Calculate the Coefficient of Friction Between Two Surfaces

Materials/Equipment/Supplies/Software

Pen/Pencil	Formica Desk Top	Electrical Tape
Rubber Matt	1-3 lb Spring scale	Masons Line/String
Bare Wood Board	Gears Battery	Calculator

Friction

Friction is a force that resists motion between two sliding surfaces in contact with each other. Frictional resistance is due in some part to irregularities on the surfaces in contact with each other, and in large part to the electrostatic attraction between the molecules of the substances in contact with each other.

Friction does not depend on the surface areas in contact with each other, but more importantly on the forces holding the surfaces in contact with each other.

We will investigate the causes and effects of frictional forces by participating in the following activities.

Investigating Friction

Procedure

Note: Before attempting this experiment, insulate the battery terminals with quick disconnect plugs or electrical tape.

1.) Using a scale, weigh the battery and record this value. It does not matter which system of units you choose to use. Always remember to "Stay within the system you choose". Do not mix and match systems of units.
2.) Attach a string securely to the battery.
3.) With the battery resting on a desktop, drag the battery **slowly** across the desktop.
4.) Note the pulling force just before the battery began to move. This is the force of static friction and it is usually greater than moving or kinetic friction.
5.) Note the difference in force required to keep the battery moving at a constant rate. This is the force of moving or kinetic friction and it is usually less than static frictional force.
6.) Attach the spring scale to the battery and repeat the procedure described above. Be certain to pull on the battery with the scale parallel to the direction of the pull

7.) Record the force on the scale just before the battery began to move.
8.) Record the force on the scale while the battery moved at a constant rate.

Repeat this experiment with the battery sliding over different materials and record your answers. It is perfectly proper to substitute different surfaces or use surfaces other than those specified below.

	Static Force	F_r **Kinetic Force**	F_n **Wgt. of Battery**	μ **Coefficient Friction**
Wood	________	________	________	________
Rubber	________	________	________	________
Formica	________	________	________	________
Steel	________	________	________	________
Painted Surfaces	________	________	________	________

Coefficient of Friction

The coefficient of friction (kinetic) is represented by the greek letter "Mu" μ. The coefficient of friction is found to be the quotient of the Force required to move the object F_r, and the weight of the object F_n acting perpendicular to the surfaces in contact.

$$\mu = \frac{F_r}{F_n}$$

Where:
μ = Coefficient of Friction
F_r = Force required to move the object at a steady speed
F_n = Force normal, or the perpendicular weight of an object acting on a surface

Calculate the Coefficient of Friction

Chances are the force required to start the battery moving (Static Friction) was greater than the force required to keep the battery moving (kinetic friction) at a constant rate. Both the force required to start the battery moving and the force required to keep the battery moving were likely less than the weight of the battery.

Using the formula provided, and the experimental data you recorded, calculate the coefficient of friction between the battery and the surfaces you experimented with.

Does Surface Area Affect the Coefficient of Friction?

Each side of the battery has a different surface area. Repeat the experiment using each side of the battery. Compare your results. Does the coefficient of friction change significantly with respect to the surface area tested?

Does the Weight of the Battery Affect the Coefficient of Friction

Determine to what extent weight affects the coefficient of friction. Repeat the experiment above using additional weight added to the battery. Be careful not to short the leads of the battery by crossing them with any conductive materials. Shorting a battery presents the risk of sparks, heat and fire.

Mechanical Design Applications

Determine The Tractive Force and the Coefficient of Friction of Your Robot wheels and Tires

When mobile robots move across a surface they interact with other robots or objects in their environment. The forces they can exert on their environment depend in large part on the traction they can develop. The tractive forces that allow robots to push and pull against other robots or objects in their environment in turn depend on the frictional forces between the tires and the surface the robot is on.

This experiment will describe a procedure for determining the tractive force of a robot with respect to the coefficient of friction between the tires and the playing surface.

When a Robot starts to move there is a static friction force between the tires and the surface. The friction that resists the initial start is static friction. When the robot begins moving, friction decreases and the surfaces are in relative motion. Sliding and rolling friction are the forces acting between the surfaces when they are in relative motion.

When the robot meets a particularly strong resistive force like a heavy object or another robot the wheels will likely “break traction” and begin to spin against the surface they are on. The maximum tractive forces are developed just before the wheels begin to spin. Both the maximum tractive forces created and the tractive forces created while the wheels are spinning are of particular interest to sport robot builders.

We will determine values for each condition.

The Experiment

Use a robot fabricated from the GEARS-IDS components, or any other available motorized vehicle. Place the robot on the surface you wish to operate the robot on. This experiment is very similar to the battery experiment described above.

1. Attach each end of a string or a masons line to a paper clip formed into a hook.
2. Hook one paper clip onto the robot at or very near to the center of the robot, between the two drive wheels. Be certain to attach the clip at or near the height of the axles.
3. Hook the other end to an accurate spring scale. The spring scale should have a range approximately equal to the weight of the robot.
4. Drive the robot **SLOWLY** forward several times while holding the scale parallel to the surface. Do not jerk the robot forward. This will give a false reading of tractive forces.
5. Record the maximum force registered on the scale just before the wheels begin to spin. (*Perform the experiments several times until you begin to see relatively consistent results.)*
6. Repeat the experiment by dragging the robot with the scale in a similar fashion to how you dragged the battery. Do the scale values differ markedly?
7. The maximum value recorded is the maximum tractive value of your robot.
8. Use the value above and the formula for coefficient of friction to determine the coefficient of static friction. This value is the ratio between the weight of the robot and the maximum tractive force the robot can develop. Can you redesign the robot to increase this tractive force?

$$\mu = \frac{F_r}{F_n}$$

Where:
μ = Coefficient of Friction
F_r = Force required to move the object at a steady speed
F_n = Force normal, or the perpendicular weight of an object acting on a surface

Perform the same experiment, but this time record the force registered by the scale while the wheels are spinning. This value will be used to determine the coefficient of kinetic friction. It is a good idea to search for tires that provide high static and kinetic coefficients of friction.

Frictional Factoids
As we stated earlier in this lesson, the force of friction (F_f) depends on the "normal" force (F_N) and the surface the object is in contact with.
The coefficient of friction is a constant with respect to specific materials; coefficients of friction have been calculated for all types of materials and can be researched online or in physics text books.

The implication of these frictional factoids is obvious. Tractive forces can be increased by positioning the heaviest robot components directly over the point of contact between the tires and the surface. The heaviest robot components are the battery and the motors.