

INTRODUCTION ACTIVITY: MOVING, STATIONARY ENERGY

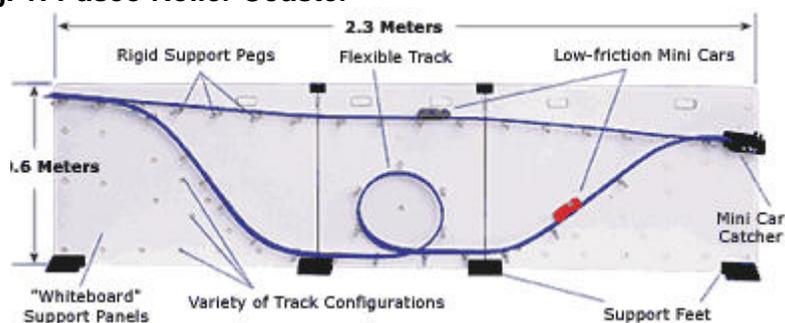
Purpose

The experiment is used to study potential energy, kinetic energy, and conservation of energy in a *real* frictional environment. The motion in question is a cart in a valley.

Materials

- Pasco roller coaster track and carts. [Alternate: construct a roller coaster track with appropriate carts.]

Fig. 1: Pasco Roller Coaster



- Computer with Motion Visualizer (MV) software and activities kit.
- Video camera with tripod.
- Bright pink, green, or yellow paper.

Set-Up Guidelines

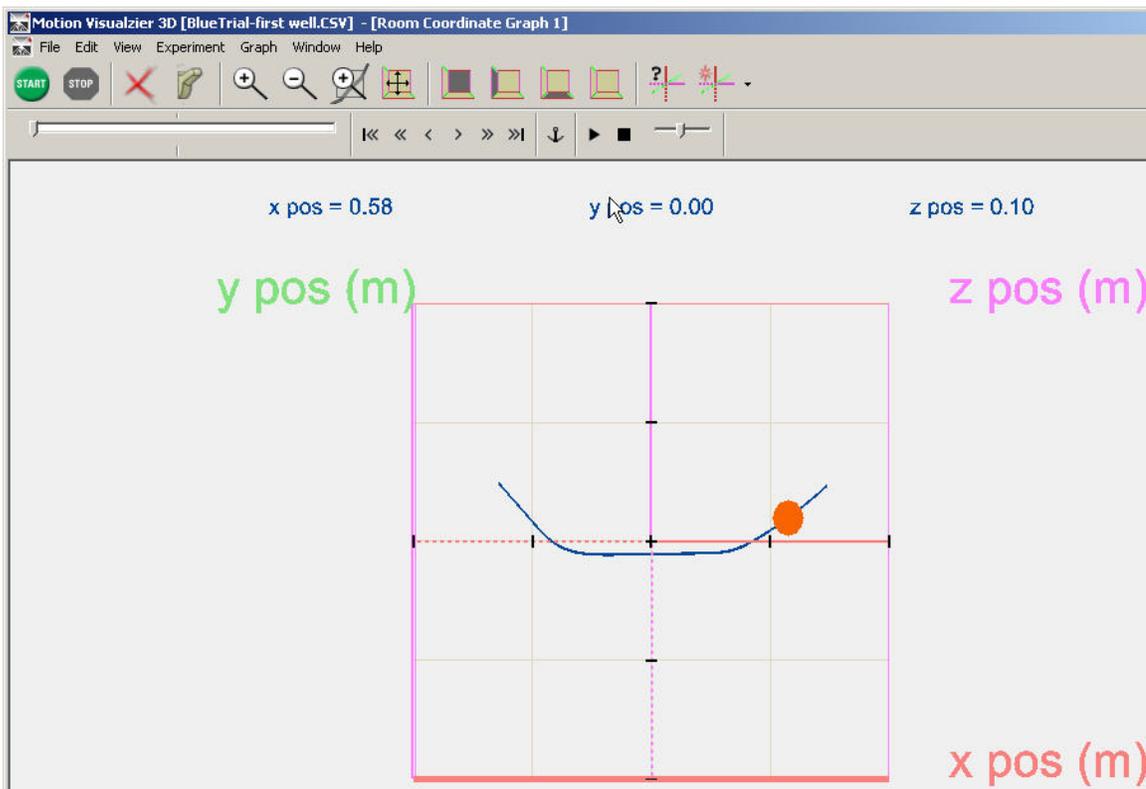
1. Assemble Pasco roller coaster on a smooth and level surface. Construct the track so as to have a valley with flat bottom.
2. Place tripod and camera to include the entirety of the roller coaster in the camera view, approximately 1.5 meters away.
3. Calibrate MV according to the quick-start guide.
4. While one person holds the cart on one of the valley slopes, have another person start the MV. Once recording has started, release the cart.
5. Use MV to bring up position, velocity, and time graphs as needed.

