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Anything included in this report in RED (with the exception of the equations which are in black) was added by me (Bill) and represents the data obtained when the experiment was run. *Use your own data you collected and perform the calculations for your own data!*

Sample Only - Do Not Copy

Work and Energy

Name:

PES 1150 Report

Lab Section: 002

Objective

The purpose of this experiment was to investigate what work is, and how it relates to energy. Though this, we were able to learn about different forms of energy and how energy is used (via the conservation of energy) to solve complicated dynamics problems. Furthermore, we will compare the relationships between work, potential energy, kinetic energy, and total energy though the processes in the experiment.

Data and Calculations

Part A: Work Done by a Constant Force

I am leaving the bulk of the writing up to you for the rest of the semester. Make sure to include all the relevant data, mathematical work and answer all questions.

For this part of the lab, we measured the work necessary for lifting an object straight upward (in the opposite direction of the gravity vector) at a constant speed. We were then able to calculate the work necessary and compare this value to the experimentally measured value (which can be obtained by plotting the displacement versus the average force, and finding the area under the curve).

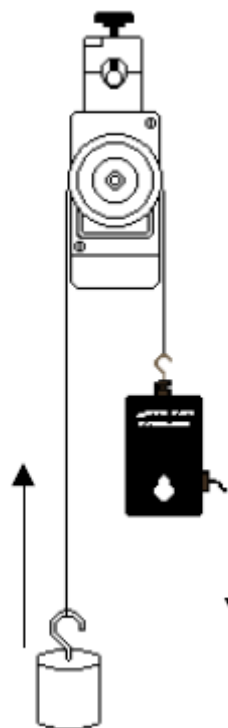


Figure 1: Experimental Setup for Part A

For sake of simplicity, we assumed the string was massless and the pulley was frictionless. We measured the mass of the hanging mass and calibrated the force sensor.

<u>Mass of hanging mass (kg)</u>	<u>0.1025 kg</u>
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We then pulled down on the force sensor and let the pulley measure the distance traversed. This produced the following distance versus time graph and force versus time graph recorded from the respective sensors.

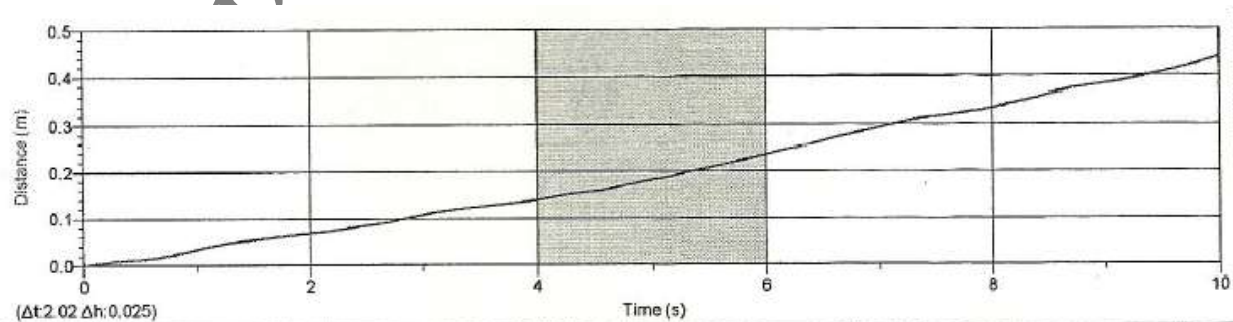


Figure 2: Experimental Data Obtained of Distance versus Time

(Note that we attempted to pull down on the force sensor at a constant velocity. Hence we selected a region of time in the distance versus time graph that was “most linear”. This was

between the times of 4.00s and 6.00s.) The following table provides a complete view of the data obtained from Logger-Pro during the experiment.

	Time (s)	Distance (m)
Start Selection	4.00 s	0.139 m
Stop Selection	6.00 s	0.234 m

