Newton’s Trap

Overview

Newton's Trap begins with a mouse trap (elastic energy) that hits a PVC pipe that has a battery in it. The pipe tilts allowing the battery to slide down the pipe. This demonstrates potential to kinetic energy with elastic potential energy. The battery sets off another trap that in turn flips up a wooden shaft that knocks down three pieces of wood that are stood up vertically in a "domino" formation. This illustrates another elastic potential to gravitational potential to kinetic energy of the wooden shaft. The domino effect also produces potential and kinetic with a series of collisions. The third and final wooden block has a ball from Newton's Cradle on top of it. When that block falls, the ball sets off Newton's Cradle. This again displays gravitational potential energy to kinetic energy. The last ball in Newton's Cradle collides with a hot wheels van that travels down a ramp.

Design Process

The idea for Newton’s Trap was random and original. Our first idea was to begin the process with a toaster but was quickly scrapped. We decided to use a series of mouse traps in the process instead. The first contraption that we built was the fourth step in our experiment. A mouse trap was set off that in turn flipped up a wooden shaft that was lying on the mouse trap itself. It took about an hour and a half to put a rough assembly together of this device. The next idea was to include a device that utilized one of Newton’s most famous laws: Newton’s Cradle. For action there is an equal and opposite reaction. The idea was at first to build Newton’s Cradle. The planning on building it led us to believe that it was crucial that the cradle work perfect or the experiment would not work. Upon further consideration, we decided to use a Newton’s Cradle that one of the team members had. Most of our ideas came from scrounging through Estabrook 13 and finding supplies. We found a channeled strip of metal and used it as a track for the van to run down. We also found the toy van in Estabrook 13. All of our supplies came from the workshop except for Newton’s Cradle.

The actual building itself took roughly seven hours. That includes testing as well. Our experiment, unlike most, was in five distinct units rather than one movable piece.
**Description of the Device**

Our device consisted five distinct parts. The first trap, which was elevated on top of two blocks of wood, set off the reaction. It triggered the PVC pipe containing a battery which is the second part. The pipe then declined and forced the battery into a second trap which set off the third step. The second trap imparted energy to a wooden shaft that was secured on top of the trap and placed on pivot. The shaft rapidly flipped up and instigated a domino effect which is the fourth part of the experiment. On top of the third standing block rested a ball bearing from Newton’s Cradle. When the shaft hits the first standing block, the domino effect releases the ball bearing and activates the cradle. The last ball in Newton’s Cradle then hits a van that is propped next to the cradle and accelerates down the channeled metal strip. This is the fifth and final step of the experiment.

**Analysis**

The first energy conversion is the mouse trap to the pipe/battery. The mouse trap is elastic potential energy. The battery traveling down the pipe represents gravitational potential to kinetic energy. The second energy conversion starts with the second mouse trap. This is an elastic potential energy to the kinetic energy of the wooden shaft. The wooden shaft activates the domino effect and third energy conversion. Most energy, however, is lost in this step. When the three standing blocks fall, the only energy left is the gravitational potential of the ball bearing. This is now the fourth energy conversion. To find the velocity of which the ball imparts to Newton’s Cradle, we said that gravitational potential energy equal the final kinetic energy. The fifth conversion is the energy imparted from Newton’s cradle to the van. We then calculated the velocity of the van using constant acceleration equations, conservation of momentum, and trigonometry. The cradle itself is an illustration of the total conservation of momentum in a system.
**Bill of Materials**

Each piece of wood- $1.00 (8)  
PVC pipe- $0.50 (1)  
Battery- $0.10 (1)  
Toy van- $0.50 (1)  
Mouse trap- $0.90 (2)  
Ramp- $2.00

**Total Cost=$12.00**

Newton’s Cradle and box- previously owned (does not factor into cost.

**Conclusions**

From our experiment, the main conclusion drawn is that the system is extremely inefficient. We have a couple of observations from the experiment. Newton’s Cradle was not completely lined up. We surmised that this resulted in a loss in the energy transfer. Some problems we had with the experiment itself were getting the ball bearing to firmly hit the cradle to finish the reaction and not projecting a marble. We first used a marble in the PVC pipe to set off the second mouse trap. We resolved that by using a battery. This worked because the battery did not fully leave the pipe therefore excluding the possibility of the projectile. We intuitively drilled a hole in the wood to hold the ball and placed the wood directly in line with the cradle. This way, the ball hit the cradle squarely and made for a better energy transfer. We were successful with the end result. We got to the point to where we were 100% efficient with the conducting of the experiment. Our first run was successful during testing. Upon looking back and wondering what could have been better, we believe that the device could have been initiated another way other than the mouse trap.
Calculating the spring constant of a mouse trap (1st Step in Experiment)

