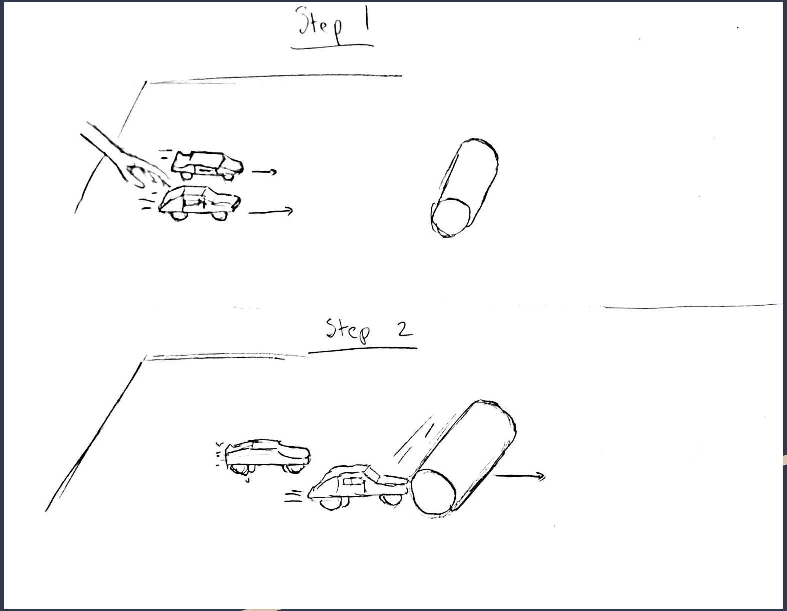
MAE 208: Rube Goldberg Machine

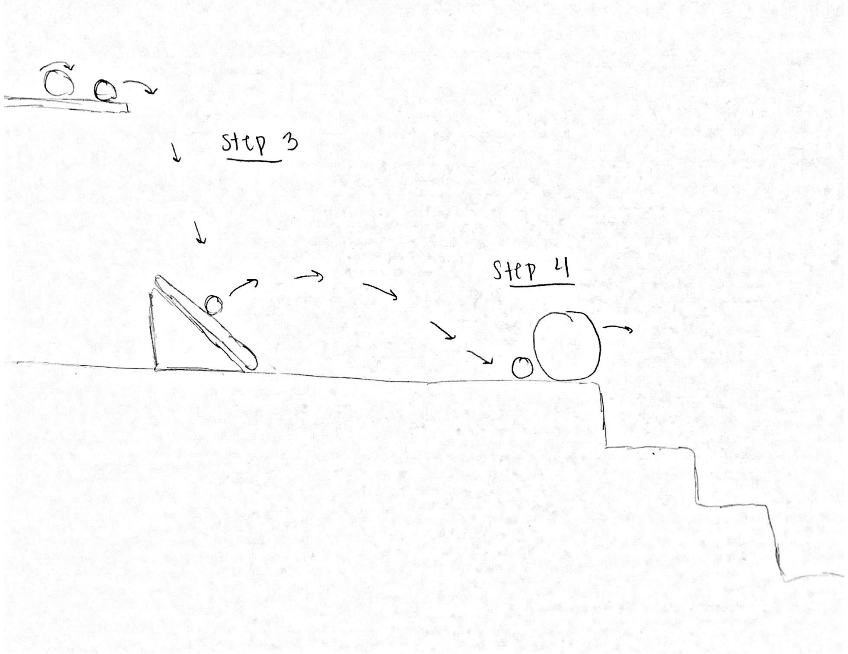
Lawrence Montano, Logan Parker, Erin McEneny, Ruthvik Pedibhotla