Data Collection and Presentation

The data collected may be analyzed in the following ways to highlight the concepts of potential and kinetic energy, conservation of energy, and frictional energy losses.

1. The initial MV screen will be displayed after gathering data. In the menu, click Graph → Projection → Orthographic, to display the data in 2-D.

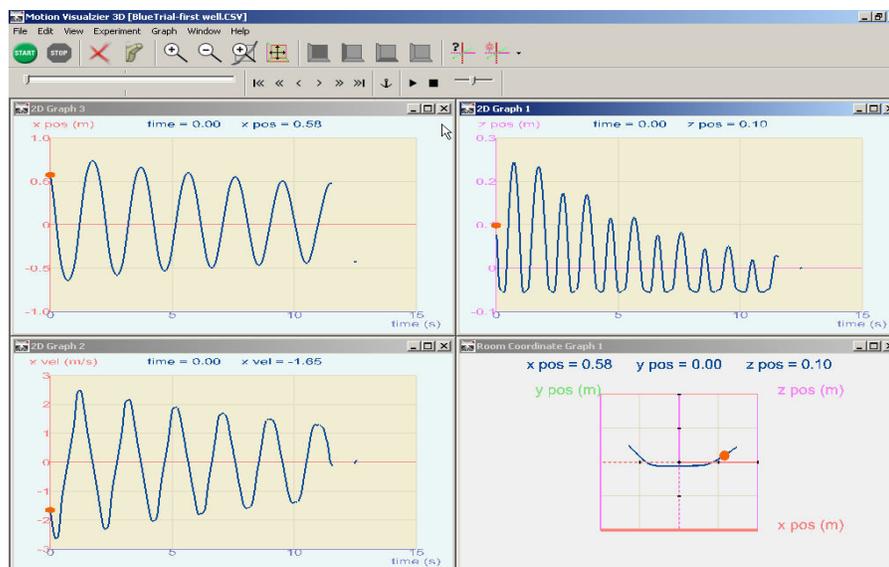
Fig. 2: MV



2. Click Graph → Add Graph → 3 Position vs. Time Graphs. Click the axis labels to change the graphs to display the data as desired.

Fig. 3: MV

Shown
Clockwise: X
pos vs Time.
Y Pos vs.
Time. Room
Coordinate
Graph. X vel
vs. Time.



3. The data may be saved in as a comma separated file (.csv) and opened in excel. Click File→Save As. Open the file in Excel. Process data as desired.

