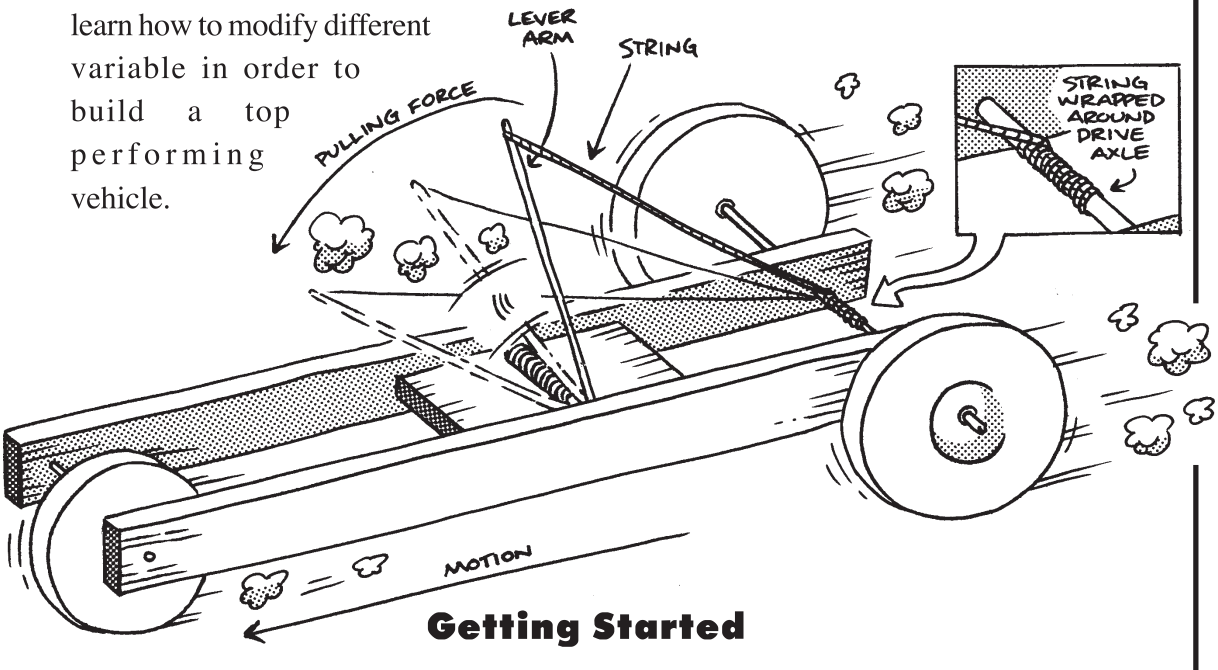
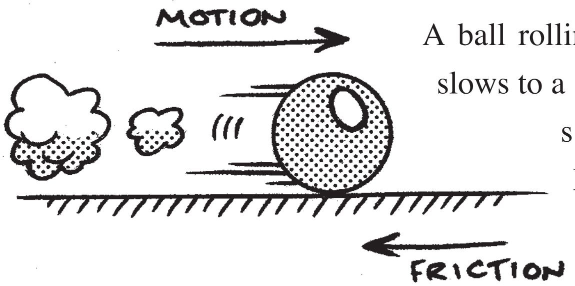
What is a Mouse-Trap Car and How does it Work?

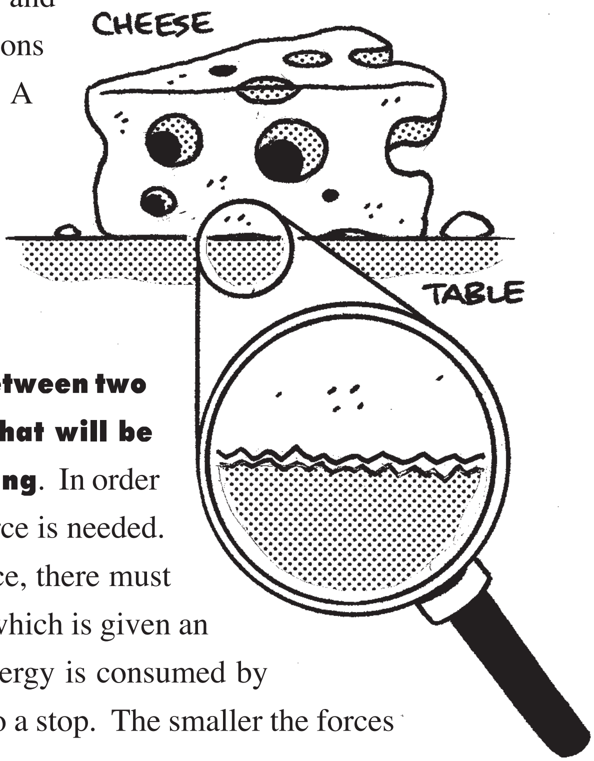
A mouse-trap car is a vehicle that is powered by the energy that can be stored in a wound up mouse-trap spring. The most basic design is as follows: a string is attached to a mouse-trap's lever arm and then the string is wound around a drive axle causing the mouse-trap's spring to be under tension. Once the mouse-trap's arm is released, the tension of the mouse-trap's arm pulls the string off the drive axle causing the drive axle and the wheels to rotate, propelling the vehicle. This most basic design can propel a vehicle several meters for any first-time builder. But in order to build vehicles that can travel over **100 meters** or extreme speed cars that can travel **5 meters in less than a second,** you must learn about some of the different variables that affect the performance of a mouse-trap car. For example, how does friction affect the overall distance that a vehicle can travel? How does the length of the mouse-trap's lever arm affect the performance? By reading each section of this book you will learn about many of the different variables that will affect a vehicle's performance. Also you will learn how to modify different variable in order to build a top performing vehicle.