Description

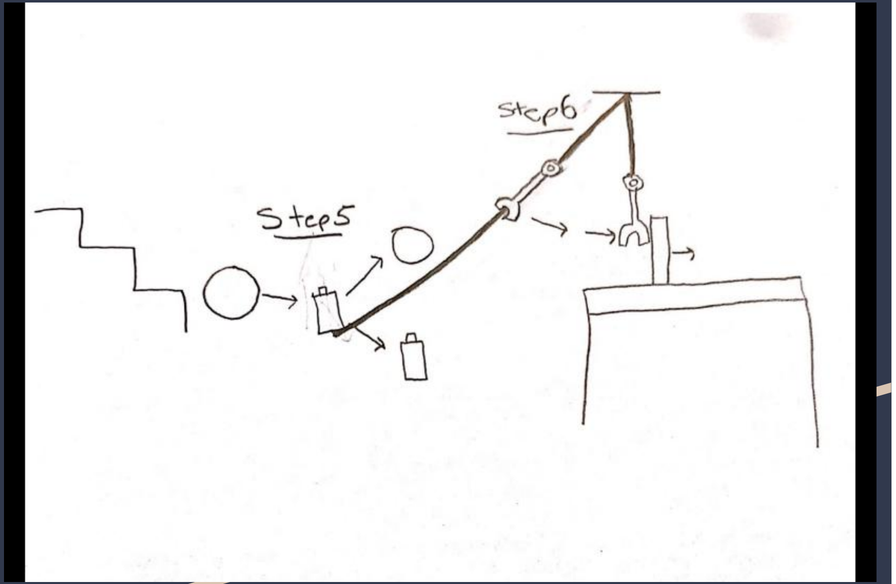
Starting by releasing a car from rest, the car will impact another object which will continue to affect other objects until the end of the machine. The function of our machine is to turn on a floor lamp using common household objects arranged into a Rube Goldberg Machine.

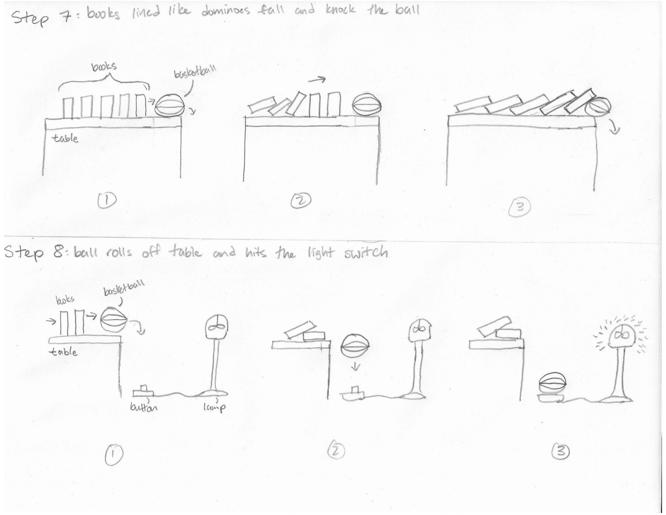
Sketches





Sketches


Step6
Step5


Step 7: books lined like dominoes fall and knock the ball
books
basketball
table
Step 8: ball rolls off table and hits the light switch
books
basketball
table
button
lamp

Flow Chart

Input: Human Release
Principle: Relative Motion
Output: Can Rolling

Input: Car hitting
Principle: General Planar Motion
Output: Golf Ball Rolling

Input: Can hitting golf ball
Principle: Impulse
Output: golf ball hits volleyball/basketball

Input: Golf ball hits volleyball/basketball
Principle: Conservation of momentum
Output: Ball rolls down stairs

Input: Basketball hits water bottle
Principle: oblique impact
Output: water bottle falls down freeing string

Input: String releases wrench
Principle: rotational motion
Output: wrench hits book

Input: Pendulum hits books
Principle: Central Impact
Output: Basketball falling

Input: Basketball falling
Principle: Projectile motion
Output: Lights on

Step ½

Bobby. “How Does A Pull Back Toy Motor Work.” *News about Energy Storage, Batteries, Climate Change and the Environment*, UpsBatteryCenter, 8 Aug. 2014, www.upsbatterycenter.com/blog/pull-back-toy-motor-work/.

“Rotational-Linear Parallels.” *Moment of Inertia*, hydrogen.physik.uni-wuppertal.de/hyperphysics/hyperphysics/hbase/mi.html.