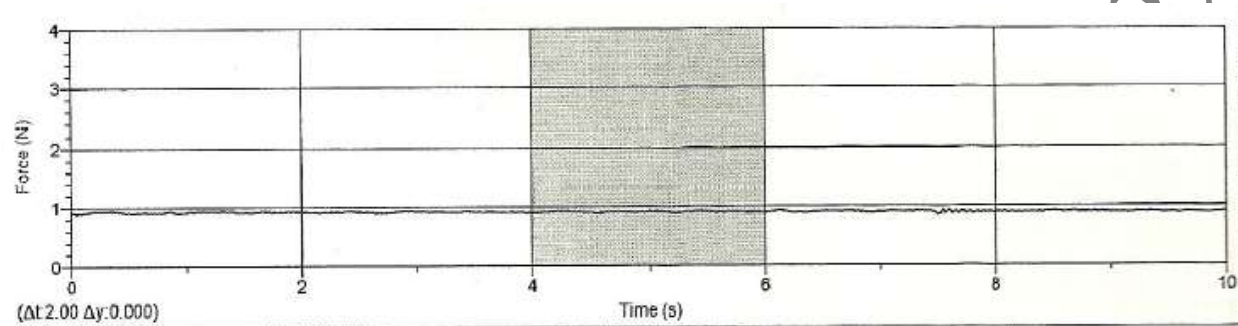


Figure 3: Experimental Data Obtained of Force versus Time

We used the statistics functionality in Logger Pro to determine the average force over the selected region (note that we used the same beginning and end times that we recorded from figure 2, above). The following results were obtained:

Average force (N)	1.0045 N
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We then calculated the theoretical value of the work done (increase in gravitational potential energy) for the mass over the given range. This was the product of the average measured force times the displacement of the mass:

$$W = mg\Delta h = \bar{F} \Delta h$$

$$W = (1.0045 \text{ N})(0.234 \text{ m} - 0.139 \text{ m})$$

$$W = 0.0954 \text{ J}$$

Work Done (J)	0.0954 N•m
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We then combined the data from figures 2 and 3 above to get a plot of distance versus force. The same selected region (note that we used the same beginning and end distances that we recorded from figure 2 above) was used to find the area under the curve on the graph.

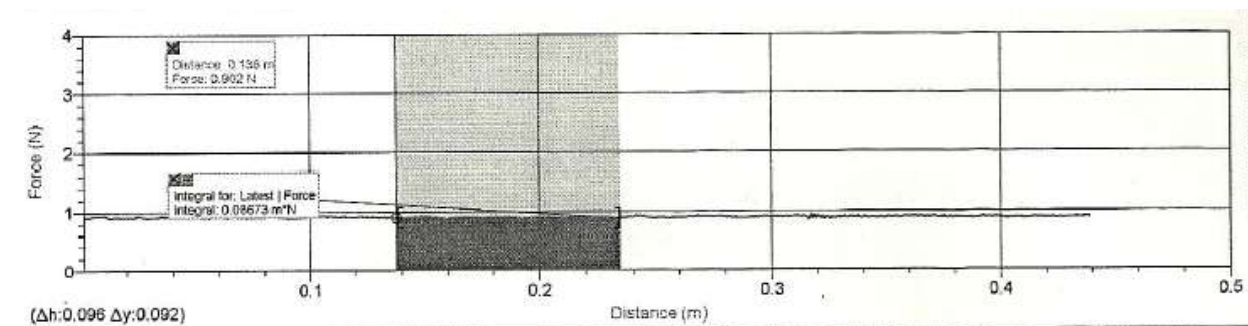


Figure 4: Experimental Data Obtained of Force versus Distance

The area under the curve over the selected distance range is the experimentally measured work needed to move the hanging mass over the selected distance. The following table provides the information found:

<u>Integral (during lift): force vs. distance (J)</u>	<u>0.08673 N•m</u>
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Including all the measurements and calculations into the table provided by the lab procedure, we have:

<u>Part A</u>		
	<u>Time (s)</u>	<u>Distance (m)</u>
<u>Start Moving</u>	<u>4.00 s</u>	<u>0.139 m</u>
<u>Stop Moving</u>	<u>6.00 s</u>	<u>0.234 m</u>
<u>Mass</u>		<u>0.1025 kg</u>
<u>Average force</u>		<u>1.0045 N</u>
<u>Work done</u>		<u>0.0954 J</u>
<u>Integral (during lift): force vs. distance</u>		<u>0.08673 N•m</u>
<u>ΔU</u>		<u>0.0087 J</u>

The integral under the curve and the calculated change of potential energy for moving the hanging mass in the opposite direction of the gravity acceleration vector should be equal. We see that the discrepancy between the two values is very nearly zero – this is most likely due to the fact that the string used in the experiment was not massless and the pulley was not frictionless.