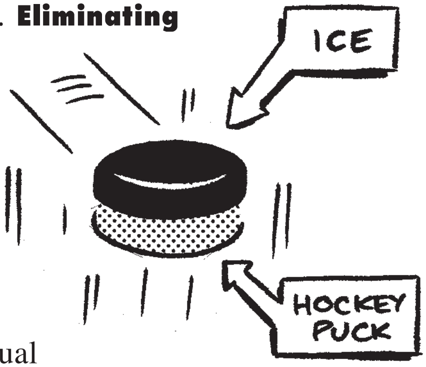
Surface Friction



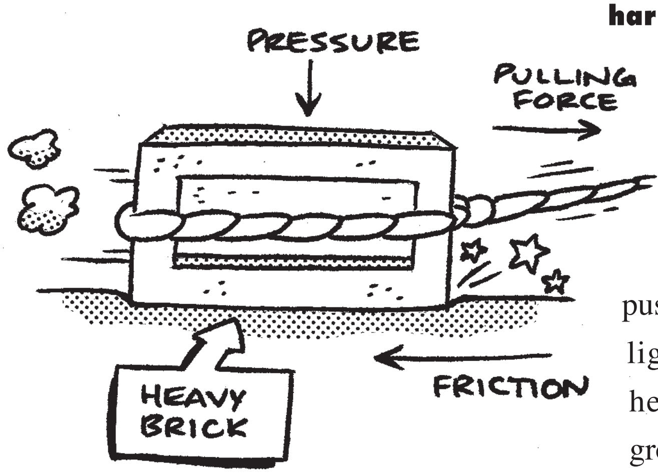
A ball rolling across the floor will eventually slows to a stop. The reason the ball slows to a stop is because of **friction**. Friction is a force that always opposes motion in a direction that is opposite to the motion of the object. An object that slides to the right experiences friction towards the left. If it was not for friction, the ball would roll forever, as long as there was nothing—like a wall—to stop its motion. Your mouse-trap car is affected by friction in the same way as the rolling ball, friction will slow it to a stop. Friction will occur anytime two surfaces slip, slide, or move against one another. There are two basic types of friction—**surface friction** and **fluid friction**. In some situations fluid friction is called air resistance. A ball falling through the air is affected by fluid friction and a block sliding on a table is mainly affected by surface friction as well as a little air resistance. **The greater the amount of friction between two surfaces, the larger the force that will be required to keep an object moving**. In order to overcome friction, a constant force is needed. In order to maintain a constant force, there must be a supply of **energy**. A ball which is given an initial push will roll until all its energy is consumed by friction, at which point it will roll to a stop. The smaller the forces



of friction acting against a moving object (like a ball or mouse-trap car), the farther it will travel on its available energy supply. **Eliminating all forms of friction is the key to success no matter what type of vehicle you are building.**



Surface friction occurs between any two surfaces that touch or rub against one another. The cause of surface friction is mutual contact of irregularities between the touching surfaces. The irregularities act as obstructions to motion. Even surfaces that appear to be very smooth are irregular when viewed microscopically. Luckily, during motion surface friction is **unaffected by the relative speed** of an object; even though the speed of an object may increase, the force of surface friction will remain constant. This means that the same force is required to slide an object at a slow or fast rate of speed on a given surface. **The amount of friction acting between two surfaces depends on the kinds of material from which the two surfaces are made and how hard the surfaces are pressed together**. Ice is more slippery than concrete; therefore, ice has less friction or less resistance to slippage. A heavier brick is harder to push and has more friction than a lighter brick only because the heavier brick pushes into the ground with more force or weight.