Components Used:

Step 1: Table, Two small pullback cars

Step 2: Table, An object that can roll along a straight line (Aluminum Can)

Assumptions Made:

Table Height = 0.7 m
Car 1 Mass = 287 g
Car 2 Mass = 302 g
Aluminum Can Mass = 384 g
Car 1 is pulled back farther than Car 2

Step 1: Moving Cars (Relative Motion)

Focus: Two cars are released into motion. They move relative to each other at different speeds while one sets an aluminum can into motion at the end of the step.

Input: Human input to release both cars.

Output: Car 1 crashes into the aluminum can to set it in motion.

Solved Variables:

s_1 = 0.2 m, t = 1s ⇒ $v_1 = s_1/t$ = 0.2 m/s

s_2 = 0.13 m, t = 1s ⇒ $v_2 = s_2/t$ = 0.13 m/s

$v_{1/2} = v_1 - v_2$ = 0.07 m/s

Step 2: Rolling Can (General Planar Motion)

Focus: Can rolls across table to tap a golf ball at the end to set it in motion.

Input: Car hits the can to set it in motion.

Output: Can hits golf ball to set it in motion.

Solved Variables: $I = MR^2/2$

$M = 0.384$ kg, $R = 0.05$m $\Rightarrow$ $I = 4.8\text{x}10^4\ \text{kgm}^2$

$m_{car}v_{car1}+m_{can}v_{can1} = m_{car}v_{car2}+m_{can}v_{can2}$

$0.287*0.2 = 0.287*0.09+0.384v_{can2} \Rightarrow v_{can2} = 0.08$ m/s

$\omega = v/r \Rightarrow \omega = 1.64$ rad/s

Step 3/4

FloVolleyball Staff. “Volleyball Facts and Dimensions.” FloSports. N.p., 11 Jan. 2017. Web. 18 Apr. 2020.

Craig, Dexter & May, Stephen. Teed Off! How a Golf Ball Really Works. The Virtual Golfer. 1995

Gutmann, Mindy . “The Physics Of Sports.” N.p., 9 June 1997. Web. 21 Apr. 2020.

Components Used:

3 - table of reasonable height, a small dense ball (golf ball), an angled surface (calf raiser), and a flat pillow on top of the calf raiser

4 - books to guide the small ball (golf ball), and a larger ball(outdoor volleyball) light enough to be knocked over by the small ball

Assumptions Made:

Table Height =69.215cm
Golf Ball Mass = 45.93g
Volleyball Mass = 270g
Angle of Surface = 30°
Angle of Impact of balls = 90°
Time of impact between golf ball and pillow = 0.05sec
e = 0.873

Step 3: Golf ball rolls of table and hits the angled surface (impulse)

Focus: Golf ball falls off the table and hits the pillow on top of the angled surface, redirecting the golf ball.

Input: Can hits the golf ball and knocks it off the table

Output: Golf ball bounces off the angled pillow towards the volleyball/stairs

Solved Variables:

$$mv_i + \int Fdt = mv_f$$

$|v_f| = 1.469$ m/s
$F_{pillow} = 4.397$ N

Step 4: Golf ball hits volleyball (Conservation of Momentum)

Focus: Golf ball hits the volleyball, knocking it off the ledge of the stairs to roll down.

Input: Golf ball bouncing off the angled surface hits the volleyball.

Output: Volleyball rolls off the ledge and down the stairs

Solved Variables:

$$m_g v_{i.g.} + m_v v_{i.v.} = m_g v_{f.g.} + m_v v_{f.v.}$$

$$E = (v_{fg} - v_{fv})/(v_{iv} - v_{ig})$$

$v_{i,g}$ = 0.7354 m/s
$v_{i,v}$ = 0 m/s
$v_{f,g}$ = -0.924 m/s
$v_{f,v}$ = 0.282 m/s

Step 5 and 6

Persson, Jonas. "Measure the Coefficient of Restitution for Sports Balls." *Physics Education*, www.academia.edu/7888446/Measure_the_coefficient_of_restitution_for_sports_balls.

