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**Lab 6: Energy Conservation**

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PHYS 261 – 005

With:

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and

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**Objective**

The objective for this lab is to be able to measure the potential and kinetic energies of an object in vertical motion. We will find such of a cart on an inclined platform. We will measure the total mechanical energy in the system of the object to verify that all energy is conserved when friction is accounted for.

**Theory**

The theory being tested in this is that kinetic energy of a cart of mass *m* will increase as its velocity *v* increases

Eq. 6-1

as the cart makes its descent down the track, and that the carts potential energy at height *h* will decrease

Eq. 6-2

simultaneously. Thus the energy is conserved with respect to the total energy of the system, as is stated by the law of conservation of energy

Eq. 6-3

with the change in energy *ΔE* equal to the loss due to work by the frictional force *Wf*. When the frictional force is zero, no energy leaves the system, forming the assertion

Eq. 6-4

which equates the total mechanical energies at any two moments in the system.

**Procedure**

The procedures for this lab involved a cart on a track set at an incline. Both procedures involved trailing the experiment five times and selecting the resulting run with the lowest standard deviation. The angle of the incline varied over the procedures by adjustments made to the wooden block being used as a prop. This procedure used the ultrasonic motion detectors collecting position measurements at 20 Hz to derive the velocity and current height of the cart.

**Procedure A**

In Procedure A, the cart starts at the top of the track. The cart is released from rest and measurements are taken on its position until it reaches the bottom of the track.

**Procedure B**

Procedure B took the same steps as Procedure A, but the cart was pushed off from the bottom of the inclined track, and measurements were taken until the cart returned to the bottom of the track again.

**Data**

Shown below is a sample of the LoggerPro readings, as well as the setup attributes, from Procedure A.

|  |  |  |
| --- | --- | --- |
| mass (kg) | 0.5072 |  |
| h (m) | 0.0365 |  |
| angle (°) | 1.973311 |  |
| time (s) | pos (m) | velocity (m/s) |
| 0.05 | 1.130254 | -0.001524444 |
| 0.1 | 1.130254 | -0.003048889 |
| 0.15 | 1.129979 | -0.004207467 |
| 0.2 | 1.129705 | -0.003048889 |
| 0.25 | 1.129705 | -0.002134222 |
| 0.3 | 1.12943 | -0.000152444 |
| … | … | … |
| 2.3 | 0.648682 | -0.532336 |
| 2.35 | 0.61987 | -0.537824 |
| 2.4 | 0.595448 | -0.551391556 |
| 2.45 | 0.565264 | -0.572581333 |
| 2.5 | 0.537001 | -0.574258222 |

**Table 6-1.** A table containing a sample of the values recorded in Procedure A. The velocity and position of the cart increases steadily as the cart descends the track.

Shown below is a similar sample of the readings for Procedure B.

|  |  |  |
| --- | --- | --- |
| mass (kg) | 0.5072 |  |
| h (m) | 0.0365 |  |
| angle (°) | 1.973311 |  |
| time (s) | pos (m) | velocity (m/s) |
| 1.1 | 0.499408 | 0.386904 |
| 1.15 | 0.518342 | 0.371659556 |
| 1.2 | 0.536452 | 0.353976 |
| 1.25 | 0.553739 | 0.33614 |
| 1.3 | 0.569929 | 0.321352889 |
| 1.35 | 0.585844 | 0.306870667 |
| 1.4 | 0.600662 | 0.291473778 |
| … | … | … |
| 3.2 | 0.62426 | -0.24436844 |
| 3.25 | 0.612186 | -0.25824089 |
| 3.3 | 0.598466 | -0.27257067 |
| 3.35 | 0.584746 | -0.28385156 |
| 3.4 | 0.570203 | -0.30519378 |

**Table 6-2.** The corresponding table for Procedure B. The velocity starts positive and ends negative, and the position values start and end at about the same value.

