**Conservation of Mechanical Energy Lab Report**

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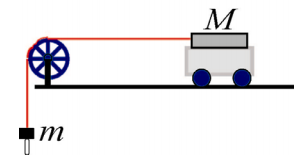
**Abstract:**

In this lab, I measured and, thereafter, calculated the conservation of mechanical energy of a particular system. The law of conservation dictates energy cannot be created and cannot be destroyed. Energy can only be transferred from one form to another. This lab incorporates kinetic energy, gravitational potential energy, potential energy of a stretched spring, and Hooke’s Law.

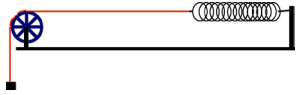
This system can be defined by *figure 1* and *figure 2* below. *Figure 1* depicts a cart and mass-block of mass M attached to an ideal pulley by an ideal string. The cart used is considered low-friction and the track is of PASCO brand. Data was recorded using a motion tracking device, encoded pulley, and *Logger Pro* program. *Figure 2* depicts a spring attached to one end of the PASCO track while the other side is attached to an ideal string. This ideal string passes over an ideal pulley and is attached to a hanging mass.

This lab verified it was indeed possible to test the concepts of conservation of mechanical energy with the supplied equipment. The lab concluded with values of the change in energy of our system to be -0.11 J/m with an uncertainty that was calculated out to be 0.01 J/m. The next part of the lab determined our spring had a spring constant of 44 N/m. This value has an uncertainty of 3 N/m. And lastly, ε = 2.26 with an uncertainty of ± 0.97. This entails something in our experiment played as a large distraction to our overall results.

*Figure 1*



*Figure 2*



**Gravitational Potential Energy:**

*Introduction and Theory*

The totality of this experiment is testing gravitational potential energy and the loss of energy due to kinetic friction from the movement of a traveling cart. A critical component of this lab was the use of an ideal string and an ideal pulley. The introduction of the non-ideal equipment in this experiment brings about new complications in the measurements and calculations; there would be unaccounted for forces in friction and in changing weights of the hanging mass and the pulled mass. As can be seen in *figure 1*, the figure that depicts the setup for the lab, the string that connects M (the cart) to m (hanging mass) redirects the string and tension from horizontal to vertical, vice versa.

For the purpose of this lab, I assume for the simplicity of calculations that I have made the surface of the track as frictionless as possible. I can neglect friction between the track and cart because I balanced it by substituting several paper clips for my hanging mass. This was to counteract the maximum static frictional force. I essentially balanced the static friction with the force of the hanging paper clips and eliminated the two forces from my equations. Note, friction did not magically disappear, it can just be neglected from the equations. The right number of paperclips was determined by a cart that moved at a constant speed. If it is moving at constant speed, then the sum of the forces is equal to zero and our system is balanced. In the calculations, we must neglect the weight of the paper clips because they accounted for static friction and therefore are not part of the system.

The Conservation of Mechanical Energy has the main concept of energy is preserved. The loss of potential energy from the system is transferred into kinetic energy as the cart begins to move down the track. Energy is taken from one location and put somewhere else. Using these known concepts, and the previously addressed concepts addressed above, we obtain the following equation to model energy in the system.

Wnc = ∆K + ∆U

The components can be further broken down. It is well-known that kinetic energy, at any point in a system, is modeled by

∆K = (1/2)(*m*)(*v*2)

where *m* is the mass of the object in motion, and *v* is the velocity of the same object. It is well-known that potential energy, at any point in a system, is modeled by

∆U = *mgh*

Where *m* is the mass of the object, *g* is the gravity constant 9.81 m/s2, and *h* is the horizontal displacement along the track. Using elementary method of substitution, our equation reforms to

Wnc = (1/2)(*m*)(*v*f2 – *v*i2) – *mg(h*f *– h*i)

*Procedure*

The following is a detailed report of the methods used to produce the corresponding calculations and reported results. The first action was determining the combined mass of our group’s cart and mass block. Their respective values are 485 grams and 499 grams to amount to a total of 984 grams. A “zeroed” electronic balance was crucial in this measurement. Each item was individually placed on the balance and recorded into our notebooks. The total mass was confirmed by placing the two objects on the balance concurrently. The uncertainty of the balance is a defined standard of 1 gram as defined by the manufacturer and it matches the balance’s least significant figure. .

The next stage of this lab revolved around balancing the static frictional force. Canceling out this opposing force proved to be rather easy. We first set up the lab to match *figure 1*. We made sure our track was leveled to the parallel. Our cart was attached to an increasing amount of paper clips until, when it was given a slight push, the cart would move at constant speed through the entirety of the track or until the paperclips reached the ground, in which case friction dominated and halted the system. This constant speed was measured by the *Logger Pro* program. It verified the slope of the velocity was zero and acceleration was hovering extremely closely to zero. The cart our group used required eight paper clips and one five gram mass to move at a constant speed. The mass of the eight paper clips and five gram washer was weighed concurrently and found to be 8 grams 1 gram. This uncertainty is again defined by the manufacturer.