Part B: The Work-Energy Theorem

In the experiment for part B we used a hanging mass to pull a cart – which caused the cart to accelerate. We used the force sensor to measure the tension in the string and a motion sensor to determine distance traveled (and by consequence the velocity of the cart). We could then deduce the speed of the cart and the work done by the hanging mass dropping in the same direction as the gravity acceleration vector (from the force versus distance graph).

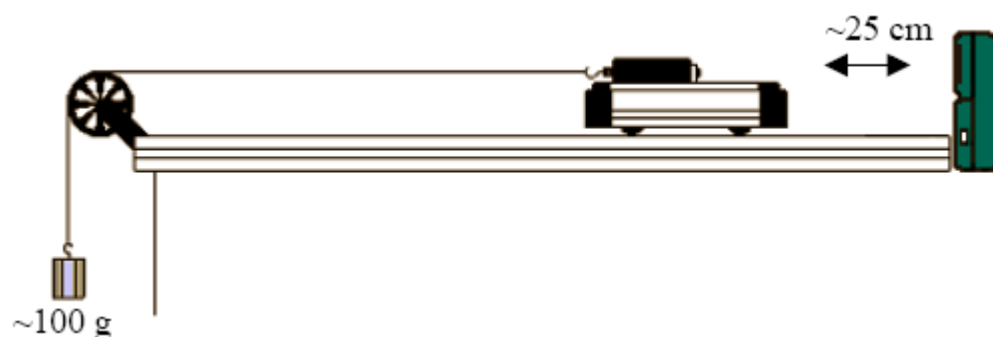


Figure 5: Experimental Setup for Part B

First we weighed the cart (with the force sensor attached) and the hanging mass. These values are recorded in the table below.

Mass of Cart + Sensor (kg)	0.7241 kg
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Mass of Hanging Mass (kg)	0.1025 kg
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Similar to part A, we obtained a distance versus time graph and also a velocity versus time graph (from which we can determine the maximum velocity of the cart generated by the hanging mass dropping).

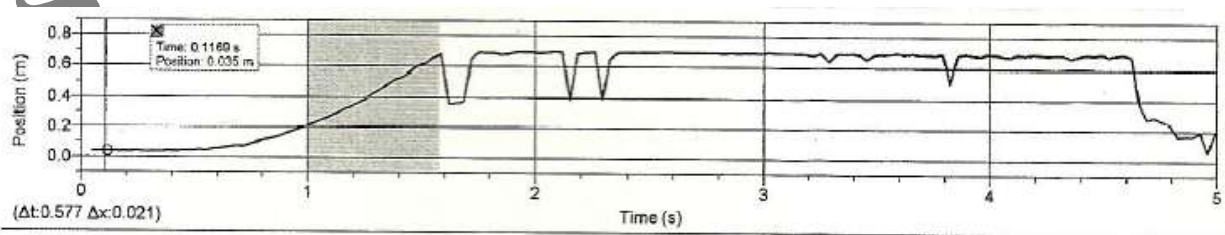


Figure 6: Experimental Data Obtained of Distance versus Time

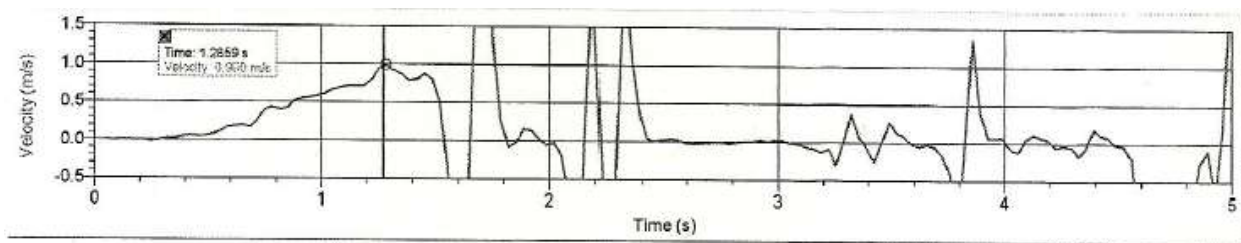


Figure 7: Experimental Data Obtained of Velocity versus Time

	Time (s)	Distance (m)
<u>Cart Released</u>	<u>1.0187 s</u>	<u>0.221 m</u>
<u>Mass Hits Floor</u>	<u>1.2859 s</u>	<u>0.438 m</u>