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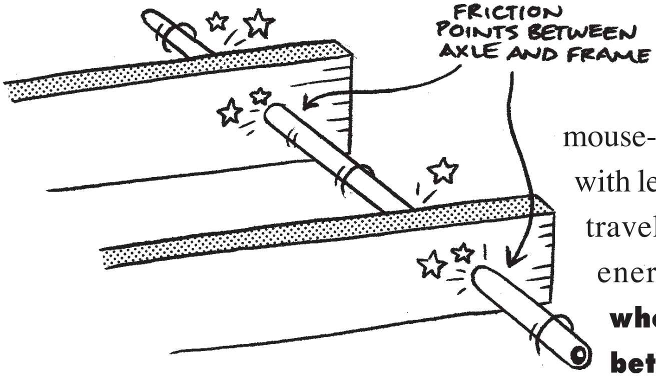
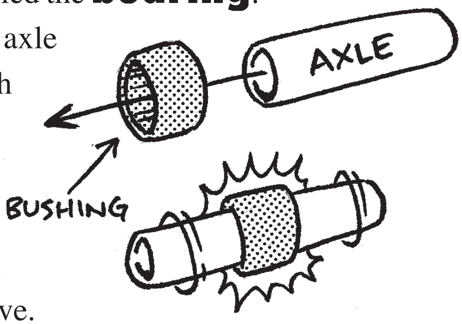
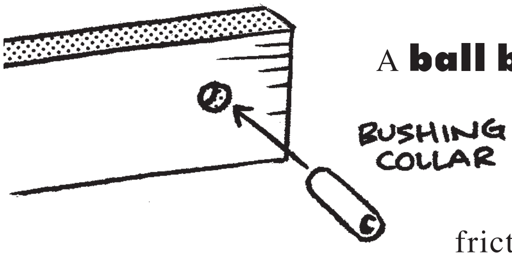


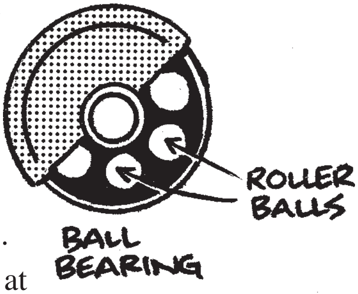
Minimizing surface friction on a mouse-trap car allows its wheels to spin with less resistance, resulting in a car that travels faster, farther and wastes less energy. **The most common area where surface friction will occur is between the axle and the chassis.**

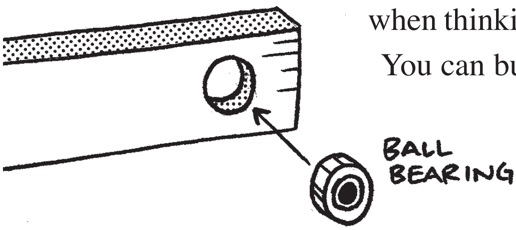
The interface between the axle and the chassis is called the **bearing**. A **plain bearing** can be as simple as an axle turning in a drilled hole. A **bushing** is a smooth sleeve placed in a hole that gives the axle a smother rubbing surface, which means less surface friction. Some combinations of material should not be used because they do not help the cause; for example, avoid using aluminum as the axle or a bearing sleeve.



