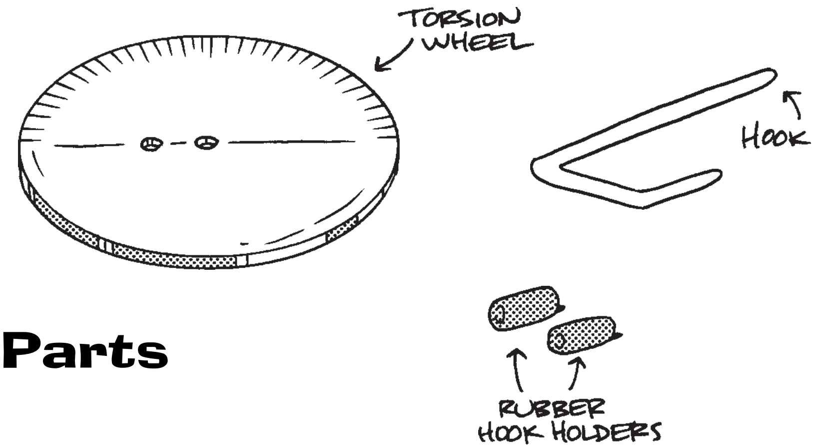
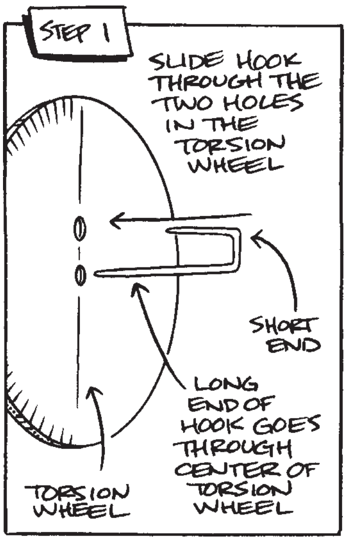
Torsion Wheel

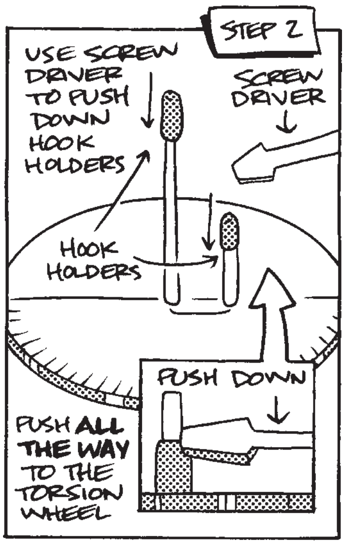
Assembly Instructions

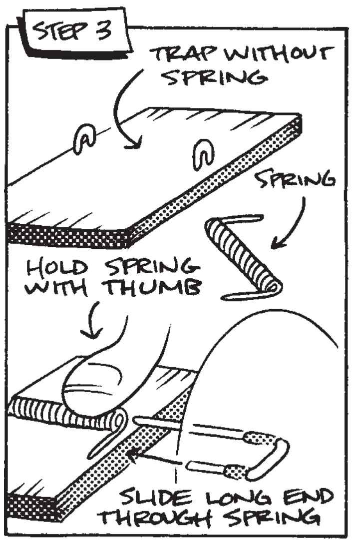
Your package should contain the following components: **Torsion Wheel** with string already attached, two (2) rubber hook holders, wire hook, and lab instructions. Assemble the **Torsion Wheel** according to the instructions. After assembly you will need to provide the following items in order to use the **Tension Wheel**: **c-clamp** or **table clamp**, **“stripped” mousetrap base**, and **mousetrap spring**. To use your **Torsion Wheel** you will need to secure a “Stripped” mousetrap base to a table using a clamp. You will place a spring on the “stripped” trap base and then guide the **Tension Wheel** through the spring hole.

