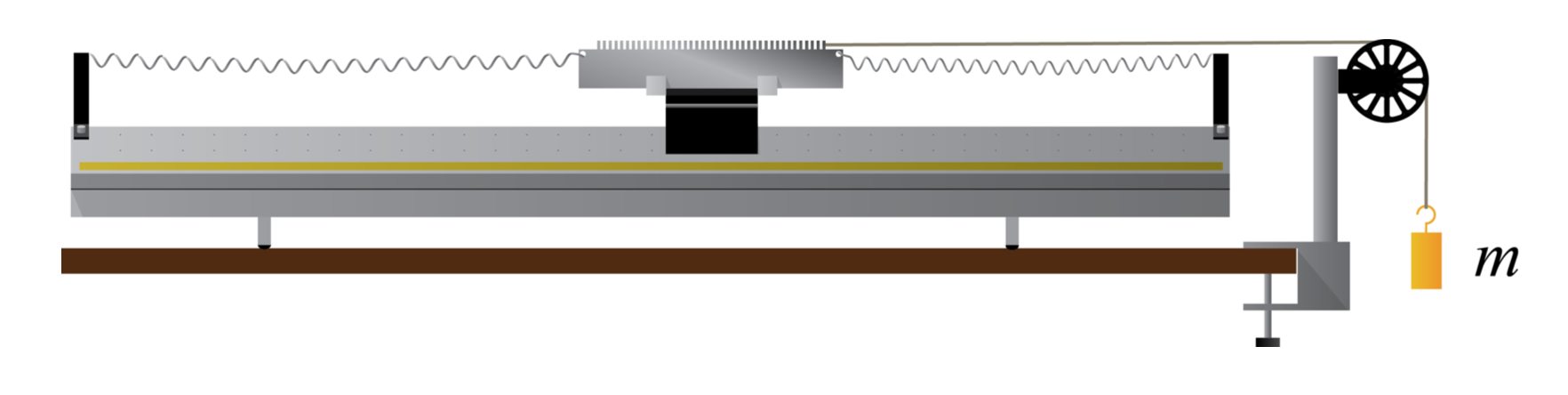
Lab Date: 20 August 2018

Lab Section 8 – Monday/Wednesday 11:30am

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**(2) Discussion**



**Figure 1:** This is an image of the apparatus that we used for this experiment. We hung masses of various sizes on the string to measure the effect of applied force on the displacement of the comb from equilibrium. The photogate comb is attached to a glider which sits on an air track. The glider and comb weight 232.6 g together. The comb has 61 teeth that are each 2 mm wide with 2 mm gaps in between.

Our photogate comb was lined up so that the photogates sensor would be positioned right in between the 30th and 31st tooth of the comb. More specifically, the sensor was at the right side of that gap, next to the 31st tooth. This point is the middle of the comb, and it made sense to have this as the equilibrium point for the comb.

Kinetic energy is dependent on velocity. Therefore, we needed to find the displacement along the comb of each tooth. We recorded the times that the photogate sensor was blocked by a tooth of the comb (sometimes referred to as a block event). We lined these up with the displacement by calculating the distance each tooth is away from the equilibrium point. We defined the equilibrium point as *x* ≡ 0. Every tooth to the left of the equilibrium point has a negative position, and every tooth to the right has a positive offset. Because our comb was set up so that the equilibrium point is at the start of the 31st tooth, that means that there were 30 teeth before the equilibrium point. Each tooth and each gap are 2 mm wide, so start of the leftmost tooth has an offset of -0.120 m relative to the equilibrium point. For each timestamp recorded, I incremented the value of the position by 0.004 m (this is 4 mm for each tooth and gap pairing). Since we have the position and the time for each block event, we can calculate velocity with equation 3.3 from the lab manual.

To find the kinetic energy, we plug in our values for velocity into equation 3.5 from the lab manual along with the mass of our glider and comb, which has a value of 232.6 g. This value was converted to kilograms before being used in the calculations.

To calculate the values for potential energy, we use our value for the spring constant, *k* = 5.963 N/m and plug that into equation 3.1 along with each value of position that we calculated to find velocity.

The total mechanical energy in the system was produced by adding corresponding values for kinetic energy and potential energy together. In an ideal system, we expect this value to be constant. In our experiment, some of our energy was lost as thermal energy because of friction from the air track.

**(3) Plots and Tables**

The mass of our glider with the mass attached is (232.6 ± 0.35) g. The scales that we used to measure mass can only measure up to 100 g, so we counter balanced the scale with two weights of 99.3 g and 99.2 g, each with uncertainty ± 0.2 g. The total uncertainty was calculated using each mass’ uncertainty and combining them with equation ii.22 from the lab manual.

|  |  |  |  |
| --- | --- | --- | --- |
| Trials | Mass (g) | Displacement (cm) | Applied Force (N) |
| 1 | 3.4 | 0.6 ± 0.03 | 0.0333 ± 0.0772 |
| 2 | 5.1 | 0.8 ± 0.03 | 0.0500 ± 0.543 |
| 3 | 19.9 | 3.2 ± 0.05 | 0.195 ± 0.0186 |
| 4 | 34.6 | 5.65 ± 0.03 | 0.339 ± 0.00785 |
| 5 | 60.4 | 9.92 ± 0.03 | 0.592 ± 0.00448 |
| 6 | 100.2 | 16.45 ± 0.05 | 0.982 ± 0.00363 |

**Figure 2:** This table has the values used to calculate the value of the spring constant. The spring constant was found by plotting each of these points and finding the slope of the trendline. For readability, mass is presented in units of grams, and displacement is presented in centimeters. The value of uncertainty for masses is 0.2 g. Uncertainties for applied force were calculated using equation ii.23 from the lab manual.

**Figure 3:** This plot shows the applied force that is applied to the springs depending on the mass. Relationship is linear. This confirms Hooke’s law which states that F = kx where k is spring constant. The slope of the line is (5.963 ± 0.0183) N/m. This is also the value of the spring constant.

**Figure 4:** This plot illustrates how the energy is divided up in our glider. Each data point in all three data series represents the amount of each type of energy that the glider has at each value of displacement from the equilibrium point. Slope of the trendline is (-0.0076 ± 0.00081) J/m. The value of total mechanical energy as the displacement becomes positive because we began our trials with a negative displacement. As the glider moved into a positive displacement, some of the energy was lost as thermal energy because of friction between the glider and the air track.

Friction force depends on the normal force, *FN*, and the coefficient of friction. The value of *FN* is equal to the weight of the glider on the sled. The value of friction force is equivalent to the slope of the trendline for total energy in Figure 3.

Most coefficients of friction are higher than our value. However, the air track is supposed to simulate a frictionless surface, so a low value makes sense in this scenario. If we look at the trend of decrease in the glider’s total mechanical energy across multiple oscillation cycles (as in section 4), then we see that the force of friction is actually less than in the half cycle case that we looked at here. Thus the coefficient of friction would also be lower if we looked at multiple cycles.

**(4) Extra Credit**

**Figure 5:** This plot shows the breakdown of the glider’s total mechanical energy into kinetic and potential energy across multiple oscillation cycles. Each data point represents the amount of each type of energy the glider has at a particular moment in time. The total mechanical energy of the glider decreases over time because of the friction between the glider and the air track. The trendline has a slope of (-0.0016 ± 0.0000727) J/s (Nm/s).

The initial value of the total mechanical energy is 0.02179 J. To find the time at which this value is reduced by a factor of *e*, we solve the following equation.

**Presentation Mini-Report**