**Experiment**

**6**

Work-Kinetic Energy and Friction

#### Introduction

The purpose of this experiment is to enhance our understanding of energy concepts by utilizing the same system use for Newton’s 2nd Law. The final velocity of a system will be measured and compared with the value predicted by using Work-Energy or Conservation of Energy ideas.

**NOTE: You will need to upload the Capstone file of your collected data into Canvas to get credit for the lab report (no emailed files accepted). The data in the Capstone file must match the data in your report. You will need to include one sample graph for each part of the lab.**

**Theory**

1. For the system shown in the following schematic (without the Friction block), write the expression for the work done on the cart, and then use the Work-Kinetic Energy Theorem to write the equation for the change in kinetic energy of the cart assuming no frictional forces are present.
2. Write the expression for Conservation of Energy for the cart, hanging mass system assuming no friction is present. Express your result in terms of the measured quantities **M1, M2, vi, vf, xi and xf.**
3. Use free-body analysis and the change in mechanical energy of the system to derive an expression for the coefficient of kinetic friction for the sliding block in terms of the measured quantities **M2, MT** (where MT=M1+M2+MBL)**, MBL vi, vf, xi, xf, and fnominal**. Make sure you explain the meaning of **fnominal.**

**Normal**

T

**Force**

Frictional Force

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T

## Equipment Needed

*•* Dynamics Track • Weight set with 50g Hanger

*•* Dynamics Cart • Adjustable feet for the track (two)

*•* Friction Block • Spirit Level

*•* Electronic Balance • Smart pulley

##### **Procedure**

**Part 1:**

1. Open the experiment file titled as shown:***WrkEngFriction.cap***.
2. Setup the apparatus as shown below. Level the track by placing a cart on the track. Make sure the portion of the string above the track is parallel to the track; otherwise the tension in the string won’t be constant.

**M2**

**M1**

1. Add about 50-90 grams of mass to the mass hanger. Carefully measure and record the total hanging mass **M2**.
2. Carefully measure and record the mass of the cart (**M1**). Record the mass of the cart and hanging mass as **M1**+**M2**.
3. Turn on the Bluetooth device on the cart and connect the computer with the cart.
4. Remove the tension from the string and zero the force sensor by clicking the gear  icon next to A picture containing text

   Description automatically generated and then clicking “Zero Force Now.”
5. Pull the cart away from the pulley, click the **Record** button to begin data recording and then release the cart.
6. Click **Stop** to end recording just before the cart reaches the pulley. **Don’t forget to** **stop the cart before it collides with the pulley**.
7. Choose an initial time and from the graphs record the initial velocity and position. Choose a final time and from the graph record the final velocity and position. You will have to select the Multi-Coordinate Tool. To do so, click on the cross-hair icon and choose the Multi-Coordinate Tool. Then, to increase the sensitivity, right click on the graph, click out of the snap-to function. **Click on the tool properties tab, then numerical, then for the vertical values, change the number of decimal places to 3. You will do this for both graphs ( e.g. repeat process for the Force vs. Position graph).**
8. Repeat steps 4-9 two more times.

**Part 2:**

1. Select one of the friction blocks, place one weight inside it, then place the block on the cart. Measure that and the hanging mass and record that as **MT**. (If you need to change the value of the hanging mass, measure that as well.)

**M2**

**MBL**

**M1**

1. Measure the mass of the friction block plus weight and record that as **MBL.**
2. Repeat steps 4 through 7 of Part 1 five times determine the average nominal frictional force on the system.
3. Now place the friction block behind the cart and repeat steps 4-7 of Part 1.

**M2**

**MBL**

**M1**

1. Repeat these measurements four more times to determine the coefficient of kinetic friction from the average of five measured values.

**Data**

Provide a clear and complete display of all the pertinent data. Remember, you are trying to make this easy for the reader, not easy for you to write. Include one sample graph for Part 1 and Part 2.

Independent Cart

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |
| Trial Attempt | Mass Hanger(kg) | Cart (kg) | Mass (g) Total | Initial Position (cm) | Position (cm) | Velocity Initial (m/s) | Velocity Final (m/s) | Work (Nm) |
| 1 | 0.09926 | 0.24909 | .249909 | 0 | 70 | 0.5 | 1.585 | 0.277 |
| 2 | 0.09926 | 0.24909 | .249909 | 0 | 70 | 0.342 | 1.525 | 0.275 |
| 3 | 0.09926 | 0.24909 | .249909 | 0 | 70 | 0.514 | 1.599 | 0.28 |

Results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Work | Percent Diff | δKE (J) | Kf (J) | Ki (J) |
| 0.277 | -2.04891 | 0.282675 | 0.313914 | 0.031239 |
| 0.3 | 1.434851 | 0.275982 | 0.290598 | 0.014615 |
| 0.28 | -2.31538 | 0.286483 | 0.319497 | 0.033014 |