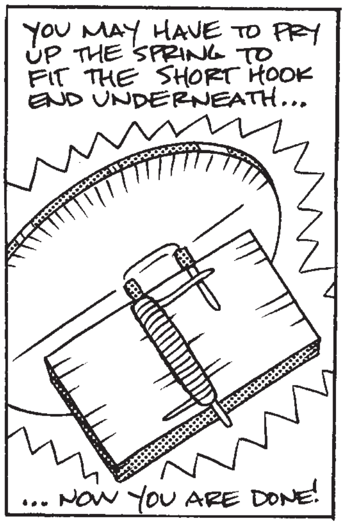
Parts











Lab #2 - All Wound Up

Purpose
To calculate the starting potential energy and to find the spring coefficient.

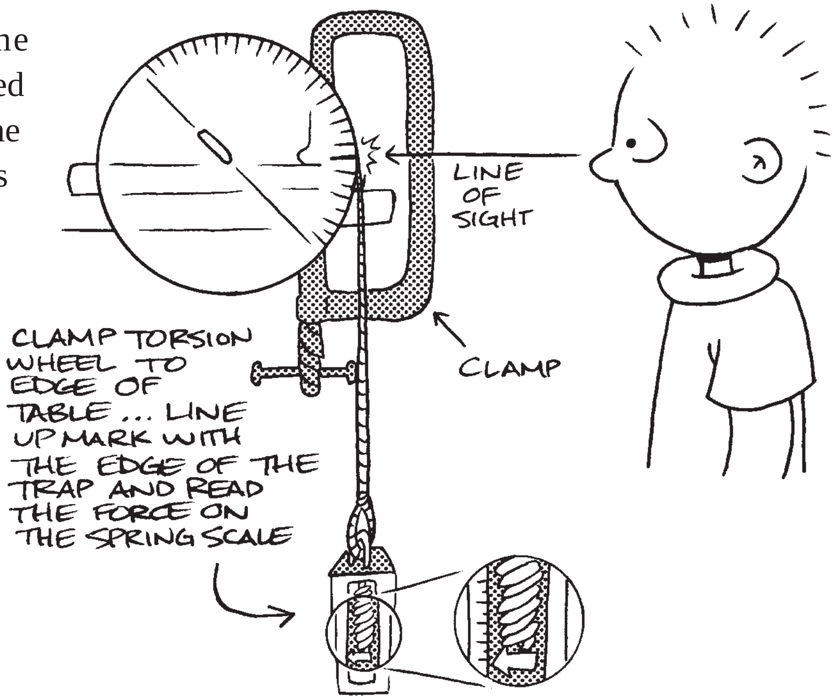
Equipment Needed
Spring Scale or a Computer Force Probe
Tension Wheel
String

Discussion
Energy has the ability to do work. Your mousetrap car's performance will depend directly on the strength of your mousetrap's spring. The stored energy of your spring in the fully wound-up position is called potential energy. The amount of stored potential energy is the same as the work that was required to wind the spring. The force required to wind the spring times the distance the force was applied is equal to the work that was done on the spring (Formula #1). Because the force required to wind the spring changes and depends on how much the spring is wound, you will have to find the average force between a series of points and then calculate the work done between those marks. The total work (or the stored potential energy) is equal to all the changes of energy between all the points added together (Formula #2). In order to measure the winding force you have to use a spring scale attached to a lever. The lever is lifted and the force is measured every 5 or 10 degrees. The scale has to be held such that the string attached to the lever arm is perpendicular. A problem with this method is that as the spring scale is held in different positions it becomes inaccurate. The spring scale cannot change from the position at which it was zeroed. For this reason you should use a **Tension Wheel**. A **Tension Wheel** allows the spring scale to remain in the same orientation, producing more accurate results and it is

The Set-up

also easier to use.

