“Nightmare Light”

Section: A-1
Team: Six

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Overview

Our Rube-Goldberg device’s ultimate goal was to turn on a light switch. To do this we started out by having a golf ball suspended on fishing line was held by a hinged coffee lid. Once the hinged lid fell down the ball was dropped and swung on the fishing line in a circular path until it hits a cup containing a marble. Once hit the marble would go down a PVC pipe until it reached the end, where a mouse trap is waiting for it. The marble triggered the mouse trap that also has fishing line attached to it at the actual part of the trap that swings. On the other end of the fishing line is a light switch. The mouse trap will pull the line causing the light to turn on. Our project turned out to be very successful with its simple design.

Design & Planning

The design process for our machine involved a culmination of brainstorming and in-depth review of practical devices of a similar nature. We were given videos and other examples in class of Rube-Goldberg devices. The videos conflicted with our design process because of their complex design. Following the guidelines provided we wanted a device that would demonstrate repeatability, uniqueness, simplicity, and at least three separate energy conservations. Upon reviewing Rube-Goldberg devices we devised a list of several components which would effectively demonstrate energy conservation, we selected the ones which we could easily work the physics behind them. Our team had decided that a swinging golf ball, a marble rolling down a tube, and a mouse trap would be our main components. The next challenge would be to join these components into a sequence. Our ball which we knew must be dropped from a constant height for the sake
of repeatability, needed a release mechanism. Upon testing a tab pulled out from underneath the ball we determined the ball had too much horizontal movement. We then designed a hinge mechanism to release the ball effectively. Another challenge faced in the design process was to develop a platform for our marble to make contact with our golf ball. We decided that if the golf ball and marble made direct contact the golf ball would impart a velocity onto the marble which would be difficult to calculate. We opted for a hinged cap to gently lift the ball to the mouth of our ramp. Our final discarded idea was using cement to attach our polystyrene base supports. We eventually found that the cement melted our supports so we used duct tape instead.

Now that the steps in our design process have been clarified, a description of our device will improve comprehension of our struggles and accomplishments. The device needed an outer structure from which our device components would be mounted. The outer structure was built much like a small bridge. It consisted of two parallel, horizontal, four foot long, pvc pipes about eight inches apart, which were supported by six, parallel, sixteen inch, vertical support legs. To improve stability the legs were fitted with polystyrene blocks. This entire outer structure was fastened with pvc joints, duct tape, and cement.
Our first component, the swinging golf ball was fastened to a cross-brace on the top of our structure with a ten inch piece of fishing line. The fishing line provides the radius for the path of the golf ball. The balls release mechanism would be a hinged coffee maker lid approximately twelve inches above the ground.

The second component is our marble ball and ramp. The ramp was made out of a two foot pvc pipe supported by a horizontal cross brace between two of or support legs. A cap on a hinge housed our marble on the end of our ramp. The golf ball would make contact with our cap, elevating it slightly, to allow our marble to roll down the ramp.
The third component placed directly below the bottom of our ramp was a mouse trap. The trap had a length of fishing line attached to its arm. This line was ran over a pulley (horizontal cross brace) at the top of our structure and secured to our light switch. When the ball activates the trap, the arm creates tension in the line pulling the switch up.

Construction & Materials

Before constructing our project, our team referred to a few sources for information. First, we had to get a few ideas on what a Rube Goldberg machine was, easily solved by videos posted on Youtube. We needed to know what guidelines to follow, and did this by visiting the team projects descriptions page on the engineering
fundamentals website. We used a link from the EF 105 cite which posted examples of
good and bad PowerPoint presentations, and referred to these as we were constructing our
PowerPoint. Last, we referred to Mr. Schleter’s photo album listed under the engineering
fundamentals website to find a picture that we could use of him.

The majority of our materials came from room 13 in Estabrook. From this room
we got the PVC pipe, golf ball, Styrofoam, rubber bands, fishing line, a mousetrap, wood,
nails, and a poster board. We also got tape and rubber cement from this room to bind
parts of our project together, and we used the tools available in this room to construct it.
Other items used were L.E.D.s (light emitting diodes), wire, battery holders, and a coffee
maker lid to hold the ball in place. Team members already possessed these items;
therefore no money was spent on these. We did have to buy a switch, switch cover plate,
and switch box, and batteries, which were easily purchased at Home Depot for fewer than
ten dollars.

Calculations

For these calculations, the weights of the golf ball and marble were determined to
be .099 lb. and .0081lb respectively. The force required to flip the light switch was
estimated at .25 lb. The k value for the mousetrap spring was estimated through
calculation at 3lb./in Friction between the marble and the PVC tube was deemed
negligible. The origin (0,0) of the coordinate system for these calculations is the support
leg with the golf ball release hinge mounted to it (x-direction) and the ground the
machine rests on (y-direction).

The Swinging Ball
Initial position of the golf ball is (0,1") with the center of the swing arc and anchor for the string at (9.17", 16"). The target marble cup is at position (18.17", 10") The radius of swing is 10". The conversion of initial gravitational potential energy to kinetic energy is as follows:

\[(m_{\text{golf ball}})(32.2\text{ft/s}^2)(1\text{ft}) = (m_{\text{golf ball}})(v^2) + (m_{\text{golf ball}})(32.2\text{ft/s}^2)(10")\]

The golf ball struck the marble cup with a theoretical velocity of 7.33ft/s. This is far greater than the actual velocity due to friction and any initial slack in the fishing line. We made sure that the marble cup was positioned to overcompensate for any losses during this step.

The Rolling Marble

The golf ball struck the marble cup, which was hinged, in a manner that did not cause the marble itself to become a projectile, but rather to let it roll down the tube with an assumed initial velocity of 0. The conversion from gravitational potential to kinetic energy of the marble is as follows:

\[(m_{\text{marble}})(32.2\text{ft/s}^2)(10") = (m_{\text{marble}})(v^2)\]

\[v=5.18\text{ft/s}\]

to determine the force the marble applied to the mouse trap this velocity was broken into x and y components and the y value was used to determine acceleration in the y direction as follows:

\[\sin(\Theta)= 10''/24'' \quad \Theta= 24.6^\circ \quad \text{y-comp} = (5.18)(\sin(\Theta)) = 2.16\text{ft/s}\]

to approximate the near instantaneous deceleration of the marble from this velocity to zero, a time of .01 seconds was used:
\[
a_{y,\text{marble}} = (0-2.16\text{ft/s})/0.01\text{ sec} \quad a_{y,\text{marble}} = -215.8\text{ft/s}^2
\]

This acceleration was then used to determine the force of the marble on the mousetrap:

\[F = (m_{\text{marble}})(a_{y,\text{marble}}) = 0.05\text{lb. downwards onto the mousetrap (which is apparently very touchy)}.\]

**The Mousetrap-Pulley**

The marble sprang the trap which released the spring potential energy, converting it into kinetic energy. The spring traveled a distance of 3.14” (estimating the radius at 1”):

\[
(1/2)(3)(3.14'')^2 = (1/2)(T/32.2\text{ft/sec}^2)(3.14''/0.2\text{sec})^2 \text{ where } T=\text{the force of tension resisting the spring.}
\]

Using this calculation the spring pulled with a force of 3.87lb. More than enough to flip the light switch.

**Conclusion**

Our project turned out to be very successful with its simple design. Although it took three attempts for our project to work during the presentation, we never encountered such inefficiency in all our test runs. We learned how much force was necessary for our project to work correctly. (Problems as discussed in our power point). The only thing we might have done differently was to have a better structure rather than relying on duct tape. This project was an overall success.