**Analysis**

**Procedure A**

Using the information from Table 6-1 with Eq. 6-1 and Eq. 6-2, we can calculate the individual kinetic and potential energies for each record in the measurements as well as the total energies at those points.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| time (s) | pos (m) | velocity (m/s) | KE (J) | PE (J) | TE (J) |
| 0.05 | 1.130254 | -0.001524444 | 5.89349E-07 | 0.193584 | 0.193585 |
| 0.1 | 1.130254 | -0.003048889 | 2.3574E-06 | 0.193584 | 0.193586 |
| 0.15 | 1.129979 | -0.004207467 | 4.48942E-06 | 0.193537 | 0.193541 |
| 0.2 | 1.129705 | -0.003048889 | 2.3574E-06 | 0.19349 | 0.193492 |
| 0.25 | 1.129705 | -0.002134222 | 1.15512E-06 | 0.19349 | 0.193491 |
| 0.3 | 1.12943 | -0.000152444 | 5.89349E-09 | 0.193443 | 0.193443 |
| … | … | … | … | … | … |
| 2.3 | 0.648682 | -0.532336 | 0.071865578 | 0.111103 | 0.182968 |
| 2.35 | 0.61987 | -0.537824 | 0.073354981 | 0.106168 | 0.179523 |
| 2.4 | 0.595448 | -0.551391556 | 0.077102679 | 0.101985 | 0.179088 |
| 2.45 | 0.565264 | -0.572581333 | 0.083142604 | 0.096815 | 0.179958 |
| 2.5 | 0.537001 | -0.574258222 | 0.083630307 | 0.091975 | 0.175605 |

**Table 6-3.** This mutation of Table 6-1 extends the information in the first three columns to derive the kinetic and potential energies.

Plotting this information results in the following graph

**Figure 6-1.** The graph of the energies in Table 6-3.

As is visible in Figure 6-1, as time progresses and the cart descends the track, the potential energy in the cart decreases, but the kinetic energy increases at an identical rate. The total energy in the system, denoted by *TE*, stays mostly constant, at an average of 0.188617 Joules. Over the duration of the run, the percent change is a meager 9.29%, which is below average for these types of sensors.

**Procedure B**

We can do the same thing for this procedure as we did for Procedure A. Below is a sample of the extended table for Procedure B.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| time (s) | pos (m) | velocity (m/s) | KE (J) | PE (J) | TE (J) |
| 1.1 | 0.499408 | 0.386904 | 0.037963 | 0.085536 | 0.123499 |
| 1.15 | 0.518342 | 0.371659556 | 0.03503 | 0.088779 | 0.123809 |
| 1.2 | 0.536452 | 0.353976 | 0.031776 | 0.091881 | 0.123657 |
| 1.25 | 0.553739 | 0.33614 | 0.028654 | 0.094842 | 0.123496 |
| 1.3 | 0.569929 | 0.321352889 | 0.026189 | 0.097614 | 0.123803 |
| 1.35 | 0.585844 | 0.306870667 | 0.023881 | 0.10034 | 0.124222 |
| 1.4 | 0.600662 | 0.291473778 | 0.021545 | 0.102878 | 0.124423 |
| … | … | … | … | … | … |
| 3.2 | 0.62426 | -0.24436844 | 0.015144 | 0.10692 | 0.122064 |
| 3.25 | 0.612186 | -0.25824089 | 0.016912 | 0.104852 | 0.121764 |
| 3.3 | 0.598466 | -0.27257067 | 0.018841 | 0.102502 | 0.121343 |
| 3.35 | 0.584746 | -0.28385156 | 0.020433 | 0.100152 | 0.120585 |
| 3.4 | 0.570203 | -0.30519378 | 0.023621 | 0.097661 | 0.121283 |

**Table 6-4.** This table contains the extended information for the Procedure B measurement records just as Table 6-3 does for Procedure A, which is the calculations for the energies using the first three columns of information.

And the corresponding scatter plot for Table 6-4

**Figure 6-2.** The scatter plot of the records for Procedure B.

As expected, the curves of the potential energy and the kinetic energy supplement each other with respect to the total energy, which is even more constant than that of Procedure A. At the beginning, when the cart is launched from rest, the system contains peak kinetic energy and minimum potential energy, but the former decays and the prior grows as the cart traverses up the incline until the cart’s velocity turns zero, and the reverse begins to take hold until it reaches the end of the track again. The total energy in the system stayed around 0.124263 Joules with a tiny 1.794% delta.

**Conclusions**

Looking at the compiled results in the final scatter plots, Figure 6-1 and Figure 6-2, we can see that the theory held fast that the total energy in a frictionless system shouldn’t change. Since the kinetic energy and the potential energy hold supplementary proportions of the total energy, the total barely changed at all. The reason for change in this experiment is because the cart does experience a frictional force with the track, albeit a very small one. Still, this force accounts for the loss in total energy. With this small frictional force in mind, it is easy to see how the total energy could have been completely constant in an ideal environment. With these results, the theory is well supported and the objective of the lab has been achieved.