

Chapter 6.00A

Physical Problem for Regression General Engineering

Problem Statement

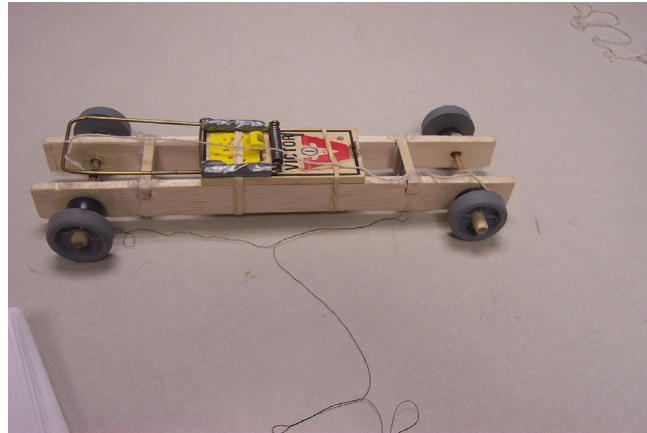


Figure 1 Mousetrap car.

In Summer of 2003, a high school student worked with me to study the physics of a mousetrap car so that he can build the car that would go the fastest and/or the farthest.

So what is a mousetrap car?

A mousetrap car (Figure 1) is a vehicle that is powered by the energy stored in the spring of a mousetrap. One of the basic ways in which most mousetrap vehicles are set into motion is by connecting the lever of the mousetrap bar through a string to the axle of the car. As the mousetrap lever is released, the tension that was built up in the spring is released, and the car sets into motion.

So to get the car to go the farthest and fastest, we need to store as much potential energy in the mousetrap spring. Since there is no specification on the mousetrap other than using a certain brand, we could use a mousetrap that had the largest spring constant as that would translate to the largest potential energy stored.

Therefore, we bought several mousetrap springs and conducted a simple experiment to determine the spring constant of the mousetrap spring. This would then allow us to find the potential energy stored in the mousetrap.

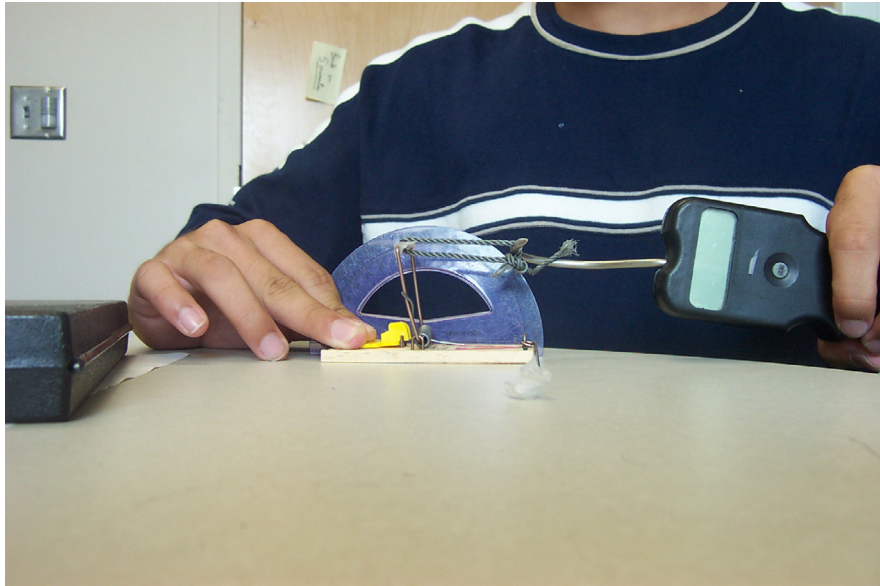


Figure 2 Experimental setup to measure the spring constant.