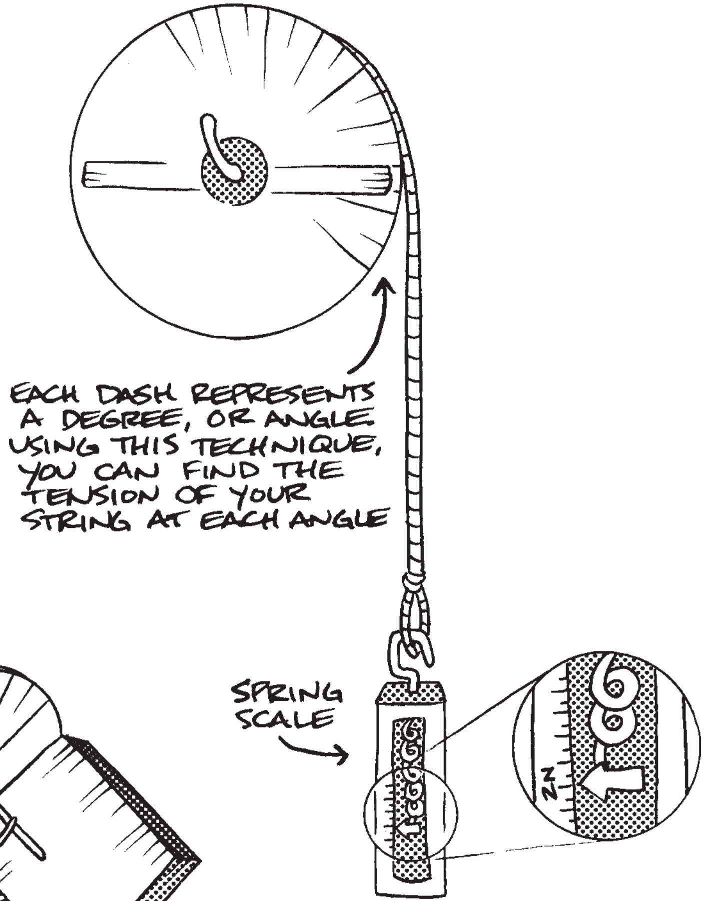
The distance that the average force was applied is equal to the angle of the measurement in radians times the length of the measuring lever arm. If you are using a **Tension Wheel**, then the radius of the wheel is the measuring lever arm (Formula #3). Formula #4 allows you to convert from degrees to radians.

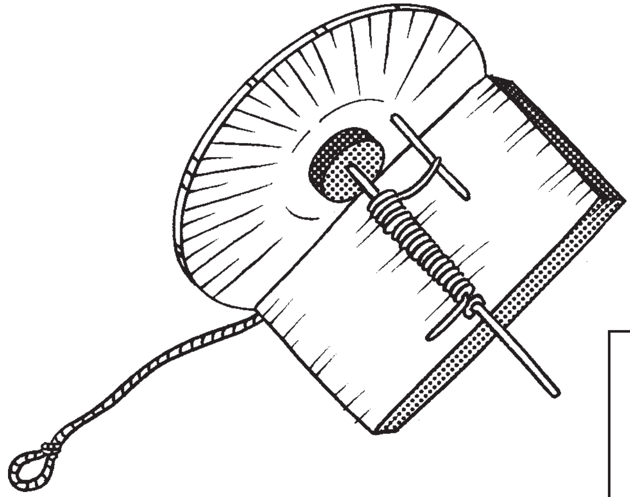


For a spring that is stretched or compressed longitudinally, Hooke's Law applies and says that the force is equal to the spring constant times the stretching or compressing displacement. But a mousetrap spring does not stretch longitudinally. A mousetrap spring is a torsion spring and winds up. For this type of spring a different formula is needed (Formula #5). It is a torque that must be applied to the spring to wind it and the displacement is measured in radians (Formula #6). The units associated with the spring constant become Newtons * Meters/ Radians. For a spring that compresses or stretches in a linear direction, the total potential energy is one half the spring constant times the displacement squared (Formula #7). For a torsion spring the displacement is substituted by the angle in radians (Formula #8).