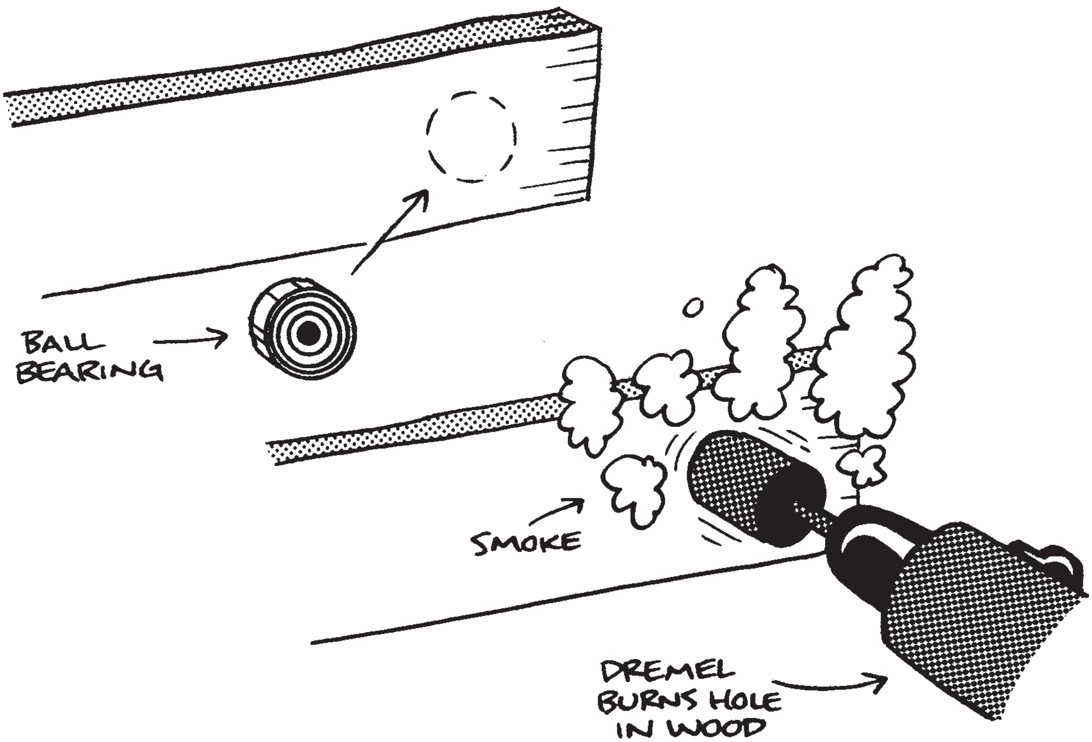


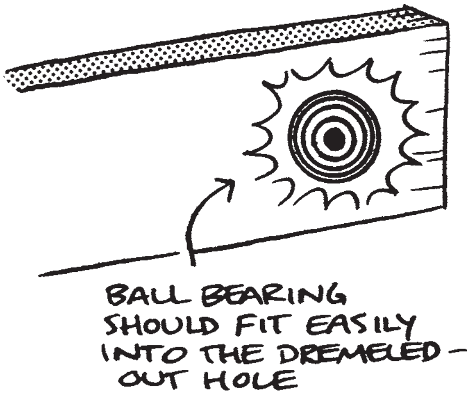
A **ball bearing** is a set of balls in the hole which is arranged so that the axle rolls on the balls instead of sliding in a sleeve. A rolling ball has very little friction; therefore, ball bearings usually provide the best performance. Ball bearings have the least friction, but they are the most expensive, so you must evaluate your budget when thinking about ball bearings. You can buy small ball bearings at a local hobby store that deals with remote-controlled vehicles.





Mounting a Ball Bearing

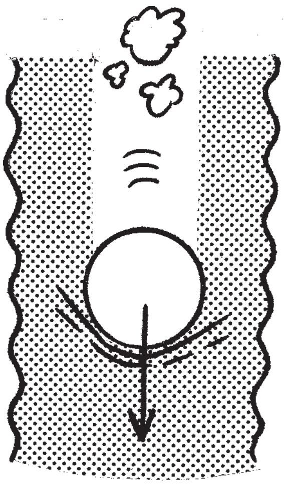




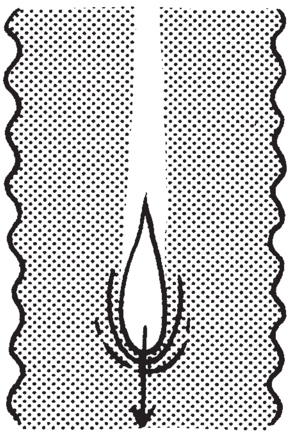
If you do not have a dremel tool, you can use a **drill** *bit that matches the size of the bearing. Be carful since large drill bits can tear up the wooden causing the wood to* **splinter**. *Wrap a piece of tape around the area to be drilled in order to help protect the wood from* **splintering**. *Try drilling a small pilot hole with a smaller drill bit first.*

Fluid Friction

Friction is not restricted to solids sliding over one another, friction also occurs in liquids and gases, collectively called **fluids**. Just as the friction between surface friction depends on the nature of the surfaces, **fluid friction** depends on the nature of the fluid. For example, friction is greater in water than it is in air. But unlike the surface friction, fluid friction **depends on speed and area of contact**. This makes sense, for the amount of fluid pushed aside by a boat or airplane depends on the size and the shape of the craft. A slow-moving boat or airplane encounters less friction than fast-moving boats or airplanes. Wide boats and airplanes must push aside more fluid than narrower crafts. If the flow of fluid is relatively smooth, the friction force is approximately proportional to the speed of the object. Above a critical speed this simple proportion breaks down as fluid flow becomes erratic and friction increases dramatically.

