**Friction Investigation**

Friction is a resulting force between two materials that are in contact and moving past each other, in other words, the sticking force between two objects being rubbed together. In a solar car, the wheels and axles have friction when they turn with respect to the chassis. Minimizing this friction will let the wheels spin more freely as well as faster, resulting in a faster car.

The interface between the axle and the chassis is called the "bearing". A "plain bearing" can be as simple as an axle in a hole, or it could be a bushing. A bushing is a smooth sleeve in the hole that gives the axle a low friction surface to run on. A "ball bearing" is a set of balls in the hole which are arranged so that the axle rolls on the balls instead of sliding in a sleeve. Ball bearings are found in many familiar devices such as bicycle, roller blade and skateboard wheels. Ball bearings have the least friction, but they are expensive, and more difficult to use than plain bearings and bushings. For these reasons, most Junior Solar Sprint cars use plain bearings.

**Friction Investigation #1: Friction between axles and bearings of various materials**

To choose the best materials for axles and bearings (e.g. metal axle in a wood bearing, etc.), find samples of the different materials and test the friction between them. This test will help determine at which angle a sample piece of material starts to slide. The steeper the hill, the more friction there is between the test piece and the material covering the slope. The more friction, the worse those materials are for bearings.

Materials

Plank that can be lifted at one end
Ruler
Small objects made of various materials
Lubricants: oil, graphite, etc.

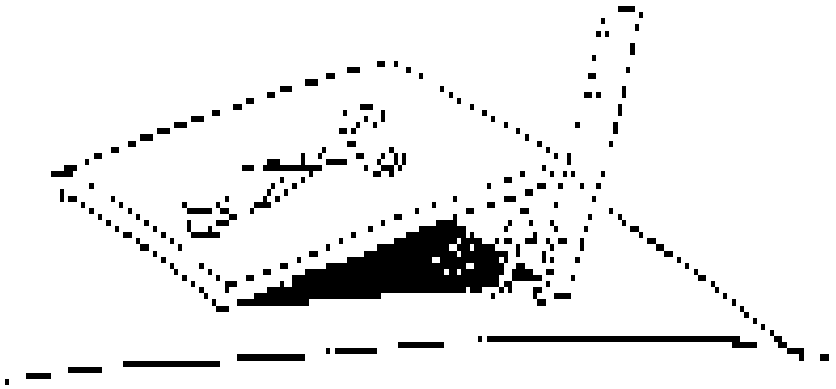
- Put an object made of the first material on a sheet of the second material.

- Then, tilt the sheet until the object starts to slide and note the angle of the sheet.

- The lower the friction, the sooner the object will start to slide and the smaller the angle will be. For example, to test metal on wood, put a piece of metal on a plank of wood and tip up the wood until the metal piece moves. Measure the height of the end of the plank so you can compare it to the next sample. One interesting feature of this test is that the weight of the object is not important. A steel paper clip will start sliding at the same angle as a heavy steel object.

- Try different lubricants and see what happens. Soap, graphite or pencil lead and oil are good to try. Which work best on which materials? Keep in mind that it can be difficult to un-lubicrate something if it doesn't work, so test a scrap piece of material using this friction test before lubricating your car if you are not sure.

Picking two materials that "run" well together will mean that less power will be used to overcome the friction and more will go towards driving the car faster.



**Friction Investigation #2: Distance of friction force from center of rotation**

In addition to the materials that are rubbing together, it makes a difference where they are rubbing. Much like a lever, the farther from the center (fulcrum or pivot) a force is, the more effect it has. It is easier to stop spinning object by grabbing the outside edge than a point near the middle. Therefore, a friction force far from the center slows a spinning object (such as a wheel) more quickly than the same force close to the center.

Materials

1 large textbook
4 similar coins

- Put the heavy, hard cover book flat on the table. Rotate it slowly back and forth and get a feel for how hard it is to turn.

- Now, put a stack of about 3 coins on the table under the center of the book and balance the book on the coins. Make sure that the corners of the book don't touch the table and try rotating the book slowly back and forth again.

- Is the flat book is harder to turn because of more surface area in contact with the table? Put a stack of coins under each corner and try the experiment again. Then move all the coins towards the center a little bit at a time and see if it gets easier as they come closer to the middle.

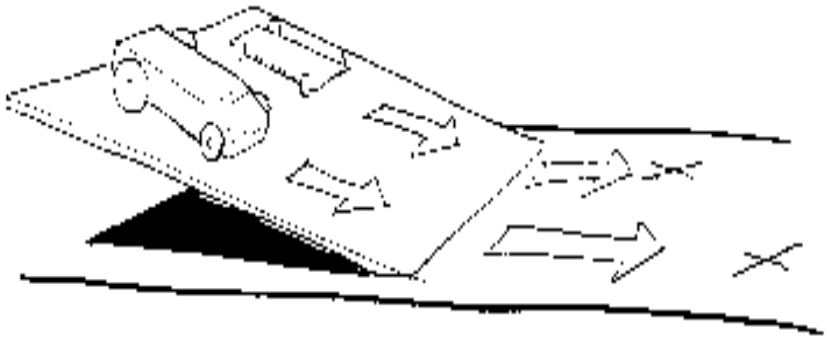
**Friction Investigation #3: Rolling resistance test**

Use the roll down test described in the "aerodynamics investigation" to find the bearing and wheel combination with the lowest rolling resistance (do not change the aerodynamics of the car during this test because that will also affect the results.) Finding the best combination is an important step in building a fast car.

Materials:

Ramp
Several prototype cars
- without motors
- built using various axle and bearing components
- approximately the same weight

- Starting from the same point on the ramp each time, let the car roll down the hill and mark the place it rolled to. Do this 3 times for each car, or until the car repeatably rolls to the same place (to make sure you are always starting the cars the same way). Did the cars travel in straight lines? Which car went further? Try improving your car with different axles or bearing materials see how different wheels, bearings, lubricants, etc. alter the final distance that the car travels.



**Some places to look for friction in your car design:**

Diameter of axle

(is smaller better? Why do “Hot Wheels” toy cars have such tiny axles and go so far?) The larger the diameter of the axle the farther away from the center they contact the bearings. Like the book dragging on the table all the way out at the corners, a large axle will be harder to turn.

Wheel alignment

If the wheels are not all pointing in the same direction, the car will tend to turn. Since the guide wire keeps it going straight, some of the wheels will have to skid sideways. This takes more energy than driving straight and will slow the car down.

Axle bearings

Choose axle and bushing materials that have low friction against each other. Surface finish is critical. Make sure all of the running surfaces are as smooth as possible.

Thrust bearings

These are whatever keeps the axle from falling out the side of the car. If the edges of the wheels rub on the body, like the book, they will have a lot of drag. If there is something around the axles that let the center portion of the wheel touch first, the drag will be lower, like the book swiveling on the coins.