Fig. 4: Raw MV Data in Excel

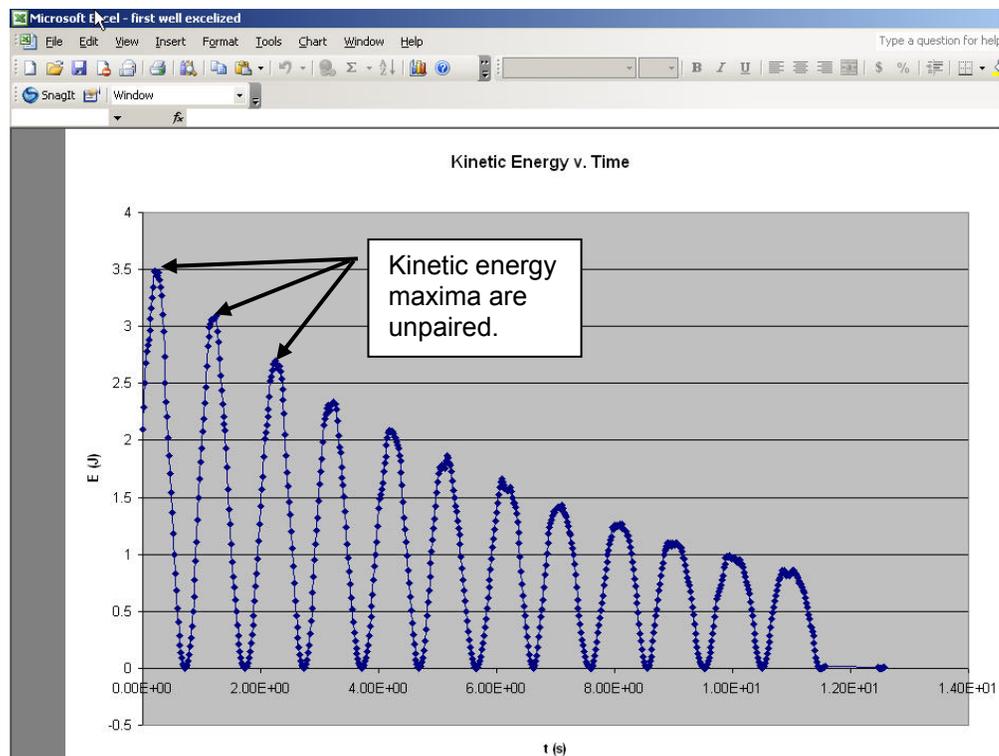
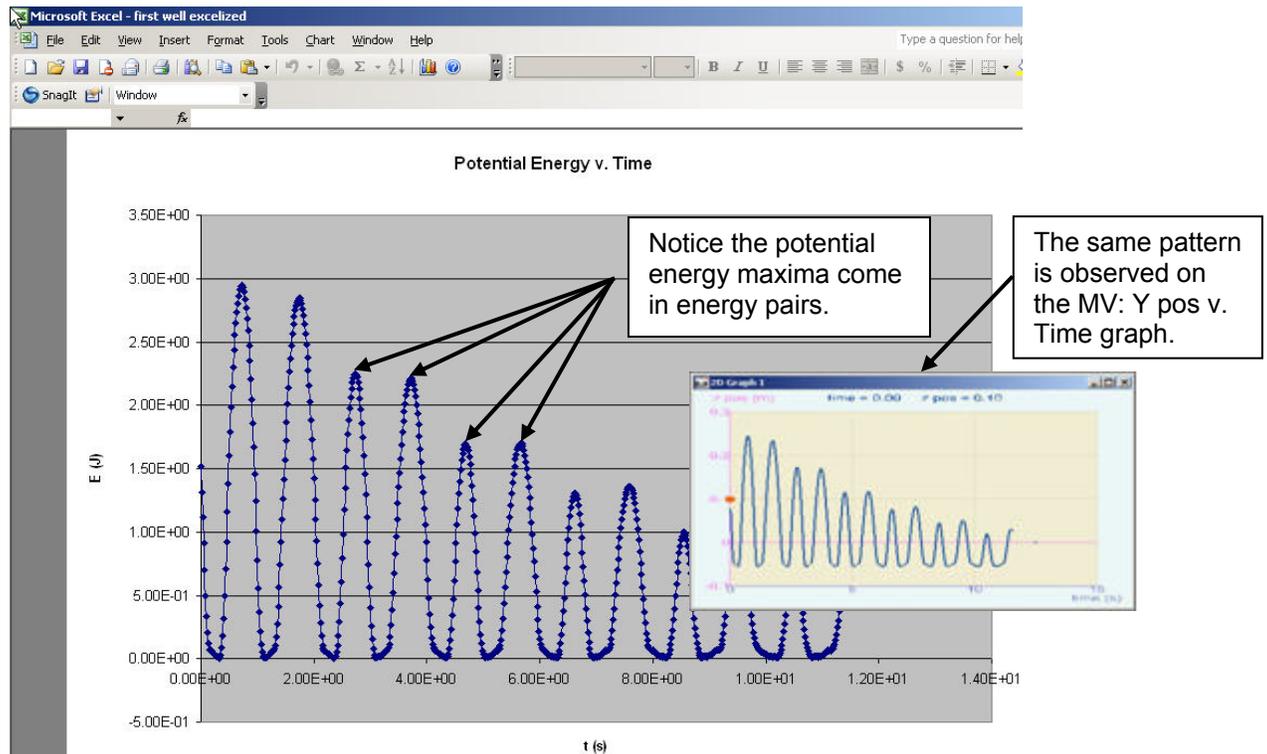
| 1 | A | B | C | D | E | F | G | H | I | J |
|----|-------------|-----------|----------------------|----------------|----------|----|-----------|-----------|----|----------|
| 1 | Alberti's W | 10 | Obj Point Count: 701 | Version: 1.2.2 | | | | | | |
| 2 | t | X | Y | Z | Vx | Vy | Vz | Ax | Ay | Az |
| 3 | 6.94E-18 | 0.575581 | 0 | 0.098783 | -1.65092 | 0 | -1.2083 | -6.34411 | 0 | -1.30707 |
| 4 | 1.67E-02 | 0.546819 | 0 | 7.78E-02 | -1.75618 | 0 | -1.22083 | -5.69516 | 0 | 5.21E-02 |
| 5 | 3.33E-02 | 0.517091 | 0 | 5.77E-02 | -1.86831 | 0 | -1.2282 | -6.53079 | 0 | -0.54678 |
| 6 | 5.00E-02 | 0.485392 | 0 | 3.65E-02 | -1.97724 | 0 | -1.20699 | -7.1406 | 0 | 0.991855 |
| 7 | 6.67E-02 | 0.450455 | 0 | 1.46E-02 | -2.06588 | 0 | -1.13366 | -4.95577 | 0 | 5.21845 |
| 8 | 8.33E-02 | 0.415443 | 0 | -5.61E-03 | -2.15918 | 0 | -1.00034 | -5.30299 | 0 | 9.507095 |
