Determining the coefficient of friction for various tires on a ramp

An experiment involving the forces on various polymers

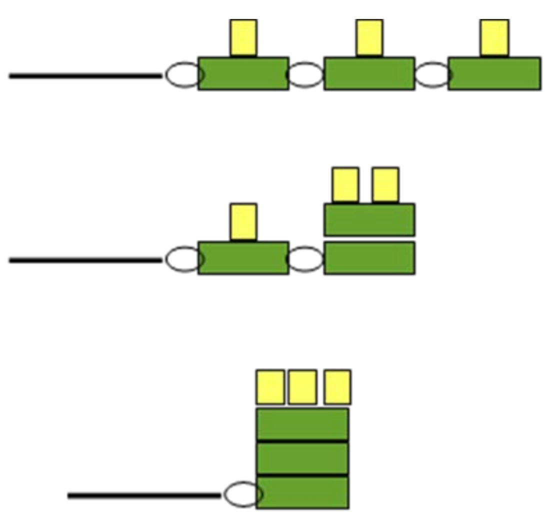
Background information: Tire companies invest a lot of money researching different properties of rubbers to make them ideal for making tires. One of the key aspects for a successful rubber for tires is the amount of friction between the tire and the road. After all, your car does not work when it is on ice because there is not enough friction between the surfaces. When a car moves forward it is the friction force from the road that pushes the car. Through Newton's 3rd Law, action-reaction, we know that the more friction force the car can put on the road the more friction the road can put on the car. Therefore it is very important for the tires to have the right amount of friction in order to create enough force to push your car as well as stop your car.

Friction is a force that exists between two surfaces due to the tiny bumps on the surfaces of the objects. There are two types of friction static friction (when the object is not moving) and kinetic friction (when the object is moving). Different types of surfaces have different coefficients of kinetic friction, $\mu_{k,}$ and static friction μ_s. Static friction is involved when the car is speeding up because the tire does not slide on the road and kinetic friction is involved when the breaks are used to stop the car.

One of the main forces you will be dealing with in this experiment is the normal force. The normal force is a force that is perpendicular to the surface of contact. For example, if a book is sitting on a table, the table exerts an upward normal force on the book that is equal to the gravitational force on the book since there is no net force in the vertical direction.

Experimental Question: What variables might affect the amount of friction between the tire and the road?

Instructor Demonstration: If the students suggest things such as surface area and speed (although speed does actually play a role in the amount of friction of a polymer-this can be discussed at a later point) the easiest way to test these is though a class demonstration. To test surface area hook 3 wood blocks together and pull them with a force probe and then change it to three blocks stacked on top of eachother and compare the friction force. The whole time you must keeep the same normal force so be sure not to change the mass of the system. A picture of this is shown below:

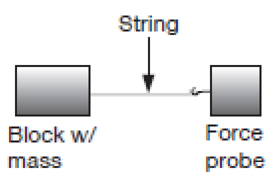


Materials needed: various rubbers or tires pieces (one for each group-you could use bike tires, tractor, truck, high performance, tourism), force sensors and computers, various masses, ramp.

If tire samples are not available a number other materials can be used. Students could remove one of their shoes, which likely have rubber soles, and use that as the test sample. A second option is to glue various rubbers or plastics, like from a bottle, plastic bag, erasers, bubble wrap, or plastic wrap to the bottom of wood block. Commercial rubber band could also be wrapped around a wood block to make a rubber surface.

Instructor Setup: The students will be collecting data through the force sensors so they will need to have the proper interface/computer program to do so. In addition they will need to have access to some type of graphing program such as Logger Pro or Graphical Analysis. The students will also need to have access to various masses so they can change the normal force on the tire.

Pre Lab question: The block below is being pulled by a string across the table. Draw a force diagram for the block if it is moving to the right at a constant velocity.



Force diagram:

Procedure: How does the normal force affect the friction of the tire?

1. Plug in your force sensor and connect your interface to collect data using the force sensor.

2. Open the logger Pro program. Go to File→ Open→Experiments→Physics with Vernier→12a Static Kinetic friction.cmbl. This is a force vs. time graph.