To find the spring constant of the mousetrap spring, we conducted the following experiment. We pulled the end of the mousetrap lever by a force probe (a fish hook) and measured the angle through which it is pulled by a protractor (Figure 2). We pulled on the end of the spring via a string so that the force on the lever is applied at right angle to the lever. This way the torque applied is simply the product of the force, as measured by the fishhook (Figure 3), and the length of the lever arm.



Figure 3 Force probe designed to measure the amount of force an object contains.

We measured the force needed to pull the lever for several different angles. The data for one of the mousetraps is given in Table 1.

The relationship between the torque applied and the angle of the rotation of the spring rotation is assumed to be a straight line

$$T = k_0 + k_1 \theta$$

where

T = Torque (N-m)

θ = Angle through which the spring is rotated

Table 1 Force vs. angle of lever rotation (Mousetrap#1).

Angle (degrees)	Force (lbs)
40	0.9
55	1.0
65	1.1
90	1.2
110	1.5

The data in Table 1 is converted to SI system of units, and the torque is calculated using the measured lever moment arm of 47 mm, that is

$$T = FL$$

where,

T = Torque (N-m)

F = Force applied (N)

L = Moment arm (m)

Angle	Torque
Radians	N-m
0.698132	0.188224
0.959931	0.209138
1.134464	0.230052
1.570796	0.250965
1.919862	0.313707

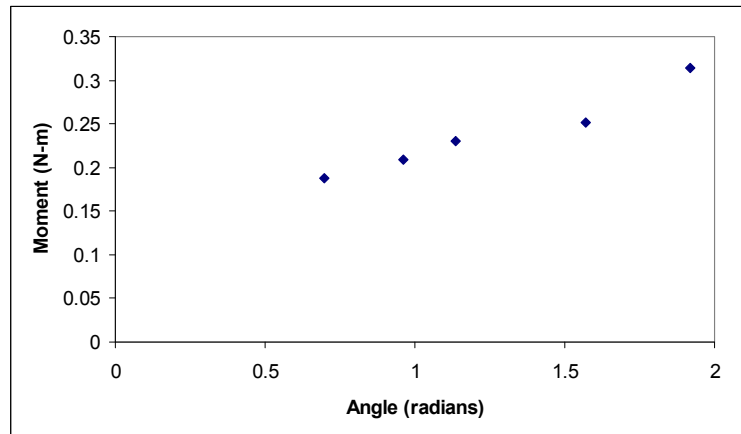


Figure 4 Data and plot of torque vs angle of rotation.

Other mousetrap springs were tested accordingly and the data is given in Tables 2 and 3.

From these tables, we can find the $T = k_0 + k_1 \theta$ relationship for each of three mousetraps.

The potential energy, U stored in the spring would be given by

$$\begin{aligned}
 U &= \int_{\theta_{low}}^{\theta_{high}} T d\theta \\
 &= \int_{\theta_{low}}^{\theta_{high}} (k_0 + k_1 \theta) d\theta
 \end{aligned}$$

Knowing that in our case, $\theta_{low} = 0$ and $\theta_{high} = \pi$, the maximum potential energy stored

$$U_{\max} = \int_0^{\pi} (k_0 + k_1 \theta) d\theta$$

$$= k_0 \pi + k_1 \frac{\pi^2}{2}$$

Table 2 Force vs. angle of lever rotation (Mousetrap#2).

Angle (degrees)	Force (lbs)
38	0.9
58	1.0
65	1.1
90	1.2
120	1.6

Table 3 Force vs. angle of lever rotation (Mousetrap#3).

Angle (degrees)	Force (lbs)
40	0.9
57	1.0
65	1.1
90	1.2
135	1.7

Questions

1. Find the constants of the regression model for the spring for the three cases (Tables 1, 2 and 3).
2. Which of the three springs would you chose based on maximum potential energy stored?

REGRESSION

Topic	Physical problem for regression
Summary	Conducting regression for the mousetrap spring to find the best mousetrap for use in a mousetrap-car.
Major	General Engineering
Authors	Autar Kaw
Date	December 23, 2009
Web Site	http://numericalmethods.eng.usf.edu
