Problem Set 7: Motion With Dissipative Forces, Potential Energy, Conservation of Energy

Design Engineering Challenge: "The Big Dig" 2.007 Contest Hockey Puck Handling Concepts

***I-PROBLEM 1*:** Draw the FBD for a two-wheel drive car, which is simple to build.

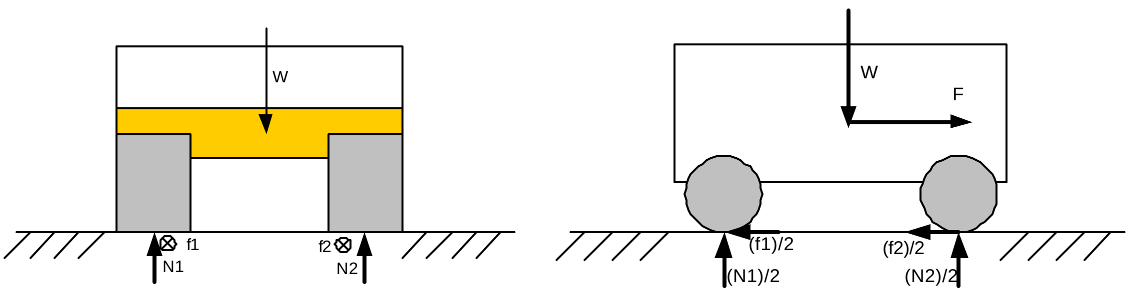


Figure 1: FBD of the two wheeled car

Where:
F: thrust force (N)
f: friction force (N)
N: reaction force (N)
W: weight of the car (N)

***I-PROBLEM 2*:** If the car's mass is located in the center midway between the wheels, given a coefficient of friction m between the wheels and the table, what would be the maximum force with which the car could push an object? This is called the *tractive* effort.

$$\sum F_y = 0 \Rightarrow N_1 + N_2 = W$$

$$\sum \Gamma_O = 0 \Rightarrow N_1 = N_2 \Rightarrow N_1 = N_2 = \frac{W}{2}$$

$$\therefore f_1 = m\frac{W}{2},\ f_2 = m\frac{W}{2}$$

$$\sum F_X = ma_x \Rightarrow F - (f_1 + f_2) = ma_x \Rightarrow F = mW + ma_x = m(mg + a_x)$$

***I-PROBLEM 3*:** The hockey pucks can be rolled into position if handled carefully, but if they tip over, they will have to be pushed. Draw the FBD of the vehicle as it *pushes* a hockey puck, and as it rolls a hockey puck.

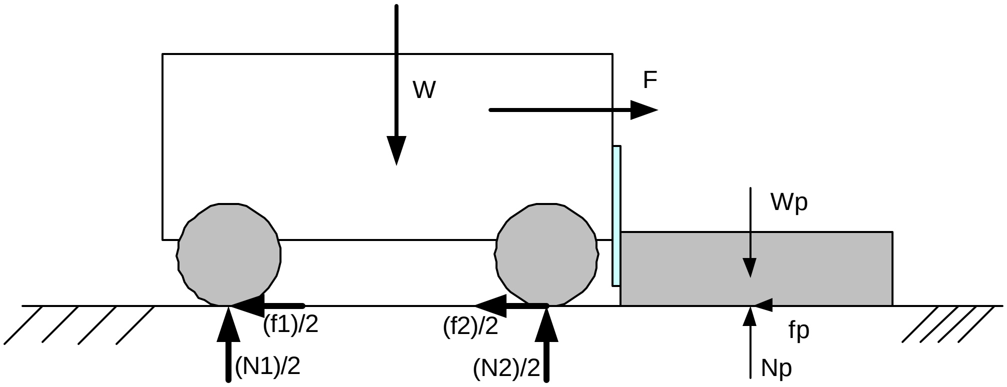


Figure 2: FBD Pushing the puck:

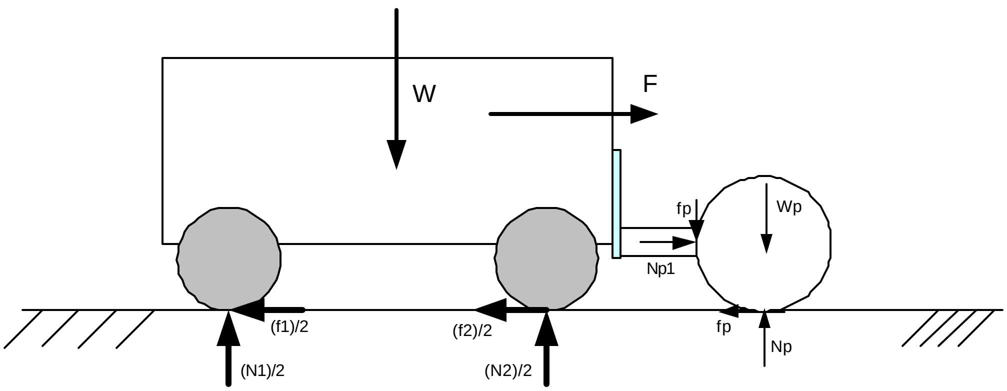


Figure 3: FBD Rolling the puck:

***I-PROBLEM 4*:** Is there anything special about the contact between the vehicle and the hockey puck to ensure low friction rolling at *all* contact interfaces?

To reduce friction a roller can be placed on the interface with the wheel. Moreover the location of where the car contacts the puck effects the overall system.

***II-PROBLEM 1*:** How much kinetic energy must be imparted to the hockey pucks in order to make them fly into the paddles without touching (and hence losing energy) the ramp?

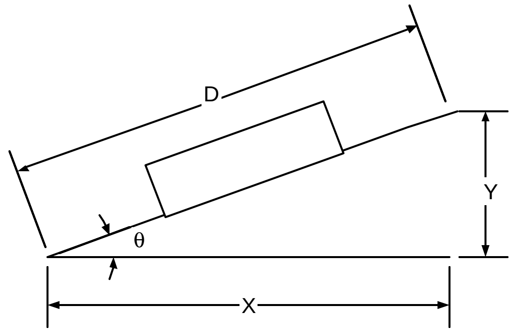
Energy is conserved:

$\Delta KE = \Delta PE$

$KE_2 - KE_1 = PE_2 - PE_1$

$KE_2 = 0$ The puck just reaches the end, $KE_2 = \frac{1}{2} m v_2{}^2 = 0$

$$PE_2 - PE_1 = mgY$$



$$q = 15^0, X = 48 - 24\frac{11}{16} = 23.3125''$$
$$\Rightarrow Y = 6.25'' = 0.159m$$
$$E_1 = mgY = (0.13kg)(9.8m/\sec^2)\sqrt{0.159m} = .6Joules$$

This accounts for the energy needed to lift the puck to a height of (0.2461)m, but not a distance of (23.3125)in (i.e. the velocity used in the kinetic energy equation above only acts in the y direction, velocity in the x direction is constant). We should approach this as a projectile, as we did in the previous problem set.

The range of a projectile: $R = \left[\frac{\left(v_0^2 \sin 2q\right)}{g}\right] = D$

In our case, R is equal to D, the length of the ramp and ? is equal to (ß-?), the launch angle of the projectile relative to the ramp (the launch angle of the projectile minus the angle of the ramp). We will have to select a launch angle (relative to the ramp) for the projectile to determine the energy needed to launch the puck into the paddles.

$$v_0^2 = \left[\frac{gD}{\sin 2(b - q)}\right]$$

For the minimum kinetic energy needed, we select an angle (ß-?) that gives us the smallest value for v_0^2 in this case the angle is 45°, which yields a value of gD for v_0^2.