Tools of the Trade: Tension Wheel

A **tension wheel** *is designed to direct the pulling force in the same direction as the spring is wound. This prevents the scale from having to be re-zeroed as its direction of pull changes. Degree markings make it easy to measure force and angle.*





How it Works:

As the wheel is turned clockwise the spring on the mousetrap is compressed. The value of the spring constant depends on the material the spring is made from, the diameter of the wire, the diameter of the coil, and the number of coils.

Formulas

What it All Means

W =Work
F = Force
d = Displacement
k = Linear Spring Constant
κ =Torsion Spring Constant
x = Spring Displacement
τ =Torque
θ = Angle
PE = Potential Energy

Formula #1: $$W = F \cdot d$$

Work formula used with a constant (non-changing) force

Formula #2: $$W = \int_0^{\pi r} F(x)\, d(x)$$

Work formula used with a changing force as with a mousetrap spring

Formula #3: $$d = \theta r$$

A formula to calculate the linear distance of travel for a wheel

Formula #4: $$\text{degrees} \times \frac{\pi}{180^o} = \theta$$

A formula used to change degrees into radians

Formula #5: $$F = -kx$$

Hooke's Law. Force of a stretched or compressed spring

Formula #6: $$\tau = \kappa\theta$$

From Hooke's Law. Used to calculate the torque from a torsional spring

Formula #7: $$PE = \frac{1}{2}kx^2$$

Potential energy of a stretched or compressed spring

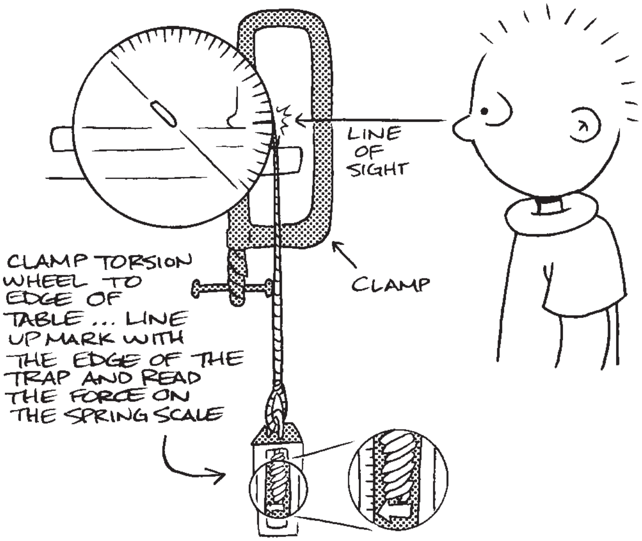
Formula #8: $$PE = \frac{1}{2}\kappa\theta^2$$

Potential energy of a stretched or compressed torsion spring

Pulling Your Weight

Steps 1: In this lab you will measure the tension at various degrees of travel for your mousetrap's spring. Start by removing your spring from your mousetrap and attach it to the **Tension Wheel** spring tester. Firmly holds the **Tension Wheel** spring assemble on a flat tabletop. It is best to use a clamp to hold the **Tension Wheel** in place. Guide the string over the top of the **Tension Wheel** making sure that the string rest in the wheel's groove. Hook the end of a spring scale or a force probe to the string of the **Tension Wheel**. (NOTE: Make sure that you have zeroed the spring scale in the same direction that you will be pulling on the string.)

Step 2: Pull down on the force probe until the start line,"0" degree mark, is line up parallel with the base of spring holder or mousetrap base, record the force on the scale at the zero mark as the starting force. Continue to pull down on the force probe until the first measuring mark, 5 or 10 degree mark, is lined up with the base of the spring holder, record the force at this mark. Continue to pull down on the spring scale, stopping at every 5 or 10 degrees. Record the tension at each point from 0 to 180 degrees in the data table.



Data Tables

Recommendations:
Try to set-up a **spread sheet** *on a computer in order to handle your data more* **efficiently**.