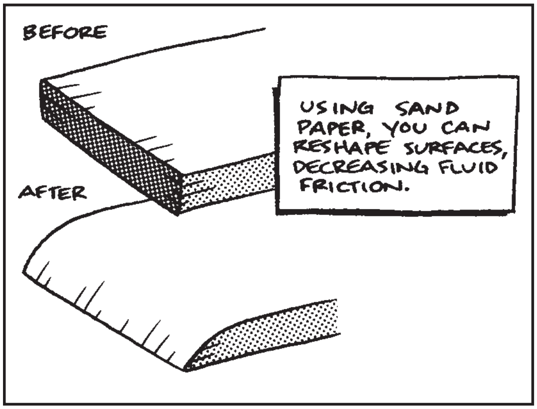


The amount of air friction or fluid friction depends on the speed and the shape of a moving object. The faster an object moves, the more collisions that occur with particles of the fluid, causing increased friction. The shape of a moving object, its **aerodynamic,** determines the **ease of flow** of the fluid around the moving object. Fast cars are designed and shaped to cut through the air with less friction so they can move faster. Trucks have a special cowling that increases their aerodynamics and allows air to flow more easily over the trailer. Increased aerodynamics saves energy. Fish have aerodynamic shapes that allow them to move through the water with less effort. Keep in mind

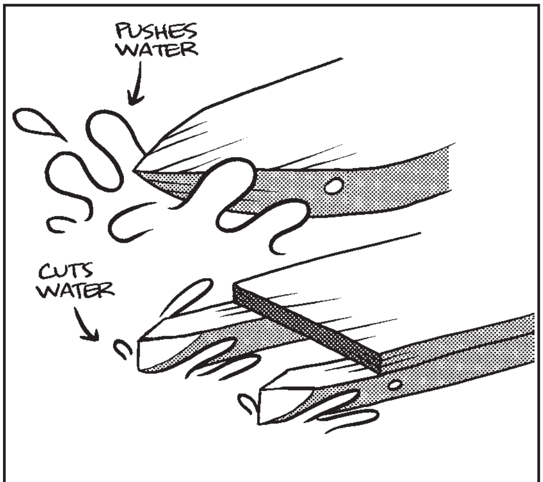


A TEAR DROP IS THE MOST AERODYNAMIC SHAPE, CUTTING THROUGH THE AIR WITH THE LEAST AMOUNT OF AIR RESISTANCE, MUCH LIKE THE WING OF AN AIRPLANE.

that there are situations in which you would want to increase the air resistance. A good example is the use of a parachute on a dragster to help it stop the vehicle or the flaps on an airplane to help slow it down.

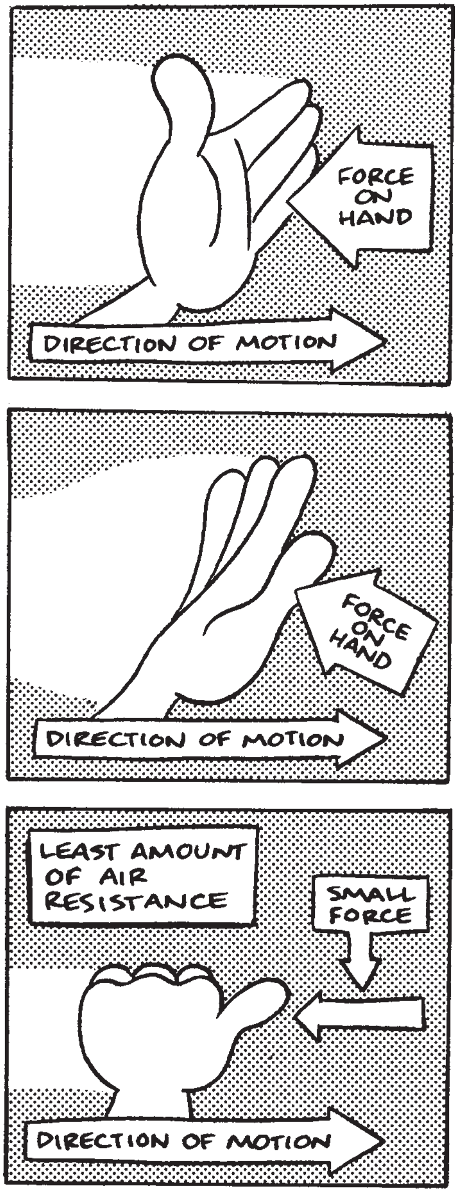


Because the force of **air resistance** increases as the speed of an object increases, faster moving mouse-trap cars will have more air resistance acting against them, causing them to use more energy and come to rest sooner than a similarly built slower-moving mouse-trap car. Keeping this in mind, good aerodynamics will improve performance of any vehicle, no matter what type of car you are building. This means that your car must be smooth with few points of **air drag**. Inspect the body for flat surfaces on leading edges that could catch air, thus increasing the air drag. Rounding the leading edges of your vehicle will allow for smoother movement of air around your vehicle. Cars made from wood need to be sanded smooth. **Sanding** will remove any unwanted irregularities, thus decreasing the force of air resistance acting on your car once it is in motion. Tires should be thin. Thin tires are more aerodynamic and slice through the air more smoothly. Wider tires will have more air drag than narrower tires. Therefore, try to pick thin tires when you are building your mouse-trap car.