| 9 | 0.1 | 0.378835 | 0 | -2.26E-02 | -2.24974 | 0 | -0.83575 | -5.5358 | 0 | 12.53622 |
| 10 | 0.116667 | 0.34064 | 0 | -3.57E-02 | -2.34575 | 0 | -0.6477 | -5.71263 | 0 | 13.83762 |
| 11 | 0.133333 | 0.300019 | 0 | -0.04412 | -2.43251 | 0 | -0.4675 | -4.30392 | 0 | 12.23005 |
| 12 | 0.15 | 0.258847 | 0 | -4.90E-02 | -2.49656 | 0 | -0.29253 | -4.13391 | 0 | 9.646314 |
| 13 | 0.166667 | 0.216675 | 0 | -4.96E-02 | -2.54652 | 0 | -0.16456 | -3.87785 | 0 | 4.050059 |
| 14 | 0.183333 | 0.172612 | 0 | -5.05E-02 | -2.58546 | 0 | -9.14E-02 | -1.60102 | 0 | 1.89292 |
| 15 | 0.2 | 0.128356 | 0 | -5.12E-02 | -2.63735 | 0 | -6.79E-02 | -0.31348 | 0 | 0.732743 |
| 16 | 0.216667 | 8.46E-02 | 0 | -5.20E-02 | -2.63742 | 0 | -5.49E-02 | -0.64874 | 0 | 0.346021 |
| 17 | 0.233333 | 3.99E-02 | 0 | -5.27E-02 | -2.62449 | 0 | -4.44E-02 | 0.744899 | 0 | 0.223913 |
| 18 | 0.25 | -3.50E-03 | 0 | -5.36E-02 | -2.62409 | 0 | -3.92E-02 | 0.241706 | 0 | 0.549623 |
| 19 | 0.266667 | -0.04717 | 0 | -5.42E-02 | -2.63444 | 0 | -2.87E-02 | -3.51E-02 | 0 | 0.508919 |

