"Rough Stuff"

7.1) Perform the following experiment: Rest a wooden block (or some other object, like your shoe) on a table. Attach a large spring scale to a string attached to the front of the block. Pull the scale harder and harder. Notice what happens to the scale reading while the block does not move. Notice the reading right before the block starts moving and right after. Keep the block moving but not accelerating.

a) Fill in the table that follows by constructing a force diagram for the block (the system) for these five situations.

The block sits on the table with no scale pulling it.	The spring pulls on the block, which does not start moving.	The spring pulls harder, but the block still does not move.	The spring pulls on the block, and the block is just about to start moving.	The spring pulls the block at a slow, constant velocity.

b) Describe in words how the magnitude of the force that the table's surface exerts on the block varies with the force exerted by the spring pulling on the block.

c) Compare the magnitude of the force just before the block starts moving to the magnitude when it is moving at a constant velocity. What do you observe?

d) What object is exerting this force that the surface exerted for the scenarios given above?

e) Summarize your findings for the force that the surface exerted on an object at rest and on the same object moving at a constant velocity.

7.2) Instead of the block in the previous activity, you have rectangular blocks with different surface areas and different types of surfaces on which the block slides horizontally. The force that the string exerts on the block (as measured by the spring scale reading) when the block just starts to slide is recorded in the table that follows. This force is equal in magnitude to the maximum static friction force (as we discovered in the previous activity). Examine the data in the table that follows:

Mass of the block	**Surface area**	**Quality of surfaces**	**Maximum static friction force**
1 kg	0.1 m^2	Medium smooth	3.1 N
1 kg	0.2 m^2	Medium smooth	3.0 N
1 kg	0.3 m^2	Medium smooth	3.1 N
1 kg	0.1 m^2	A little rougher	4.2 N
1 kg	0.1 m^2	Even rougher	5.1 N
1 kg	0.1 m^2	Roughest	7.0 N

7.3) Use the table below to make a graph of the maximum static friction force versus the normal force exerted by the surface on the block.

Mass of the block	**Extra downward force exerted on the 1-kg block**	**Normal force exerted by the surface on the block**	**Maximum static friction force**	**Ratio of maximum static friction force and normal force**
1.0 kg	0.0 N	9.8 N	3.0 N	0.31
1.0 kg	5.0 N	14.8 N	4.5 N	0.30
1.0 kg	10.0 N	19.8 N	6.1 N	0.31
1.0 kg	20.0 N	29.8 N	9.1 N	0.31

Design an experiment to test that the magnitude of the maximum static friction force is equal to $F_{s\ \text{surface on object}} = \mu_s N$. Describe what you will do, what data you will collect and what the predicted outcome should be if the expression is correct.

Then perform the experiment and make a judgment about the hypothesis.

7.4) Imagine that you could watch yourself walk in slow motion. Analyze your steps in terms of the friction force that the floor exerts on your foot and in terms of Newton's Second and Third Laws. In order to do this, break the step into two parts: (1) when you put the foot down to finish up the previous step, and (2) when you are pushing off the floor to start a new step. Draw force diagrams to represent your reasoning.

7.5) Brian says that the friction force is something that we should reduce in order to make the cars go faster. What friction force could he mean? Do you agree or disagree with his opinion? If you agree, how would you argue for it? If you disagree, how would you argue against it?

7.6) According to *Auto Week* magazine, a Chevrolet Blazer traveling at 60 mph (97 km/h) can stop in 48 m on a level road. Determine the coefficient of friction between the tires and the road. Do you think this is kinetic or static friction? Explain.

7.7) A 50-kg box rests on the floor. The coefficients of static and kinetic friction between the bottom of the box and the floor are 0.70 and 0.50, respectively. (a) What is the minimum force a person needs to exert on it to start the box sliding? (b) After the box starts sliding, the person continues to push it exerting the same force. What is the acceleration of the box?

7.8) A car is moving to the right increasingly faster. A leaf is on the back vertical side of the car and does not slide down. Explain how this can be.

7.9) The Ford P2000 fuel cell car has a mass of 1520-kg. While it is traveling at 20 m/s, the driver applies the brakes to stop the car on a wet surface with a 0.40 coefficient of friction. (a) How far does the car travel before stopping? (b) If a different car with the mass 1.5 times as much as the mass of the Ford P2000 is on the road traveling at the same speed and the coefficient of friction between the road and the tires is the same, what will its stopping distance be? Does the answer make sense to you?

7.10) Compare the ease of pulling a lawn mower and pushing it. In particular, in which case is the friction force that the grass exerts on the mower greater?
(a) The same. (b) Pulling is easier. (c) Pushing is easier. (d) Not enough information to answer.

Did You Know?

The friction force is a resistive force exerted by the surface on an object. There are two kinds of friction forces you observed in the experiments above. The **static friction force** is variable. As you saw, once the **maximum** static friction force is overcome, the object will start to move. The **kinetic friction force** is the resistive force exerted on a moving object.

When two objects touch each other, they exert a normal force on each other. In physics it is customary to break the force that each exerts on the other into two forces – a force perpendicular to the surfaces and the force parallel to the surfaces.

Normal force: This is the perpendicular component of the total force that one object exerts on the other object. it points *perpendicular* to the surface of contact. Often one symbol N is used to denote this force (do not confuse with the Newton, N). There is no equation for calculating the normal force. Its magnitude must be determined for each situation by some other method.

Static friction force: The parallel component of the force that two objects exert on each other is called a friction force. The friction force of the one object on the other object points *parallel* to the surfaces of contact. If the objects are not moving with respect to each other, the friction force that they exert on each other is *static*. The static friction force between two surfaces opposes the tendency of one surface to move across the other and provides flexible resistance (as much as is needed) to prevent motion—up to some maximum value. This maximum static friction force depends on the relative roughness of the surfaces (on the coefficient of static friction μ_s between the surfaces) and on the magnitude of the normal force N between the surfaces. The magnitude of the static friction force is always less than or equal to the product of these two quantities:

$$F_{s\ \text{surface on object}} = \mu_s N$$

Kinetic friction force: The kinetic friction force between two surfaces is exerted parallel to the surfaces and opposes the motion of one surface relative to the other surface. The kinetic friction force depends on the relative roughness of the surfaces (on the coefficient of kinetic friction μ_k) and on the magnitude of the normal force N between the surfaces:

$$F_{k\ \text{surface on object}} = \mu_k N$$