1. Calculating the spring constant of a mouse trap (1st Step in Experiment)

\[ \Delta x = S = \frac{kx}{F} \]

\[ S = 0.45 \text{ ft} \]

\[ F = 0.08 \text{ lb} \]

\[ k = \frac{F \cdot \Delta x}{S} \]

\[ k = \frac{0.08 \text{ lb} \cdot 0.45 \text{ ft}}{0.45 \text{ ft}} = 0.08 \text{ lb-ft} \]

\[ F = \text{ma} \]

\[ F = 0.008 \text{ lb} \cdot (627 \text{ in/s}^2) \]

\[ k = \frac{F}{\Delta x} \]

\[ k = \frac{0.08 \text{ lb}}{0.45 \text{ ft}} = 0.18 \text{ lb-ft} \]

\[ V = \sqrt{\frac{2(mgh + \frac{1}{2}k\Delta x^2)}{m}} \]

\[ V = \sqrt{2(0.08 \text{ lb-ft}) + \frac{1}{2} \cdot 0.08 \text{ lb-ft} \cdot (0.45 \text{ ft})^2} \]

\[ V = \sqrt{2(0.08 \text{ lb-ft}) + 0.08 \text{ lb-ft} \cdot 0.2025 \text{ ft}^2} \]

\[ V = \sqrt{0.16 \text{ lb-ft} + 0.016 \text{ lb-ft}} \]

\[ V = \sqrt{0.176 \text{ lb-ft}} \]

\[ V = 0.42 \text{ lb-ft/s} \]

Calculating the spring constant of a mouse trap (2nd Step in Experiment)

1. Elastic energy conversion - Mouse Trap to Pipe/Battery (2nd Step in Experiment)

\[ U_{\text{spring}} + U_{\text{elastic}} = KE \]

\[ mg(h + \frac{1}{2}k\Delta x^2) = \frac{1}{2}mV^2 \]

\[ V = \sqrt{2(mgh + \frac{1}{2}k\Delta x^2)} \]

Velocity of Ball: \[ V = 6.80 \text{ ft/s} \]

*All equations are identical to Step 1.*
2nd Energy Conversion:

\[ F = k \Delta x \]
\[ K = \frac{F}{\Delta x} \]
\[ k = 0.45 \text{ lb} \cdot \text{in}^{-1} \]
\[ K = 0.373 \text{ lb} \cdot \text{in}^{-2} \]

We have found the spring constant by calculating the arc length that the shaft travels as well as the acceleration of the trap to the shaft.

Now we will calculate the velocity of the shaft imparted to the dominoes.

\[ U = \frac{1}{2} k (V_f)^2 \]
\[ V_f = \sqrt{\frac{2U}{m}} \]
\[ m = \text{mass of shaft} = 0.03 \text{ lb} \]
\[ V_f = 21.49 \text{ ft/sec} \]

3rd Energy Conversion:

**Domino Effect** (5th Step in experiment)

Almost all energy is lost in the domino effect, therefore the calculation would be futile.

4th Energy Conversion:

**Newton's Cradle** (6th Step in experiment)

\[ m_{ball} = 0.045 \text{ kg} \]
\[ V_{after} = k \frac{V}{m} \]
\[ V = \sqrt{2 \left( \frac{V_{after}}{k} \right) \cdot 0.33 \text{ ft}} \]
\[ V = 7.61 \text{ ft/sec} \]

Duanne Newton's Cradle when the first ball strikes the second, energy and momentum is conserved. Therefore, no momentum calculation is needed.

5th Energy Conversion:

**Newton ball to van down ramp** (7th Step in experiment)

\[ \sin^{-1} \left( \frac{1825 \text{ ft}}{4971 \text{ ft}} \right) = 9.9^\circ \]

Time down ramp = 1.56 seconds

Find \( V_f \) Using Cons. of Momentum

\[ m_v V_f = m_v V_f + m_v V_3 \]
\[ V_f = \frac{m_v V_3}{m_v} = \frac{0.045 \text{ kg})(4.92 \text{ ft})}{0.045 \text{ kg}} = 0.95 \text{ m/s} \]
\[ V_f = \left( \frac{0.95 \text{ m}}{m} \right) \left( \frac{1 \text{ m}}{2 \text{ sec}} \right) \cdot \left( \frac{1 \text{ ft}}{0.3048 \text{ m}} \right) \cdot \left( \frac{1 \text{ sec}}{1 \text{ sec}} \right) = 3.12 \text{ ft/sec} \]

\[ \frac{1}{2} m v_1^2 = v_2 \left( \frac{4.92 \text{ ft}}{1.56 \text{ sec}} \right) - 0 = 16.3 \text{ ft/sec} \]

Velocity of van at end of ramp.