Fig. 5: Processed MV Data in Excel

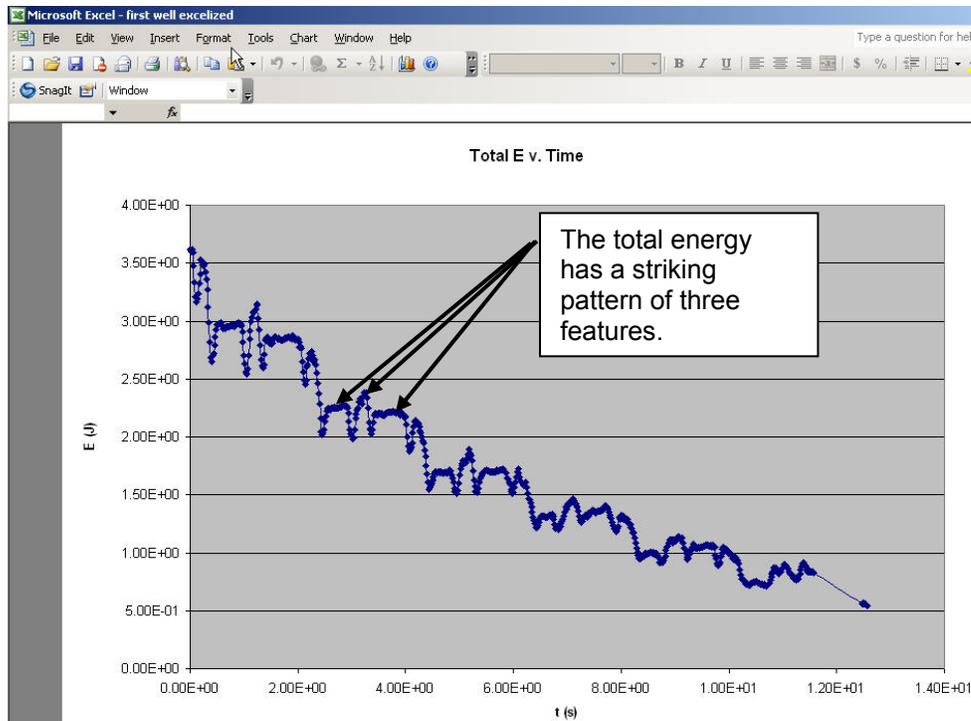
| 1 | A | B | C | D | E | F | G | H | I | J | K | L |
|----|----------------|-----------|-----------|----------|-----------|----------|---|----------|----------|----------|--------------|---|
| 1 | Potential Well | | | | | | | Gravity: | 9.8 | | | |
| 2 | t | X | Z | Vx | Vz | Speed | | height | g'h | v^2/2 | Total Energy | |
| 3 | 6.94E-18 | 0.575581 | 0.098783 | -1.65092 | -1.2083 | 2.045851 | | 1.55E-01 | 1.52E+00 | 2.092754 | 3.61E+00 | |
| 4 | 1.67E-02 | 0.546819 | 7.78E-02 | -1.75618 | -1.22083 | 2.138831 | | 1.34E-01 | 1.32E+00 | 2.2873 | 3.60E+00 | |
| 5 | 3.33E-02 | 0.517091 | 5.77E-02 | -1.86831 | -1.2282 | 2.235856 | | 1.14E-01 | 1.12E+00 | 2.499525 | 3.62E+00 | |
| 6 | 5.00E-02 | 0.485392 | 3.65E-02 | -1.97724 | -1.20699 | 2.31653 | | 9.30E-02 | 9.11E-01 | 2.683155 | 3.59E+00 | |
| 7 | 6.67E-02 | 0.450455 | 1.46E-02 | -2.06588 | -1.13366 | 2.356493 | | 7.10E-02 | 6.96E-01 | 2.77653 | 3.47E+00 | |
| 8 | 8.33E-02 | 0.415443 | -5.61E-03 | -2.15918 | -1.00034 | 2.379655 | | 5.08E-02 | 4.98E-01 | 2.831378 | 3.33E+00 | |
| 9 | 0.1 | 0.378835 | -2.26E-02 | -2.24974 | -0.83575 | 2.399962 | | 3.38E-02 | 3.31E-01 | 2.879909 | 3.21E+00 | |
| 10 | 0.116667 | 0.34064 | -3.57E-02 | -2.34575 | -0.6477 | 2.433527 | | 2.07E-02 | 2.03E-01 | 2.961028 | 3.16E+00 | |
| 11 | 0.133333 | 0.300019 | -0.04412 | -2.43251 | -0.4675 | 2.47703 | | 1.23E-02 | 1.21E-01 | 3.06784 | 3.19E+00 | |
| 12 | 0.15 | 0.258847 | -4.90E-02 | -2.49656 | -0.29253 | 2.513636 | | 7.45E-03 | 7.30E-02 | 3.159183 | 3.23E+00 | |
| 13 | 0.166667 | 0.216675 | -4.96E-02 | -2.54652 | -0.16456 | 2.551829 | | 6.83E-03 | 6.69E-02 | 3.255917 | 3.32E+00 | |
| 14 | 0.183333 | 0.172612 | -5.05E-02 | -2.58546 | -9.14E-02 | 2.587072 | | 5.93E-03 | 5.81E-02 | 3.346471 | 3.40E+00 | |
| 15 | 0.2 | 0.128356 | -5.12E-02 | -2.63735 | -6.79E-02 | 2.638226 | | 5.26E-03 | 5.15E-02 | 3.480119 | 3.53E+00 | |
| 16 | 0.216667 | 8.46E-02 | -5.20E-02 | -2.63742 | -5.49E-02 | 2.637989 | | 4.46E-03 | 4.37E-02 | 3.479494 | 3.52E+00 | |
| 17 | 0.233333 | 3.99E-02 | -5.27E-02 | -2.62449 | -4.44E-02 | 2.624861 | | 3.70E-03 | 3.62E-02 | 3.444948 | 3.48E+00 | |
| 18 | 0.25 | -3.50E-03 | -5.36E-02 | -2.62409 | -3.92E-02 | 2.624379 | | 2.82E-03 | 2.76E-02 | 3.443683 | 3.47E+00 | |
| 19 | 0.266667 | -0.04717 | -5.42E-02 | -2.63444 | -2.87E-02 | 2.634599 | | 2.27E-03 | 2.23E-02 | 3.470557 | 3.49E+00 | |
| 20 | 0.283333 | -9.13E-02 | -5.49E-02 | -2.61035 | -2.61E-02 | 2.610476 | | 1.55E-03 | 1.52E-02 | 3.407292 | 3.42E+00 | |
| 21 | 0.3 | -0.13521 | -5.52E-02 | -2.5871 | 1.31E-02 | 2.587135 | | 1.27E-03 | 1.24E-02 | 3.346635 | 3.36E+00 | |