<u>Final Velocity (m/s)</u>	<u>0.990 m/s</u>
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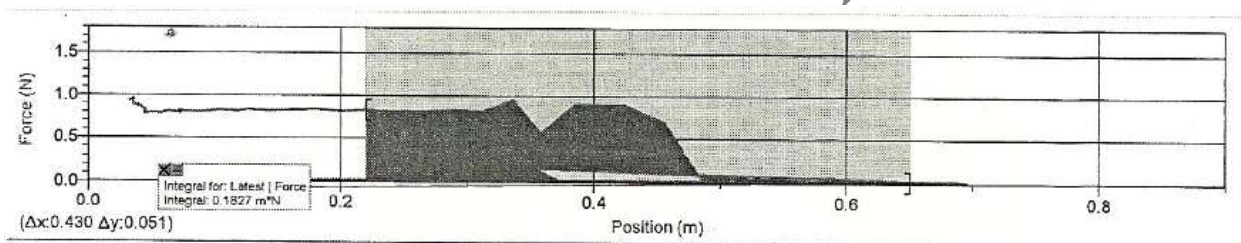


Figure 8: Experimental Data Obtained of Force versus Distance

<u>Integral (during lift): force vs. distance (J)</u>	<u>0.1827 N•m</u>
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We then calculated the theoretical value of the kinetic energy for the moving cart.

$$\Delta K = \frac{1}{2}mv^2$$

$$\Delta K = (0.5)(0.7241\text{ kg})\left(0.990\frac{\text{m}}{\text{s}}\right)^2$$

$$\Delta K = 0.3548 \text{ J}$$

Including all the measurements and calculations into the table provided by the lab procedure, we have:

Part B		
	Time (s)	Distance (m)
Cart released	1.0187 s	0.221 m
Mass hits floor	1.5531 s	0.651 m

Mass of cart & Force Sensor	0.7241 Kg
Final velocity	0.990 m/s
Integral during pull	0.1827 N•m
ΔK of cart	0.3548 J

Since the Work performed by the dropping mass is nearly equal to the kinetic energy of the cart, we can assume that the conservation of energy is in effect – and the work created the motion in the cart due to the Work-Energy theorem. (Since there was an initial jerk to the cart due to the instantaneous tension in the string the acceleration is not constant. This will tend to dramatically adjust the velocity of the cart.) Of course, we are not considering the mass of the string, the friction in the pulley and the friction between the wheels and the track (all which will contribute to the error).

Part C: Playground Ball

Part C of the experiment consisted of throwing a ball straight up into the air and measuring the components of Potential Energy, Kinetic Energy and Total Energy. After obtaining a graph of Energy versus Time we can verify if Total Energy is conserved by viewing if it remains constant over the duration of the flight.

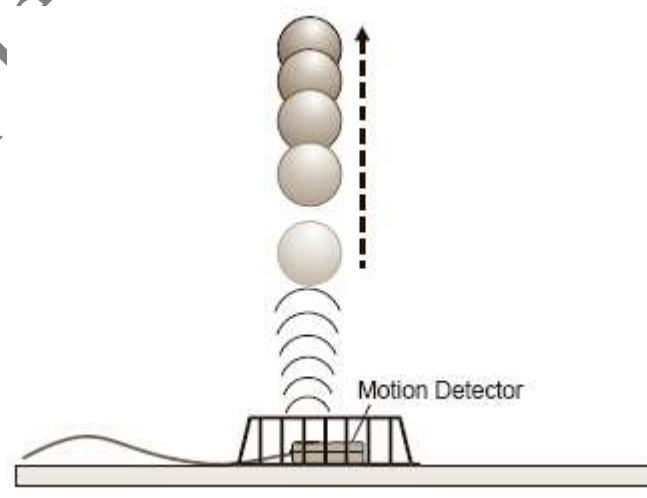


Figure 8: Experimental Setup for Part C

Since both Potential Energy and Kinetic Energy are functions of the mass of the object, we weighted the ball we were throwing.

Mass of the ball	(kg)	0.3986 kg
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Using Logger-Pro we obtained the following data over the duration of the ball being in the air.

Position	Time (s)	Height (m)	Velocity (m/s)	PE (J)	KE (J)	TE (J)
After release	2.4	0.013161	-0.18138	0.055271	0.007042	0.0623125
Top of path	2.55	0.1163352	-0.5535814	0.4885684	0.0655961	0.5541645
Before catch	2.75	0.0120632	-0.1466793	0.0506614	0.0046052	0.0552666

The following graph shows a plot of all data collected during the ball's flight.