The two side runners of the bottom boat reduce the surface area and the fluid friction over the top boat's big hull.

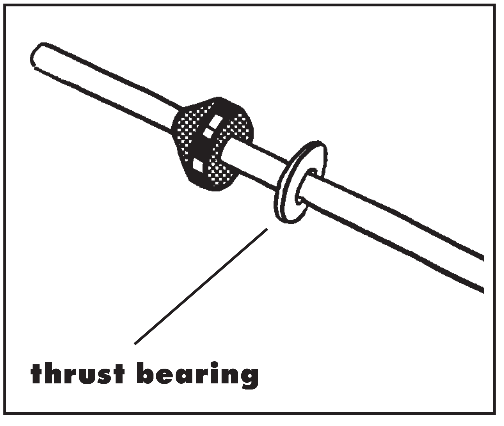
To see how much force the air can have, try the following **experiment** *next time you are in a car. Carefully hold your hand out the window. Try holding your hand so that your thumb points toward the sky and then try holding your hand so that your thumb point towards the direction of travel. You will have a better understanding of* **fluid friction** *after this experiment.*

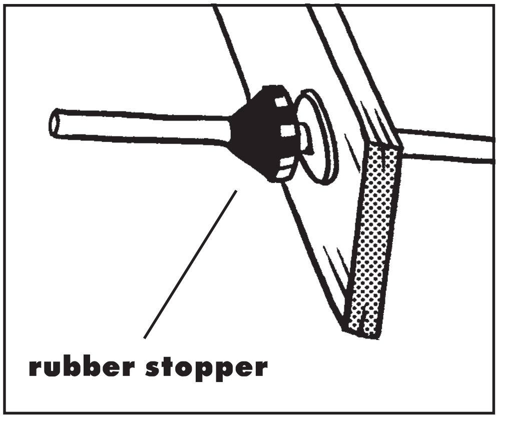


Construction Tip

Thrust Washers

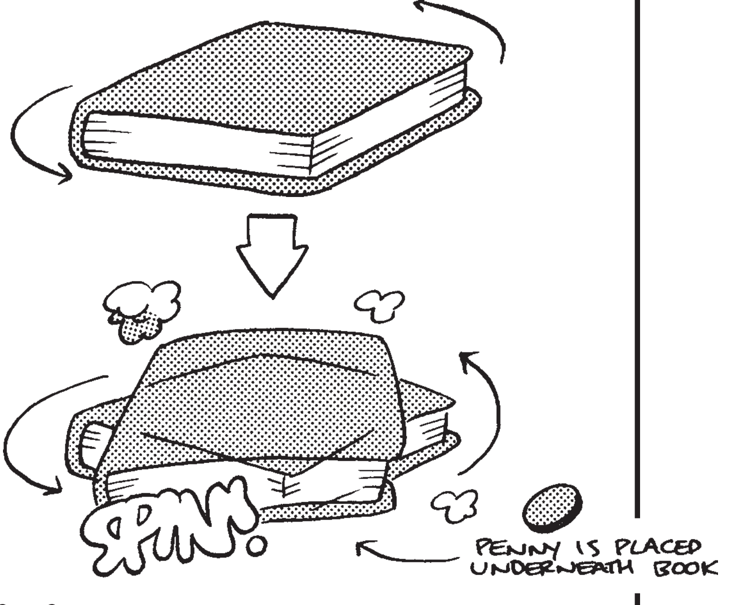
Thrust washers can be used to eliminate the rubbing friction of a wheel touching the frame. If a wheel has a side-to-side movement and touches the frame, a metal washer can be used to prevent the wheel from directly touching the frame, which will causing poor performance of your vehicle In these pictures, a rubber stopper is placed on the axle to help eliminate the side-to-side movement and then a metal washer is placed between the frame and the stopper.





Experiment

Try an experiment to learn about a **thrust bearing**. *Place a book on the table and give it a spin. The book should spin slowly and then stop quickly. Now place a coin under the book and give it a spin again. The book should spin for a considerably longer time before stopping.*



Lab #2- The Force is Against You

Purpose

To determine the amount of rolling friction acting against your mousetrap car and the coefficient of friction.