- Through Excel several graphs may be constructed. Several examples include Kinetic Energy vs. Time; Potential Energy vs. Time; Total Energy vs. Time; X-position vs. Z-position.

Fig. 6: Excel Graphs of MV Data

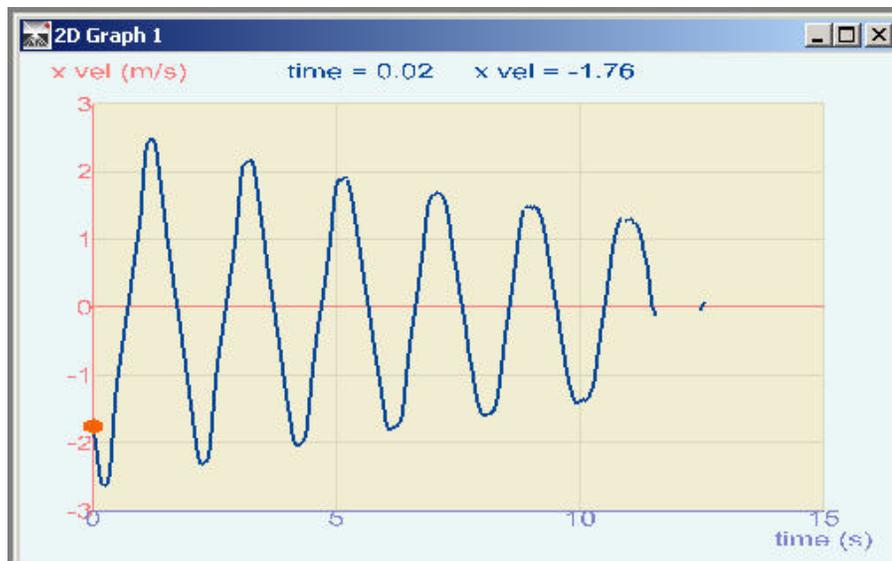


Written by Lick-Kong Tam. LK is a Brown University sophomore who spent the summer of 2004 working with Alberti's Window under the NSF's Research Experiences for Undergraduates program.