The experiment was concluded by adding an additional 30 grams to the counterweight. The cart was released and then its motion was measured by the *logger Pro* program. Values were recorded and graphed using the data for acceleration, velocity, and position with respect to time.

*Analysis*

The analysis for this section of the lab consisted of transferring data from *Logger Pro* program into another program known as *Origin*. *Origin* is a program that aids in plotting graphs and with statistics of the results. Attached is a plot of our data titled “Energy v. Distance.” It depicts the measurements for potential energy, kinetic energy, and total energy, as are the results of a moving cart. *Origin* utilized the velocity and position tracked in the *Logger Pro* program to calculate these values. As previously stated, the values for energy are calculated by the following equations.

Wnc = ∆K + ∆U

∆K = (1/2)(*m*)(*v*2)

∆U = *mgh*

Wnc = (1/2)(*m*)(*v*f2 – *v*i2) – *mg(h*f *– h*i)

Mass remained constant because it is unchanging in this experiment at 984 grams, *g* is the gravity constant, 9.81 m/s2, and *v* is the velocity of the cart. Our calculations still neglect the weight of the paper clips. The paperclips were only necessary to eliminate friction from our calculations which ultimately takes energy out of the system and places it elsewhere. The equations we used correspond to a frictionless surface and that is what the paperclips’ purpose were. The mass of the system is the loaded cart, and the counterweight. The lab assumes that the kinetic and potential energy are both initially zero, which, according to the above equations, makes total initial energy zero. The total energy is then calculated and graphed by origin using the same equations. Referring to the corresponding graph, *Origin* calculated the slope of energy, or the change of energy (∆E/∆y) in the system to be -0.11 J/m. The uncertainty for this measurement was calculated by *Origin* using the standard deviation divided by the root number of samples and measured to be less than 0.01 J/m. The uncertainty in ∆E/∆y for balancing mass can be calculated with the computational method with uncertainty of energy lost to friction (0.1 J/m).

E/y  =

= 0.01 J/m

∆E/∆y = -0.11 0.01 J/m

**Spring Potential Energy**

*Introduction and Theory*

The purpose of the second half of the physics lab is yet again conservation of energy, but whereas it entailed the movement of a cart in the first section, this section delves into Hooke’s Law. This part of the experiment tested energy of a spring. Hooke’s Law states

Fx = -*kx*

where Fx is the force of some spring with respect to some distance *x* and a spring constant *k*. Deriving the spring constant *k* is a large portion of the learning concept andwill be derived later from the lab. At equilibrium, the spring was considered limp and at rest. At this point we will set the reference frame to *x*o = 0. The spring constant is the inverse of acceleration so *k* = a-1.

*x* = *ma*/*k* + *x*o

so *k* = *ma*/(*x* – *x*o)

where *m* is the mass of the counterweight, *x* is the horizontal displacement of the spring, and *a* is the acceleration.

Total energy is represented by similar equations used in the first half of the lab.

E = ∆K + ∆U

∆K = (1/2)(*m*)(*v*2)

∆U = *mgx* + (1/2)*kx2*

Total Energy is the change in kinetic energy summed with the change in potential energy. This concept remains unchanged from Gravitational Potential Energy. In the above equations, *m* is the mass of the hanging mass, *g* is the gravity constant at 9.81 m/s2, and *v* is the velocity that the system is moving at.

*Procedure*

This half of the lab began by calculating the spring constant *k* of the used spring. The first step in doing so is to measure the position of the spring after hanging different masses over the pulley. The mass hung over the pulley increased by five grams with each measurement recorded. When the spring stopped oscillating from the dropping force of the hanging mass, the displacement from the position it was relaxed to the same position on the spring was measured and recorded. This position was previously decided before adding masses. The position was the first coil closest to the string it is attached to the hanging mass by.

We used a pencil to make a normal line to the string. This would produce accurate visual results as if the string was mapped onto the PASCO track with the measurements at the string’s side. Yet, even with this visual aid, we concluded our eyesight could only be accurate within 1 cm. Therefore, our uncertainty in distance is ±1 cm.

Our range of masses stretched from 50 to 95 grams. These masses were weighed prior to each addition to our hanging mass just to validate they were of their marked weight. Each one measured to the marked weight. However, this still may not be perfectly accurate. Therefore, the uncertainty of the weight in the hanging mass is ±1 gram as noted by the manufacturer of the electronic balance. At the point 95 grams was the mass of the total hanging mass, the system came within centimeters of touching the floor. At the point 100 grams was the mass of the total hanging mass, the system fell to the floor.