Materials

Ruler (A caliper works better for smaller measurements.)
Smooth Ramp
Tape Measure

Variables needed from other labs

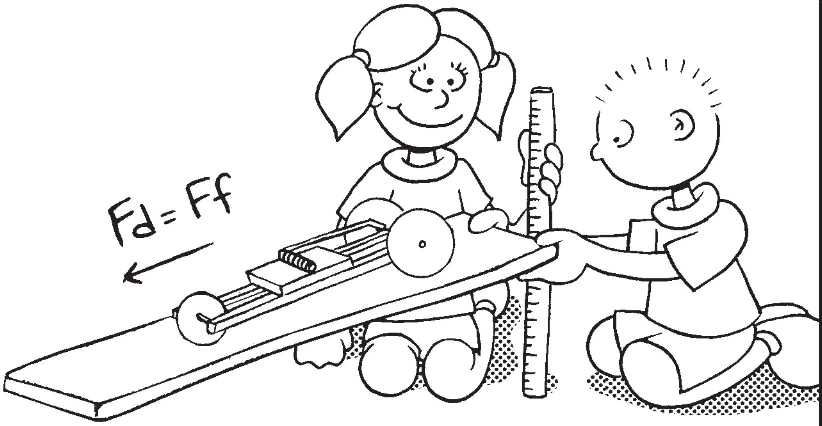
Total Potential Energy from Lab #5

Discussion

Friction is a force that acts against the motion of all moving objects. Energy is required to overcome friction and keep an object moving. Mousetrap cars start with a limited supply of energy. This energy is used to overcome friction and propel the vehicle. The less friction acting against a moving mousetrap car, the less energy that is consumed to friction and the further that the vehicle will travel. A moving mousetrap car is affected by two type of friction: airfriction and bearing friction. Airfriction is a large factor only with cars that are moving fast and is nearly negligible for slow-moving distance cars; therefore, in this lab you will only take bearing friction into consideration. Bearing friction is actually caused by two surfaces rubbing against one another. The amount of friction depends on the materials that are doing the rubbing and the force pressing them together (Formula #3). In this lab you will find the combined force of friction from all bearings on your vehicle. This combined frictional force will be called the rolling friction. The smaller the coefficient of friction, the more efficient your mousetrap car and the greater the travel distance will be.

The Set-up

Finding the theoretical rolling friction requires placing your mousetrap car on a smooth and flat board or ramp. The ramp will be elevated from one end slowly until your mousetrap car "JUST" begins to roll at constant velocity. This point or angle is where the force pulling the car down the ramp is equal to the force of rolling friction acting against the car (Formula #2). The force pulling the car down the ramp is a combination of two forces: the force of gravity pulling straight down and the normal force of the ramp pushing back (Formula #4). As the angle of the ramp is increased, the normal force decreases (Formula #5). The force of gravity remains unchanged for all angles. The difference between the two forces causes the force down the ramp to increase. The greater the angle required to move the car, the more friction there will be acting against the car's motion. The angle is directly proportional to the force of friction or the coefficient of rolling friction. **LOWER ANGLES** are more desirable (Formula #7).



How it Works:
The force pulling the vehicle down the ramp is equal to the force of friction acting against the car AS LONG as the mousetrap car moves down the ramp at a constant velocity. In some cases, once the vehicle starts to move the ramp has to be lowered in order to maintain constant velocity.

Formulas

Formula #1: $\sum F = 0$

The sum of all forces must equal "zero" if there is no acceleration.

Formula #2: Force Pulling = Force of Friction

Formula #3: $f_{rf} = \mu N$

Force of friction is equal to the coefficient of friction times the normal force

$$\sin\theta = \frac{h}{L}$$

Because your measurements are from a slope, you will have to use some trigonometry

Formula #4: $f_{rf} = \sin\theta \cdot w$

The force down an angled ramp is equal to the force of friction as long as the vehicle rolls down the ramp with a constant velocity.

Formula #5: $N = \cos\theta \cdot w$

The normal force is the force that is perpendicularto the angled ramp.

Formula #6: $\mu = \dfrac{\sin\theta \cdot w}{\cos\theta \cdot w} = \tan\theta$

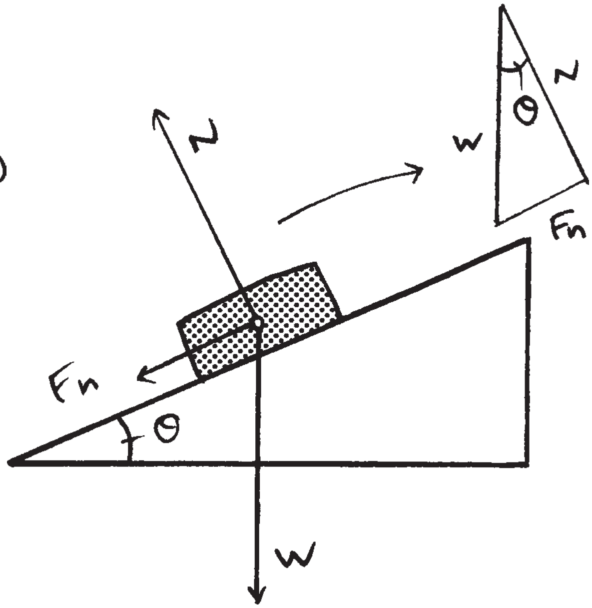
Resolving for the coefficient of friction from Formulas #3, #4 and #5