3. Determine the mass of your piece of tire and record it below in the data section.

4. Zero your force sensor by going to Experiment → Zero

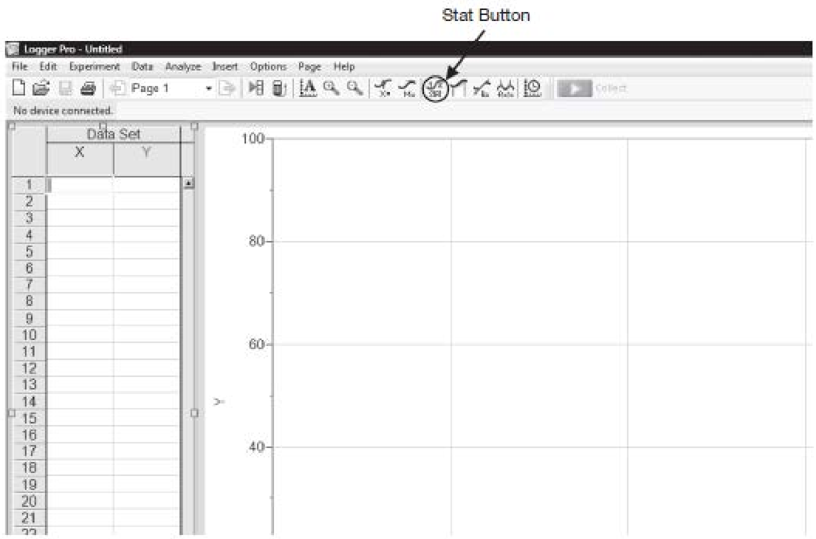
5. Attach a string to the tire and then tie the force sensor to the other end of the string. Place the tire on your ramp.

6. Hit "collect" then pull horizontally on the force sensor until the tire SLOWLY starts to move at a constant velocity. Make sure that the force sensor is absolutely horizontal when you are pulling **(don't pull at an angle!)** Make sure that you pull AT A CONSTANT SPEED - NO ACCELERATION!

7. When you pull the tire across the ramp the graph should show a gradual increase and then a peak (this is the peak static friction). Then the graph will level out to be a horizontal line (when the

block is moving with a constant velocity) this is the kinetic friction. You may have to practice this a few times until you get it correct – remember pull very gradually on the tire.

8. To determine the peak static friction you can highlight the peak area of your graph and click on the “stat” button at the top and record the maximum. Record this in column 3 in the data table.



9. To determine the kinetic friction you can highlight the horizontal line on the graph and hit the “stat” button at the top and record the mean. Record this in column 4 of the data table.

10. Now change the normal force by adding masses to the top of the tire. Record the mass that you add to the tire in column 1 of the data table. Repeat these steps for at least 6 different masses.

11. In column 2 of the data table determine the normal force exerted on the tire = (mass of the tire + mass of on top of tire) x 9.8 N/kg.

Data table:

Mass of Tire piece: _________________ kg

1 Mass used on top of tire (kg)	2 Normal Force (N) Don’t forget to include the tire!	3 Peak Static friction (N)	4 Kinetic friction (N)
0			

Analysis Questions:

1. Which friction force is greater peak static friction or kinetic friction?

2. What happens to the force of friction as the normal force increases?

3. Make a graph with the kinetic friction on the *y*-axis and the normal force on the *x*-axis (you may use Logger Pro to do your graph and sketch it below).

Kinetic
Friction (N)

Normal Force (N)

4. The slope of this line is the coefficient of static friction (μ_k) and depends on the type of surface. Using your graph determine the coefficient of static friction for your surface. Recall: the R = button will give you the slope in Logger Pro.

5. Now write an equation for your line (Recall: $y = mx + b$ where $m = \mu_k$). This equation should look familiar – it sure is a FUN one!

6. What tire in the class has the lowest value of kinetic friction? Which one has the highest?

7. If you are going to drive your car up a very steep hill which tire in the class would be the best option to ensure your safety? Why?

Practical Application Problem:

Your rubber is placed on the bottom of a block of unknown mass and is set on a hill. The hill is slowly raised up. Determine at what angle the block will start to slide down the hill? You will be using your ramp and rubber from the previous part of this lab to test your prediction.