So, the energy needed to launch the puck into the paddles is:

$$E_2 = \frac{1}{2}mv_0^2 = gD = 0.6Joules$$

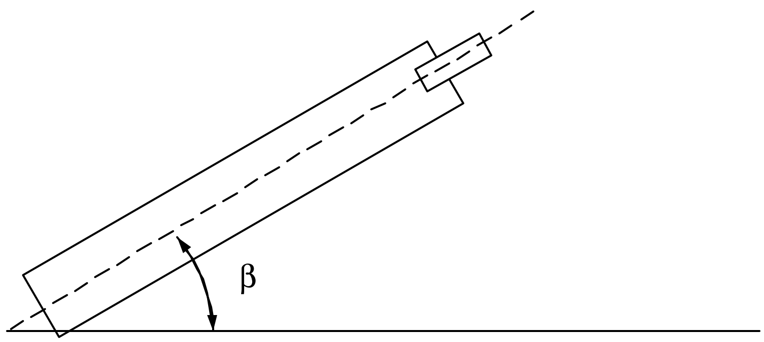
Hence $Total\_Energy = E_1 + E_2 = 0.6 + 0.6 = 1.2Joules$

***<u>II-PROBLEM 2</u>*:** What elements of the 2.007 kit of parts could store and suddenly release energy to enable them to flip up the hockey pucks? Estimate if they can store enough energy to accomplish this goal. How many pucks could they flip up?

To throw the pucks up the ramp into the bins, We can use three options from the kit:

1) Compression Spring
2) Tension Spring
3) Constant Force Spring

4) The solenoid can be used to trigger the springs



1) Extension Spring:

Small: K=2.14N/mm,

Spring needs to be extended by x to get the puck to the scoring bin, where x is:

$$W_1 = \frac{1}{2}kx^2 = .5(2.14)(x^2) = 1200Nmm \Rightarrow x = 33.5mm = 1.32"$$

Medium: K=.508N/mm,

Spring needs to be extended by x to get the puck to the scoring bin, where x is:

$$W_1 = \frac{1}{2}kx^2 = .5(.508)(x^2) = 1200Nmm \Rightarrow x = 68.7mm = 2.7"$$

Large: K=1.996N/mm,

Spring needs to be extended by x to get the puck to the scoring bin, where x is:

$$W_1 = \frac{1}{2}kx^2 = .5(1.996)(x^2) = 1200Nmm \Rightarrow x = 35mm = 1.4"$$

2) Compression Spring:

K=1.068N/mm,

Spring needs to be extended by x to get the puck to the scoring bin, where x is:

$W_1 = \frac{1}{2}kx^2 = .5(1.068)(x^2) = 1200Nmm \Rightarrow x = 47.4mm > 20mm$: Maximum deflection of spring. Hence this option is not feasible

3) Constant Force Spring:

Pull Force = 11.6N

The force required to launch a puck into the paddles is,

$$F = \left(\frac{m}{t}\right)\left[\frac{gD}{\sin 2(b - q)}\right]^{\frac{1}{2}}$$

If this force is less than 11.6N (2.6 lbf), then the constant force springs will work.

m~1N
t~1sec
? = 45°
D = 22.5"(here ? is equal to 15°, the angle of the ramp)
F = 3.05 N

The constant force springs can launch the pucks into the paddles.

Multiplying,

$$F = \frac{m}{t}\left[\frac{gD}{\sin 2(b - q)}\right]^{\frac{1}{2}} = 3.1N < 11.6N$$

Hence these springs can be used

***II-PROBLEM 3*:** Do you think this is a feasible idea? What are the risks and possible countermeasures?

I don't think this is a feasible idea, because of the risks that accompany a projectile. These risks include

- Aligning the device to actually get the pucks into the bins.
- Building the mechanism to load pucks for launching, may be very intricate.
- The performance might vary; sometimes it may work, other times it may not.

However, if you can design a mechanism to load pucks consistently and if you are able to align the launcher and repeatedly launch projectiles into the paddles successfully, then it is a very good idea. Note: that is a very big if.