Data Table #1

Angle	Tension	Change in Radians	Total Radians	Change in Displacement	Total Displacement
5	$F_0=$	$\Delta\theta_0=0$	$\theta_0=0$	$\Delta d_0=0$	$d_0=0$
10	$F_1=$	$\Delta\theta_1=$	$\theta_1=$	$\Delta d_1=$	$d_1=$
15	$F_2=$	$\Delta\theta_2=$	$\theta_2=$	$\Delta d_2=$	$d_2=$
20	$F_3=$	$\Delta\theta_3=$	$\theta_3=$	$\Delta d_3=$	$d_3=$
25	$F_4=$	$\Delta\theta_4=$	$\theta_4=$	$\Delta d_4=$	$d_4=$
180	$F_{36}=$	$\Delta\theta_{36}=$	$\theta_{36}=$	$\Delta d_{36}=$	$d_{36}=$

Data Table #2

Spring Constant	Torque	Change in Potential Energy	Total Potential Energy
$k_0=0$	$T_0=$	$\Delta PE_0=0$	$PE_0=0$
$k_1=$	$T_1=$	$\Delta PE_1=$	$PE_{0\text{-}1}=$
$k_2=$	$T_2=$	$\Delta PE_2=$	$PE_{0\text{-}2}=$
$k_3=$	$T_3=$	$\Delta PE_3=$	$PE_{0\text{-}3}=$
$k_4=$	$T_4=$	$\Delta PE_4=$	$PE_{0\text{-}4}=$
$k_{36}=$	$T_{36}=$	$\Delta PE_{36}=$	$PE_{0\text{-}36}=$
Ave		Total	

Step 3: Calculate the change in radians for each angle, from 0 to 180 degrees, and record them in the data table. If each measurement was made at the same increment (e.g., 5, 10, 15, 20 …) you can use the same change in radians for all angles. Use the following method to calculate the change in radians:

$$\Delta\theta_1 = (\text{degrees}_1 - \text{degrees}_0) \times \frac{\pi}{180^o}$$

$$\Delta\theta_2 = (\text{degrees}_2 - \text{degrees}_1) \times \frac{\pi}{180^o}$$

Step 4: Measure the radius of the **TensionWheel** and record this as the radius. Calculate the change in displacement, also known as the arc length, for each angle using the following formula. If each measurement was made at the same increment, (e.g. 5, 10, 15, 20 …) you can use the same arc length (displacement) for all angles.

$$\Delta d_1 = \Delta\theta_1 r \qquad \Delta d_2 = \Delta\theta_2 r \qquad \Delta d_3 = \Delta\theta_3 r$$

Step 5: Calculate the total displacement for each angle by adding each of the previous changes in displacement to the next.

Step 6: Calculate the change in potential energy for each point using the following method. Multiply the average force between the starting and ending points with the change in distance. Add each of the change in PE values together in order to find the total potential energy from the column. This added value should be the energy your vehicle starts with before it is released.

$$\Delta PE_{0,1} = \frac{F_0 + F_1}{2} \cdot \Delta d_1$$

$$\Delta PE_{1,2} = \frac{F_1 + F_2}{2} \cdot \Delta d_2$$

$$\Delta PE_{2,3} = \frac{F_2 + F_3}{2} \cdot \Delta d_3$$

Step 7: Calculate the spring constant for each angle. Because of the type of spring your are dealing with (a spring that coils as opposed to stretching), you will have to use the following equation to calculate the spring constant: $\tau = \kappa\theta$. Torque is equal to the spring constant times the angle in radians. Torque is calculated from the force that is applied to a lever arm times the length of the lever arm, or where the force is applied. $\tau = Fr_{\text{lever arm}}$ Total each spring constant and find an average.