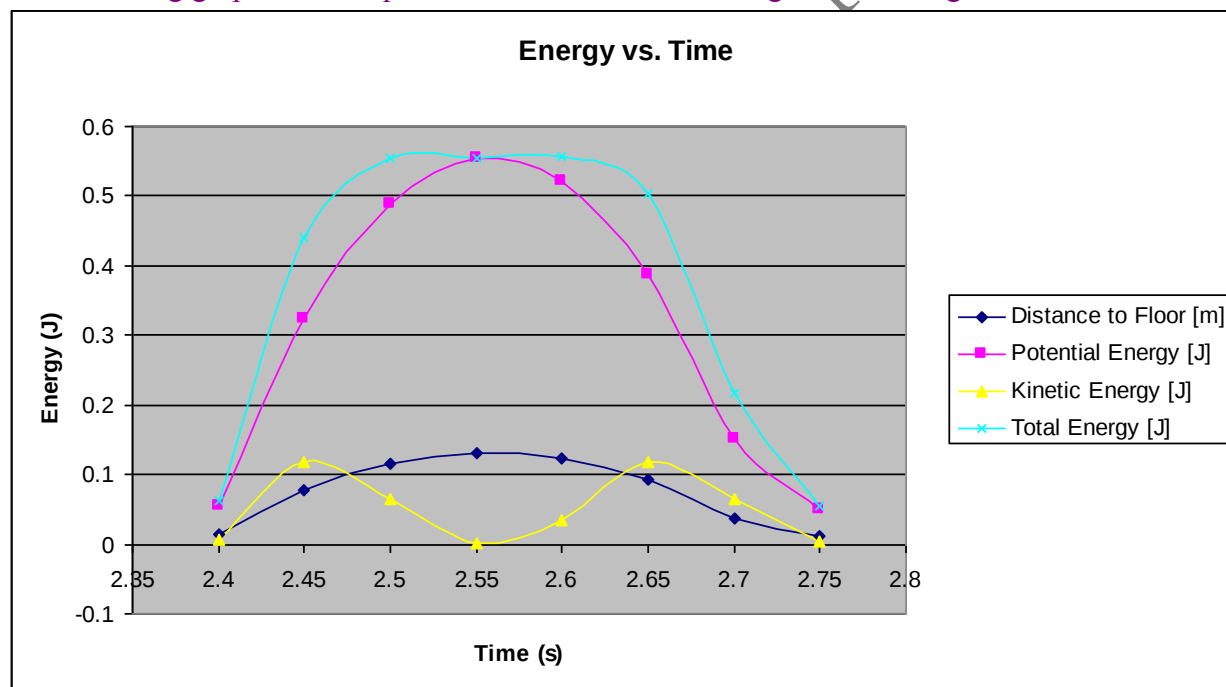


Figure 9: Experimental Data Obtained of Energy (Potential = Pink, Kinetic = Yellow, Total = Light Blue) versus Time

By analyzing the graph above, it appears that Energy is Conserved over the region of “pure free flight” (2.5s – 2.65s).

Results and Questions

Part A:

Step 13: The work done on the mass corresponded very well to the change in gravitational potential energy.

Part B:

Step 15: As work was being done on the cart by the hanging weight, the kinetic energy was increasing. We can see that Work is directly proportional to the increase in kinetic energy.

Part C:

Step 11: The Kinetic energy was greatest at the points immediately after release and before the catch. Since a force was applied to accelerate the ball upwards, its total energy was greatest at the point of release and catch, as well. As a result the graph should show a concave parabolic graph with sharp points at the times of release and catch.

Step 12: The shape of the Potential energy versus time graph is correct in the fact that Kinetic Energy is proportional to Potential Energy. As Kinetic energy slows, the potential energy increases.

Step 15: The total energy stayed relatively constant during the “free flight”.

Step 16: If a heavier ball were used, the kinetic and potential energies would increase since both depend on mass.

Step 17: If grams were used instead of kilograms the energies would look a lot larger.

Conclusion

You are intelligent scientists. Follow the guidelines provided and write an appropriate conclusion section based on your results and deductive reasoning. See if you can think of any possible causes of error.

** NOTE: There are several components of error which could significantly modify the results of this experiment. Some of these are listed below:

- Data Selection
- Calibration of Sensors
- Ignoring String’s Mass and Pulley’s Friction
- Lost Energy due to sound, heat, compression, etc...
- Snagging and catching
- Sensor limitation parameters
- Computer processor speed and reading registration
- Sensor Alignment
- Other ...

A few of the potential errors listed above may be applicable to YOUR experiment.