"Geode Rose: S'well® Bottle Official: Reusable Insulated Water Bottles." *S'well® Official*, www.swell.com/products/swell/bottles/geode-rose/?&gclid=EAIaIQobChMI7eP0xLTw6AIViorICh3oeAAYEAQYAiABEgL8-_D_BwE&gclsrc=aw.ds.

Components that could be used:

5 - an item that could froll/slide down stairs (box, ball, basket, bucket) and an item heavy enough to hold a string taught and tall enough to fall over when hit (water bottle, book, cups, jug)

6 - tall item that string can be tied to (ladder, shelf, chair, stool, ceiling), a string (yarn, rope, fishing line), an object that can be tied to the string (tape, wrench, hammer, small water bottle), and an item that can be knocked down (book, water bottle, box)

Assumptions made:

5- coefficient of restitution = .87; mass of basketball = .625 kg; mass of water bottle = .787; basketball hits water bottle at a 45 degree angle, height of stairs = .635 m, assume no friction when ball rolls down stairs

6- radius = .508 m, initial height= .9114 m, final height = .7112 m

Step 5: Basketball hits water bottle (oblique impact)

Focus: water bottle falls over to the side so that the it is on top of is freed

Input: the basketball has velocity after rolling down the steps

Output: the string is no longer holding the wrench at an angle on the pendulum

$mgh = 1/2mv^2$ $v = \sqrt{2gh}$ $v=\sqrt{2(9.81)(.635)}=3.53m/s$

$V_{ax} = 3.53\cos(45) = 2.5$ $V_{ay} = 3.53\sin(45) = 2.5$

$e=(V_{bx2} - V_{ax2})/((V_{ax1} - V_{bx1})$ $.87(2.5-0)=V_{bx2}-V_{ax2}$

$M_aV_{ax1} + M_bV_{bx1} = M_aV_{ax2} + M_bV_{bx2}$

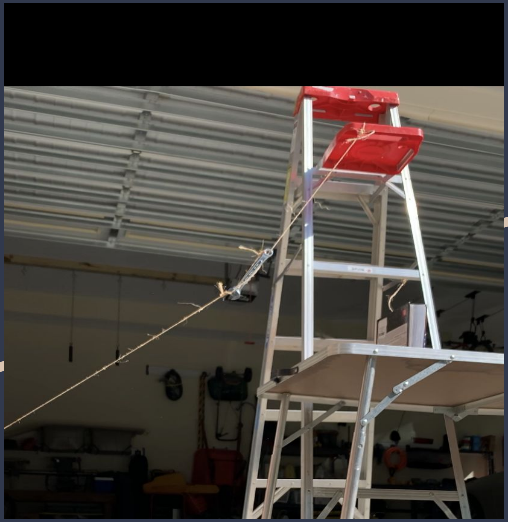
$.625(2.5) + .787(0) = .625V_{ax2} + .787V_{bx2}$

$v_{ax2} = .472m/s$ $v_{bx2} = 2.647m/s$

$M_aV_{ay1} = M_aV_{ay2}$ $M_bV_{by1} = M_bV_{by2}$

$V_{ay2} = 2.5m/s$ $V_{by2} = 0m/s$

Step 6: Pendulum swings and hits book (rotational motion)



Focus: the potential energy created by the change in height of the wrench translates into kinetic energy giving the wrench speed

Input: the string tied to the wrench is no longer taut once the water bottle falls, and the wrench falls creating kinetic energy

Output: the wrench hits the textbook at the bottom of the pendulum

$mg\Delta h = .5I\omega^2 = .5mr^2(v/r)^2 = .5mv^2$

$V = \sqrt{2gh}$ $\quad v = \sqrt{2(9.81)(.9114 - .7112)}$

$V = 1.982$ m/s

$\omega = v/r = 1.982/.508$

$\omega = 3.902$ rad/s

Step 7/ 8

Alexander, Jason, et al. *Characterising the Physicality of Everyday Buttons*.

Nilsen, Lottie, and Denver Post. “E-Textbooks Win Fans, but Some Students Still Prefer Paper.” *The Denver Post*, The Denver Post, 4 May 2016, www.denverpost.com/2012/04/14/e-textbooks-win-fans-but-some-students-still-prefer-paper-3/.