Formula #7: $\mu = \tan\theta$

The coefficient of friction

Trigonometry

Trigonometry is a fancy type of mathematics that is based on simple relationships of all right triangles. Ancient mathematicians found that all right triangles are proportional by ratios of their sides and angles. These ratios times the angle are known as sine, cosine, and tangent. Knowing one of the angles other than the right angle-and any one of the sides to the triangle-will allow you can calculate everything else you would ever need to know about that triangle's sides or angles.



How it Works

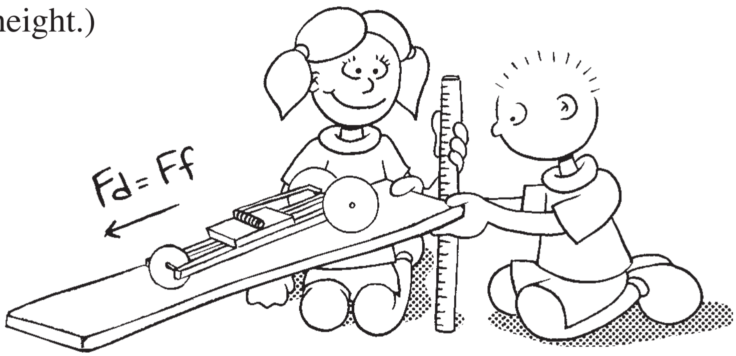
The angle of the ramp in this experiment forms a right triangle. The force due to gravity and the normal force of the ramp's surface cause a force directed down the ramp called "Force Down." These three forces form a right triangle which has the same angle as the base of the ramp. Knowing the angle of the base of the ramp and the weight of the car on the ramp, we can solve for any other force including the force acting down the ramp and which is equal to the force of friction.

Let The Good Times Roll

Step 1: Start by selecting a long and smooth board or ramp that will not bend or flex when lifted at one end. Your vehicle must fit on the ramp.

Step 2: Measure the length of the board and record this measurement as the board length (L).

Step 3: Place your vehicle on the ramp and begin lifting by one end. Slowly lift until the vehicle "JUST" begins to roll. Measure carefully and accurately the elevation of the board when the vehicle begins to roll and record this in the data table as the height (h). Repeat this process 5 to 10 times for more accurate results. (Note: You must subtract the thickness of the board from the height. Measure both ends of the ramp to correctly calculate the height.)

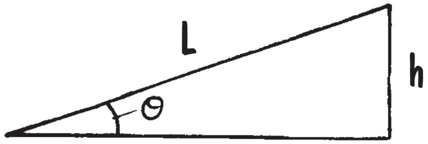


Data Table #1

Trial #	Board Length (m)	Raised Height (m)	Angle	Coefficient of Rolling Friction	Friction (N)	Starting Energy (J)	Predicted Travel Distance
1	L=	h_1=	θ_1=	μ_1=	f_1=	PE=	d_1=
2	L=	h_2=	θ_2=	μ_2=	f_2=	PE=	d_2=
3	L=	h_3=	θ_3=	μ_3=	f_3=	PE=	d_3=
4	L=	h_4=	θ_4=	μ_4=	f_4=	PE=	d_4=
AVE		h=	θ=	μ=	f=		d=

Step 4: Calculate the angle for each trial using the following equation:

$$\theta = \frac{h}{L}\sin^{-1}$$



Step 5: From the derived formula, calculate the coefficient of friction for each trial. The coefficient of friction is directly proportional to the angle of the ramp. Smaller angles translate into greater travel distance.

$$\mu = \tan\theta$$

Step 6: If this lab is performed correctly, the force of rolling friction acting against your car is equal to the force pulling the vehicle down the ramp in the elevated state. Calculate the force of friction by assuming that the force down the ramp is equal to the force of friction acting against the motion of your vehicle. Solve for the force down the ramp. MAKE SURE to use the weight of your vehicle in Newtons. If you have the mass in killograms, you can calculate the weight by multiplying the mass of your vehicle by 9.8 m/s^2 or find the weight by weighing your vehicle on a spring scale.

$$f_{rf} = \sin\theta \cdot \mathrm{w}$$

Step 7: Using the starting energy that you calculated in Lab #4 you can calculate the predicted travel distance by using the following:

$$\text{Predicted Travel Distance} = \frac{\text{Total Potential Energy}}{\text{Rolling Friction}}$$