Results (Total System)

|  |  |  |
| --- | --- | --- |
| δKE (J) | Kf (J) | Ki (J) |
| 0.394949715 | 0.438595872 | 0.043646 |
| 0.385598263 | 0.40601838 | 0.02042 |
| 0.400265059 | 0.446390941 | 0.046126 |

|  |  |  |  |
| --- | --- | --- | --- |
| M\_t (g) | delta X (cm) | G | PE (J) |
| 0.349169 | 0.4174 | 9.8 | 1.428284 |
| 0.349169 | 0.4089 | 9.8 | 1.399198 |
| 0.349179 | 0.424 | 9.8 | 1.45091 |

Cart Carrying Block

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Trial Attempt | Mass Hanger (kg) | Mass Cart (kg) | Friction Cart (kg) | Mass Total (kg) |
| 1 | 0.09926 | 0.24981 | 0.34117 | 0.69024 |
| 2 | 0.09926 | 0.24982 | 0.34117 | 0.69025 |
| 3 | 0.09926 | 0.24983 | 0.34117 | 0.69026 |
| 4 | 0.09926 | 0.24984 | 0.34117 | 0.69027 |
| 5 | 0.09926 | 0.24985 | 0.34117 | 0.69028 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Initial Position (m) | Final Position (m) | Velocity Initial (m/s) | Velocity Final (m/s) | Mech Work (J) |
| 0 | 0.4586 | 0.45 | 1.217 | -0.00547 |
| 0 | 0.4331 | 0.595 | 1.218 | -0.05327 |
| 0 | 0.4538 | 0.257 | 1.142 | -0.01415 |
| 0 | 0.4841 | 0.497 | 1.217 | -0.04501 |
| 0 | 0.42 | 0.579 | 1.198 | -0.02728 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| δKE (J) | δHeight (m) | G (m/s^2) | Kinetic F (m/s) | Kinetic I (m/s) | δU (J) | *FNominal* |
| 0.441267 | .5212 | 9.8006 | 0.511153436 | 0.050361291 | -0.44613 | 0.010544 |
| 0.389818 | .4625 | 9.8006 | 0.512001221 | 0.144919368 | -0.42132 | 0.072683 |
| 0.427311 | .4981 | 9.8006 | 0.450106121 | 0.022795491 | -0.44146 | 0.03112 |
| 0.425924 | .5223 | 9.8006 | 0.511175652 | 0.085251451 | -0.47094 | 0.092921 |
| 0.381297 | .4286 | 9.8006 | 0.4970016 | 0.058018034 | -0.40858 | 0.064899 |

**Cart Dragging Block (Friction)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Trial Attempt | Mass Hanger (kg) | Mass Cart (kg) | Friction Cart (kg) | Mass Total (kg) |
| 1 | 0.09926 | 0.24981 | 0.34117 | 0.69024 |
| 2 | 0.09926 | 0.24982 | 0.34117 | 0.69025 |
| 3 | 0.09926 | 0.24983 | 0.34117 | 0.69026 |
| 4 | 0.09926 | 0.24984 | 0.34117 | 0.69027 |
| 5 | 0.09926 | 0.24985 | 0.34117 | 0.69028 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Initial Position (cm) | Position (cm) | Velocity Initial (m/s) | Velocity Final (m/s) | Work (J) |
| 0 | 0.4059 | 0.281 | 0.886 | -0.12394 |
| 0 | 0.431 | 0.407 | 0.93 | -0.12078 |
| 0 | 0.5841 | 0.329 | 0.939 | -0.26391 |
| 0 | 0.446 | 0.342 | 0.862 | -0.17742 |
| 0 | 0.4591 | 0.3 | 0.865 | -0.18837 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| δKE (J) | δHeight (m) | G (m/s^2) | Kinetic Final (m/s) | Kinetic Initial (m/s) | δPotential (J) |
| 0.270918 | -0.4059 | 9.8006 | 0.27091782 | 0.02725102 | -0.39486 |
| 0.298499 | -0.431 | 9.8006 | 0.298498613 | 0.057169611 | -0.41928 |
| 0.304308 | -0.5841 | 9.8006 | 0.304308369 | 0.037357216 | -0.56822 |
| 0.25645 | -0.446 | 9.8006 | 0.256450491 | 0.04036837 | -0.43387 |
| 0.258242 | -0.4591 | 9.8006 | 0.258242377 | 0.0310626 | -0.44662 |

**Analysis**

**Part 1:**

1. From the data collected calculate the work done on the system using the “Area” tool in Capstone for each run.
2. Using the area tool to calculate the work done we found a work amount done for a single trial to be .28Nm.

Chart

Description automatically generated

1. For each run, calculate the change in kinetic energy of the system consisting of the cart only and compare (%difference) with the work done on the cart. Show your work in the Results section (yes you need you create the results section yourself).

***Chart

Description automatically generated***

***Example Trial 1:***

1. Are these two values the same for each run? Why or why not? (Hint, is friction negligible?). The answer to these questions should be expressed in your conclusion.

This answer will be expressed in the conclusion.