Winkler, Eric. “What Is the Mass of Basketball?” *Dunk or Three*, 20 Mar. 2020, dunkorthree.com/mass-of-basketball/.

Components Used:

7 - somewhat large books (textbooks), table of reasonable height, a decently-sized object that can roll (basketball, soccer ball)

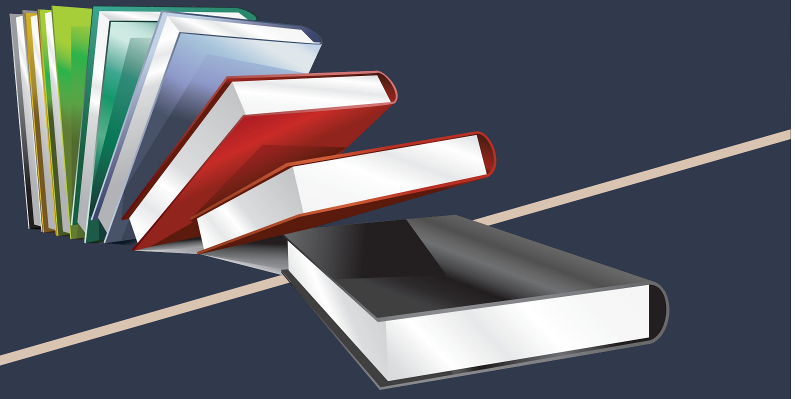
8 - table of reasonable height, object that falls off the table (basketball, soccer ball), a lamp/light with a foot switch

Assumptions Made:

7 - Mass of the books: ~1.6 kg , Mass of the basketball: 625 g, Coefficient of restitution = 0.87

8 - Mass of the basketball: 625 g, Table height: 70 cm, minimum force required to push the light switch: 287.9 g +- 376.3g

Step 7: Books create a chain reaction and hits basketball (central impact)



Focus: Books fall in a chain reaction like dominoes

Input: Pendulum hits the books, causing them to fall over

Output: Books will hit the basketball, pushing it off the table

Equations: (assuming $v_{book,1} = 2$ m/s)

$e = (v_{ball,2} - v_{book,2})/(v_{book,1} - v_{ball,1})$

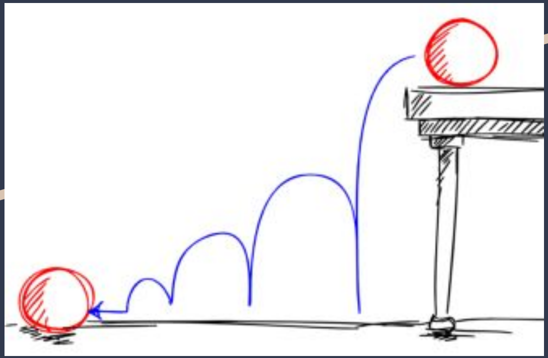
$0.87 = (v_{ball,2} - v_{book,2})/(2- 0)$; $1.74 = v_{ball,2} - v_{book,2}$

$m_{book}v_{book,1} + m_{ball}v_{ball,1} = m_{book}v_{book,2} + m_{ball}v_{ball,2}$

$(1.6)(2)+ 0 = (1.6)(v_{book,2}) + (0.625)(v_{ball,2})$

$v_{ball,2}= 2.69$ m/s , $v_{book,2}= 0.95$ m/s

Step 8: Basketball falls off the table, hitting the light switch and turning on the lamp (projectile motion)



Focus: Basketball will fall and hit the light switch on the ground

Input: Books hit the basketball, causing it fall off the table

Output: The lamp switch is hit, turning on the lamp

Equations:

$y = v_{0,y}*t + 0.5at\text{^}2$

$0.7m = 0*t + (0.5)(-9.81)t\text{^}2, t = 0.377s$

$F_{ball,y} = ma = (0.625kg)(9.81) = 6.131N$

Video Step 1

Video Step 3

Video of Step 6

Video of Step 8