Workshop Tutorials for Introductory Physics
MI5: **Newton's Laws II – Frictional Forces**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
resistance, lumpy, constant, atoms, normal, experimentally, lubricants, static, reforming, kinetic, maximum, coefficients, feet

Friction

When you're driving a car at _____ speed all the petrol or gas you're burning is being used just to overcome frictional forces, such as air _____ and friction in the moving parts of the car. Friction is due to the interaction between _____ on the surfaces of materials. Even what looks like a very smooth surface, such as glass or polished metal, is actually very _____ on a microscopic scale.

When you first try to slide one surface across another you have to break many bonds. The force which prevents the surfaces sliding is the _____ frictional force, f_s. As the surfaces slide past each other there is a continuous tearing and _____ of bonds as chance contacts are made. The _____ friction, f_k, is the sum of the forces due to these contacts. Sometimes the surfaces briefly stick together then slip, giving a jerky motion, which can produce squeaking or squealing.

Consider a block sitting on a surface. The _____ magnitude of f_s is $f_{smax} = \mu_s N$, where N is the _____ force. The direction of f_s is always parallel to the surface and opposite to the component of applied force parallel to the surface. Once the block starts to move the frictional force decreases to the kinetic frictional force, which is given by $f_k = \mu_k N$. The constants μ_s and μ_k are called the _____ of friction and are determined _____. They depend on the properties of the two surfaces, and we usually assume that they don't depend on the speed of the sliding. In contrast, air resistance does depend on the velocity of the moving object.

Around 20% of the petrol used by a car is used just to overcome friction in the moving parts, and oil companies spend a fortune developing new and better _____. But friction is also necessary to drive the car at all. If there was no friction between the tyres and the road the wheels would spin on the spot and the car wouldn't go anywhere. And you wouldn't be able to go for help without friction, because you couldn't walk if there was no friction between your _____ and the ground.

Discussion questions
If air resistance didn't increase with increasing speed, would sky divers ever reach a terminal velocity? Hint: draw force diagrams at less then terminal velocity and at terminal velocity.
In a game of tug of war, what is it that limits your ability to pull your opponents across the line?

B. Activity Questions:

1. Shoes
Examine the shoes on display.
When would you use these types of shoe?
Why do they have different soles?

2. Boxes on a Trolley
Several boxes of the same size, shape and material are packed so that they have different weights. These are placed on a stationary trolley.
If the trolley is accelerated, which box, if any, do you expect to slip off the trolley first? Why?
Do the masses of the boxes affect the falling and slipping in the situations described above?

3. Block on a rough variable ramp

For a particular angle, is the force needed to keep a block stationary on the ramp larger, smaller or the same for a rough surfaced ramp in comparison to a smooth surfaced ramp. Why?

Draw a free body diagram for the block.

Adjust the angle of inclination and note when the box begins to slide.

How will this angle be different for a smooth ramp?

C. Qualitative Questions:

1. A passenger sitting in the rear of a bus claims that he was injured when the driver slammed on the brakes causing a suitcase to come flying toward the passenger from the front of the bus.

Can this occur when the bus is initially travelling forwards?

What if the bus is travelling backwards?

2. A box is placed on the back of a truck and the truck drives away (forwards). The coefficient of friction between the surface of the truck and the box is μ.

a. Draw a sketch showing the box on the truck.
Add each piece of information, from the questions below, to your sketch.
b. What is the direction of motion of the box relative to the ground?
c. Under what circumstances will the box not move away with the truck?
d. Identify each force, including frictional force, acting on the box.
e. What is the direction of the net force acting on the box?
f. What is the direction of acceleration of the box?
g. What force causes the acceleration of the box?

D. Quantitative Question.

A box is placed on the back of a truck. The coefficient of static friction between the surface of the truck's tray and the box is μ_S.

a. What is the maximum acceleration of the truck before the box starts to slide? You will need to draw a free-body diagram.

The truck is moving at 10 m.s^{-1} when it hits a tree and suddenly comes to a halt. The box slides 1.2 m before stopping.

b. What is the coefficient of kinetic friction between the box and the tray of the truck?