Data Analysis

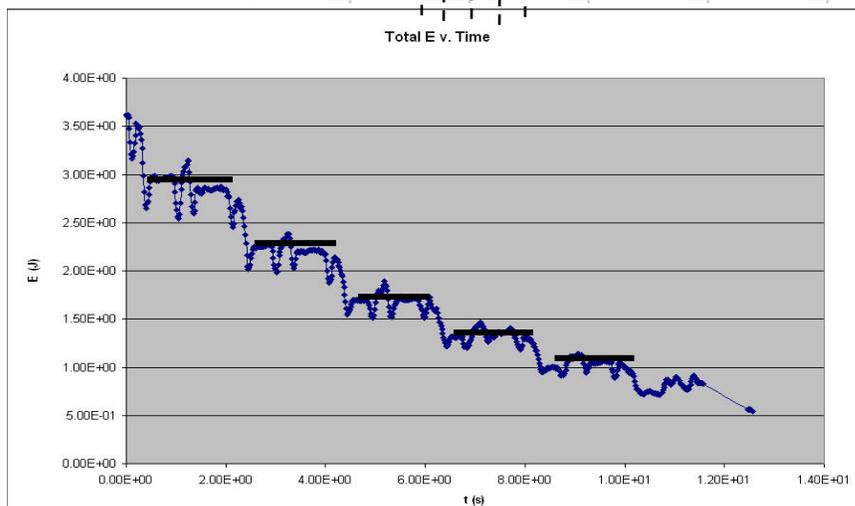
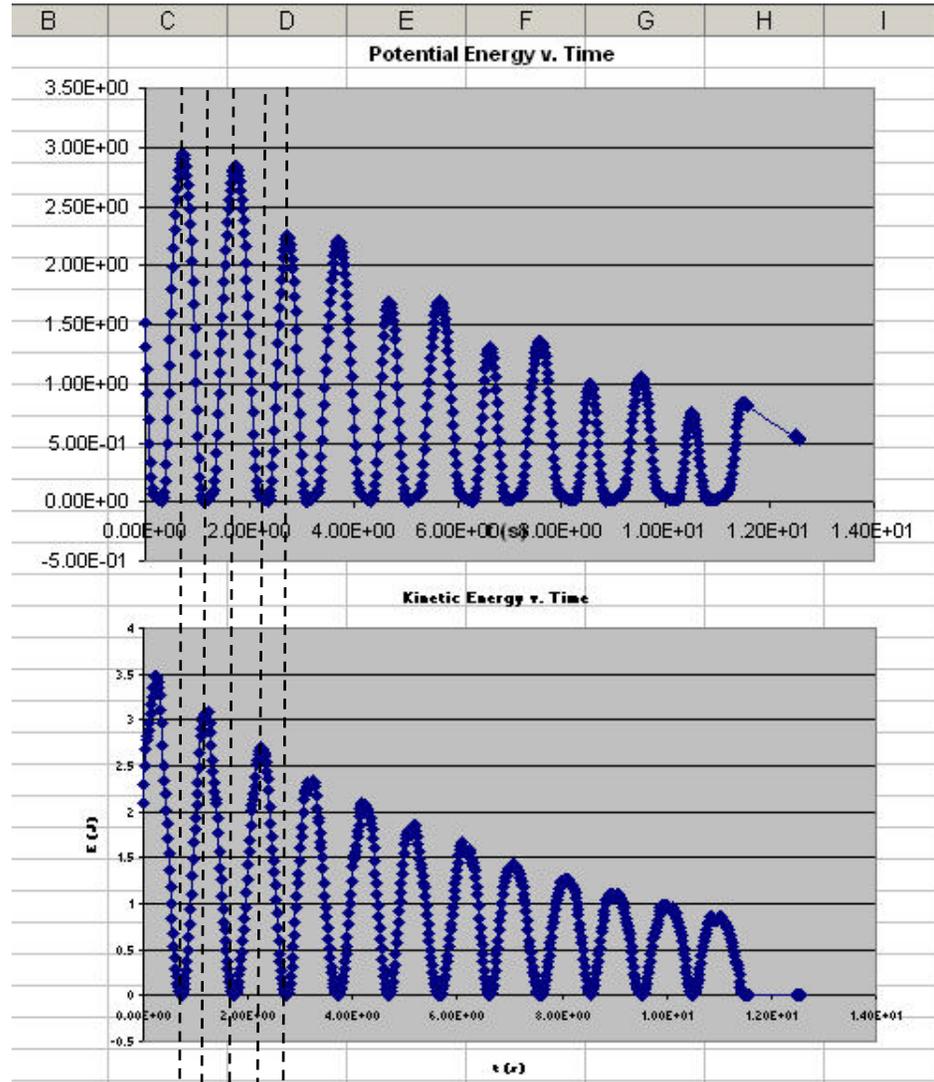
Using the MV and Excel graphs, key analyses may be drawn about the experiment. The X-velocity vs. Time graphs in MV show a periodic and attenuated pattern. The attenuation of velocity is attributed to frictional losses between the track and the cart wheels.



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In Excel, the Potential Energy vs. Time graph may be put next to the Kinetic Energy vs. Time graph. The two graphs are almost exactly out of phase, illustrating the transformation of potential energy into kinetic energy and vice versa.



The Total Energy vs. Time graph shows an interesting step-like shape. From the graph, an approximate conservation of energy within each cycle may be inferred.

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