$$\kappa = \frac{\tau}{\theta}$$

$$\kappa_0 = \frac{(F_0 r_{\text{lever arm}}) - (F_0 r_{\text{lever arm}})}{\theta_{\text{0-0}}}$$

$$\kappa_1 = \frac{(F_1 r_{\text{lever arm}}) - (F_0 r_{\text{lever arm}})}{\theta_{\text{0-1}}}$$

$$\kappa_2 = \frac{(F_2 r_{\text{lever arm}}) - (F_0 r_{\text{lever arm}})}{\theta_{\text{0-2}}}$$

Step 8: Use the total displacement and the total potential energy at each point in order to determine the spring constant. Again, because the spring starts partly wound and under tension, you will have to subtract the starting energy from each total energy in order to calculate the correct spring constant. Total each spring constant and find an average.

$$PE = \frac{1}{2}\kappa\theta^2$$

$$\kappa_1 = \frac{2*(PE_{\text{total}_{0,1}} - (F_0 r_{\text{lever arm}} \theta_1))}{\theta_{0-1}^2}$$

$$\kappa_2 = \frac{2*(PE_{\text{total}_{0,2}} - (F_0 r_{\text{lever arm}} \theta_2))}{\theta_{0-2}^2}$$

$$\kappa_3 = \frac{2*(PE_{\text{total}_{0,3}} - (F_0 r_{\text{lever arm}} \theta_3))}{\theta_{0-3}^2}$$

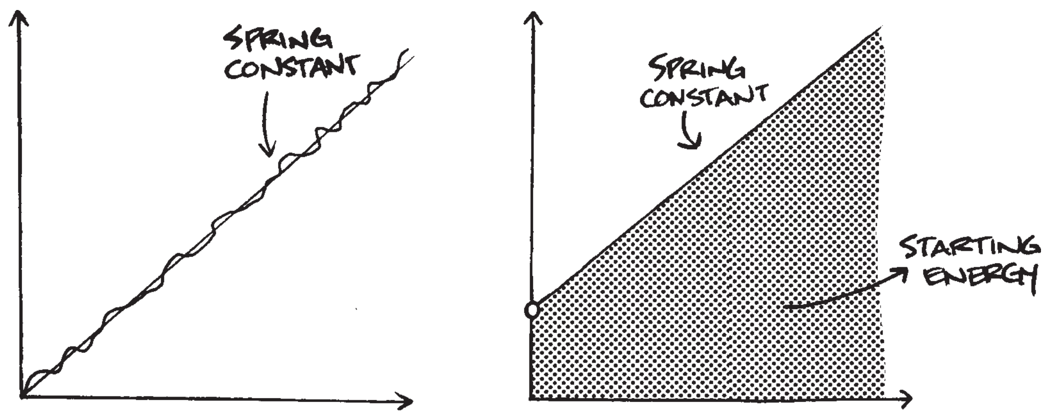
Graphing the results

In each of the following graphs attempt to draw the best fit lines. If data is widely scattered do not attempt to connect each dot but instead draw the best shape of the dots. If you have access to a computer, you can use a spread sheet like Microsoft Exel to plot your data.

1. Graph **Pulling Force** on the vertical axis and the **Displacement** on the horizontal axis.
2. Graph **Torque** on the vertical axis and **Angle in Radians** on the horizontal.

Analysis

1. The slope from your graph of "torque vs. angle" represents the spring constant. Does the slope change or remain constant? Do you have an ideal spring that follows Hooke's Law?
2. What does the slope of the line from each of your graphs tell you about the strength of your spring compared to other students' graphs?
3. Calculate the area under all parts of the best-fit line from the graph of "torque vs. angle." This number represents the potential energy you are starting with. The larger the number, the more energy you have to do work. This number should be close to the total potential energy calculated from your data table. How does the slope compare to the number in the data table?
4. How does your potential energy compare to other students' potential energy in your class? Discuss.



GRAPHING THE TENSION AT EACH ANGLE, YOU CAN GET THE **SPRING CONSTANT** AND THE **STARTING ENERGY**. YOUR RESULTS SHOULD ROUGHLY FORM A STRAIGHT LINE.

Potential Energy, Spring Constant