The next part of the second half of the lab mandated dropping the hanging masses. The spring would be relaxed and the group would note the position where the spring was relaxed at the beginning of the first coil. One partner should drop the weight while the other partner should take note of where the spring lies at its maximum displacement. The lab manual recommended a total mass of 75 grams, but at that mass, the hanging mass would hit the floor. So we then had to rearrange the positioning by about 30 cm to account for the mass hitting the floor. This utilized the entire track, but the hanging mass still made contact with the floor. So our group had to adjust the hanging mass to 70 grams. And then there was another change to 5 grams; the problem was solved. This mass came within a centimeter of the floor. Our initial position, *x*o, was where the spring’s string-most coil started. The uncertainty in the weight of the hanging mass is identical to the uncertainty of the electronic balance and the uncertainty in *x*o arises from my eyesight. I could only measure within ±1 cm. We measured the spring’s mass expansion four trials per each partner (a total of 8 trials) and recorded each result. The uncertainty in the max displacement also arises from eyesight: ±1 cm.

And finally, after letting the masses drop, we measured the equilibrium point of the spring after the spring stopped oscillating. The uncertainty is the same as above. Our eyesight only allows for measurements within ±1 cm. This stays true for all 8 trials that were conducted.

*Analysis*

Referring to the Position v. Mass graphed attached at the end of this report, we were able to calculate spring constant *k*. This measurement is the slope of the attached graph. *Origin* has this value measured at 0.44 N/cm with an uncertainty also measured by *Origin* at ±0.03 N/cm. The spring constant can also be derived from an earlier equation:

K = *ma*/(*x – x*o)

I then calculated the uncertainty in *k* using the derivative method:

UNCg = 0.02 m/s2

UNCslope = (*g*/(slope + UNCslope)) – (*g*/slope)

UNCk = (UNCg2 + UNCslope2)1/2 = ±0.03 N/cm

This uncertainty takes into account the uncertainty in *x* uncertainty in gravityand the uncertainty in mass of the hanging weights. The final result was k = 0.44 N/cm ±0.05 N/cm.

I then proceeded to utilize the zero point of the gravitational potential energy at the point where the hanging mass was lowest, allowing for the calculation of the total energy of a system with aforementioned equations:

E = ∆K + ∆U

∆K = (1/2)(*m*)(*v*2)

∆U = *mgx* + (1/2)*kx2*

The uncertainty in the hanging mass can be neglected because it only accounts for fractional bit of the overall uncertainty. The masses are relatively accurate to what we measured, within 0.001kg. To measure the uncertainty of energy used in the system, we must utilize the derivative method. This method will allow us to find UNCx, uncertainty in the horizontal distance, and UNCk, uncertainty in the spring constant that we previously determined. The lab manual gave guidance to calculate these important values.

ε = (∆Uk + ∆Ug)/(|∆Ug|)

∆Uk = 38993 J

∆Ug = 30943 J

ε = (38993 + 30943)/(30943) = 2.26

UNCe,x = | ε (k,x + UNCx) - ε (k,x)| = 0.01 joules

UNC ε = ((UNC ε , k)2 + (UNC ε , x)2)1/2

ε = 2.26 ± 0.97

Sanam Patel’s Results

|  |  |  |
| --- | --- | --- |
| Trial # | Displacement(cm) | Equilibrium (cm) |
| 1 | 61 | 37 |
| 2 | 60 | 37 |
| 3 | 61 | 37 |
| 4 | 60 | 37 |

Jacob Alspaw’s Results

|  |  |  |
| --- | --- | --- |
| Trial # | Displacement(cm) | Equilibrium (cm) |
| 1 | 61 | 37 |
| 2 | 61 | 37 |
| 3 | 60 | 37 |
| 4 | 60 | 37 |

Effects on spring displacement with respect to changing mass:

|  |  |
| --- | --- |
| Hanging Mass (g) | Displacement (cm) |
| 55 | 3 |
| 60 | 2 |
| 65 | 2 |
| 70 | 2 |
| 75 | 3 |
| 80 | 3 |
| 85 | 2 |
| 90 | 3 |
| 95 | 1 |

**Conclusion**

In the first part of this lab, I had to calculate gravitational potential energy in a system. In the second part of this lab I had to witness and test the potential energy of a spring. Both parts of these labs allowed me to further develop my knowledge in physics dealing with the conservation of mechanical energy. My value for ∆E/∆y was found to be -0.11 0.01 J/m. This is within reason to agree with what the theory predicts. However, it doesn’t perfectly reflect the theory. The data is good, but not perfect. There is a loss of energy in some place. This is probably due to friction that was unaccounted for. To decrease error in this system, the participant should eliminate uncertainty and frictional forces with more accurate masses or attempt the use of a different cart. Multiple trials in the *Logger Pro* program should be used for precise results. The second part of this lab resulted in a spring constant of 44 N/m. This value is certainly reasonable for a spring that we had in lab. However, after conferring with the teaching assistant, the actually spring constant is a mystery. We cannot be entirely sure if our produced value is accurate. My values for ε = 2.26 ± 0.97. This is a ratio and should theoretically be 0. Outside forces must have been acting largely at play. One possible source of error is calculation error, but I have checked my work, and nothing seems to be wrong. Overall, these calculations, measurements, and observations all support the conclusion that there is conservation of mechanical energy in ideal systems.

**Acknowledgements**

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**References**

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