1. For each run, calculate and compare the change in kinetic energy of the system (consisting of the cart and hanging mass) and the change in potential energy of the system. Show your work in the Results or in an Appendix section. Discuss results in conclusion.

**Part 2:**

1. For the run with the friction block on the cart, calculate ΔK and ΔU, the change in kinetic and potential energy respectively (g=9.8006m/s2 assume exact). Is mechanical energy conserved?

Potential Energy Sample

Kinetic Energy Sample:

# Using the formula:

# Here determine if mechanical energy is conserved:

We find mechanical energy is conserved.

1. Use ΔU+ ΔK to determine the nominal frictional force acting on the system (fnominal=|Wnominal|/x1). Show your work.

Sample Calculations

Finding Average

Finding Standard Deviation:

Graphical user interface, text

Description automatically generated

3. For the run with the block behind the cart calculate ΔK and ΔU and determine the “work” done by net frictional force acting on the system (WNC, this value should be less than zero). Then, determine the “work” done by the frictional force of the block itself (since WNC = WBL- fnominalx2, then

WBL=WNC+ fnominalx2) along with the net force acting on the block itself. Show your work.

Finding

Finding average:

Sample Work Calculation:

Sample Work (Box) calculation:

1. Use free-body analysis to determine the coefficient of kinetic friction for this block. Compare with the accepted values. Note: The accepted values for the coefficients of friction are: µcork = 0.45, µfelt = 0.22 and µplas = 0.16. Show your work.

**M2**

**MBL**

**M1**

mgh

Isolate

5. Calculate the average, standard deviation, and uncertainty of the coefficient of kinetic friction of the block. Compare your results with your peers. Do you results agree with those of your peers?

*It important to note that we cannot do error propagation to determine the uncertainty of the coefficient of kinetic friction of the block because the experimental condition for each run is not the same. The conditions of the surfaces of the block and the track are not guaranteed to be the same after each run. Therefore, we must resort to calculating the standard deviation and uncertainty of the coefficient of the measured value of the kinetic friction.*

My results are relatively close to those of my peers. Comparing results with Ivana Thomas, I found her coefficient of friction to be .112N while mine was .151N. I’m satisfied with the results we have discovered.

Finding average:

Finding Standard Deviation:

Graphical user interface, text, application

Description automatically generated

Finding Margin of Error:



# Conclusion

Your conclusion must include a description of the experiment and its purpose, a discussion and statement of results, a discussion of random errors and systematic errors. Be sure to be quantitative in your discussion.

The purpose of this experiment is to practice the fundamental scientific process and verify the equations we have been introduced to. In this experiment we focused on kinetic energy, work and potential energy. These three concepts are seen everyday throughout a variety of activities and can be used to explain events that occur in nature. Kinetic energy and potential energy are different than newtons second law and used in this case to describe the total energy within a system. Both kinetic energy and potential energy encompass the total energy within a system given no external forces. These two combined can provide the scientist with a ton of useful information. For example, albeit a morbid case, the French guillotine. In this case, the machine is raised to a certain height and given potential energy. That means it will fall with an expected rate of As the height decreases, the machine will gain kinetic energy and force. Because potential energy is being translated into kinetic energy, as potential energy decreases, kinetic energy increases. Again, the total energy in the system is kinetic + potential, thus we find . With this information we can reasonably deduce how fast the machines instruments will be moving when it contacts its target. In a similar fashion, That is what we have accomplished in this lab except with carts and the added caveat of friction. This sort of information isn’t just useful for antiquated French machinery but for a wide variety of tools as well. Planes flying at a certain height have potential energy. Cars rolling uphill have kinetic energy that is being transferred into potential energy. Satellites in orbit have potential and kinetic energy. These concepts are all around us.

Our results for this experiment were reasonable without having analyzed them against a wide array of data. I have found my coefficient of fricition average to be .15N which seems accurate. One of the systematic errors present throughout this laboratory experiment is the existence of nominal friction. The results were not the same every single time due to the systematic error of friction. For the purposes of the lab, we were able to confirm that change in kinetic energy is equivalent to work. We calculated for this by using PasCO Capstone and determining the initial and final velocities of the cart. Using that information and measuring force against distance, we can determine the kinetic energy in a system and measure that against the known force distance (work) value. We are quantifying , we found a percent difference between Work and Kinetic energy in all initial trials of less than 2.5%. 2.04%, 1.43%, and 2.31% difference between the measured values of work and our change in kinetic energy were observed. Using a second formula for our analysis, we analyzed the total work in a system as change in kinetic energy plus change in kinetic energy. This is called conservation of energy. Here we found that the change in kinetic energy + the change in potential energy for cases 4-8 were .004J, .0315J, .01415J, .04501J, and .02278J. These numbers are remarkably close to zero and thus confirm our conservation of energy theorem.

Finally, we created friction within the system and calculated for the new variable of friction with the same expected conservation of energy. This time, while the system is operating, the cart will move much slower due to friction. It was our job to find that coefficient of friction which we have found to be .15N.