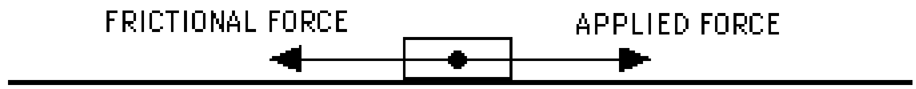
FRICTION

PROBLEM PRESENTATION / EXPLORATION

A. Frictional force is a force acting in the opposite direction of an object's motion. If the object is at rest, the frictional force (static friction) is equal to the force it takes to just get the object moving. If the object is in motion, the frictional force (sliding friction) is the force it takes to keep the block moving at constant velocity (this means that the acceleration is zero.)



1. At least four different blocks should be provided at each station. Two of the blocks must be of the same kind, only differing in weight. The other blocks can be of the same or different types of wood.
2. Weigh each of the wooden blocks by suspending them, individually, from a spring balance.
3. Attach a spring balance to each of the different wooden blocks and pull it horizontally over the table top. Determine the amount of force to overcome a block's inertia and start it moving. This is the static frictional force.
4. Attach a spring balance to a each of the wooden blocks and determine the amount of force needed to keep each block moving at a constant velocity. This is the sliding frictional force.
5. **Is there any relationship between the weight of the block and the frictional force for the same type of wood?**

BLOCK #	FORCE TO GET GOING	FORCE AT CONSTANT VELOCITY	WEIGHT OF BLOCK	μ_{static}	$\mu_{sliding}$
Example	100 N	30 N	200 N	0.5	0.15

CLASS RESPONSE / CONCEPT INVENTION

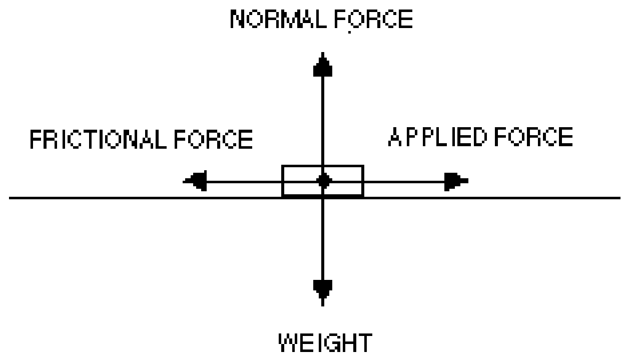
A. A ratio between the frictional force and a force equal to the weight produces a relationship known as the coefficient of friction. In its simplest form:

$$\frac{\text{Frictional Force}}{\text{Weight}} = \mu \quad \text{or} \quad \text{Frictional Force} = \mu\,(\text{Weight}).$$

But really

$$\frac{\text{Frictional Force}}{\text{Weight}} = \mu \quad \text{or} \quad \text{Frictional Force} = \mu\,(\text{Weight}).$$

The normal force is the perpendicular force with which the supporting surface pushes on the sliding object. The magnitude of this normal force, F_N and the weight, F_W, is the same but the direction is 180° different. Note also that these two equal but opposite forces are on different objects. F_W pushes down on the table; F_N pushes up on the block. These are an example of the two opposite but equal forces discussed in Newton's Third Law of Motion.

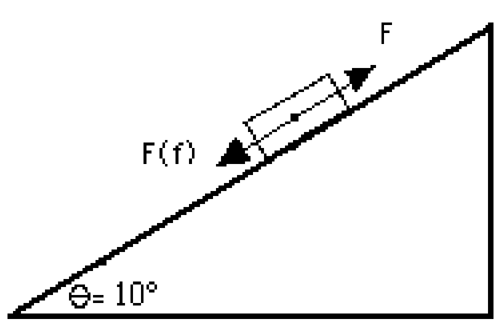


1. Within the experimental fluctuations of the spring balances, this ratio (μ) should remain constant no matter what the weight is for the same type of wood. The reason is that as the downward weight becomes larger the frictional force proportionately becomes larger too. This ratio, therefore, does not change to any large degree with respect to weight.
2. Both the coefficient of static friction, μ_{static}, and the coefficient of sliding friction, $\mu_{sliding}$, remain relatively constant as the weight increases. The two constants do not equal each other, however.

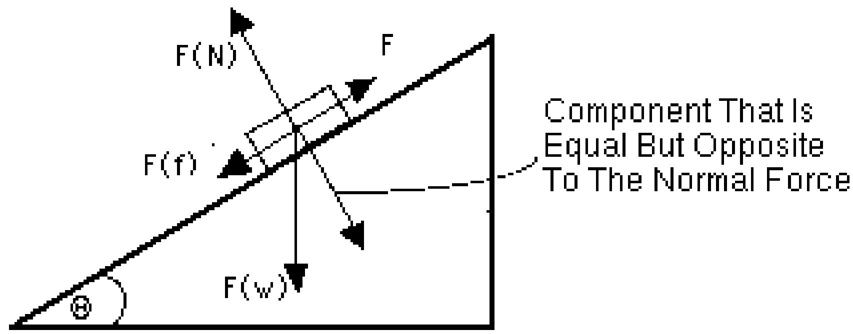
B. Will the surface area of the block in contact with the table top or floor affect the coefficient of friction?
1. Take each block and systematically turn it so that different sides come in contact with the table top (this allows a different amount of surface area to come in contact with the table but does not change the weight). Determine how much force it takes to keep the block moving at constant velocity for each of the three sides.
2. What is the relationship between the frictional force and the amount of surface area in contact with the table top? [They are independent of each other. There are some students who will not be convinced right away about this. Let them try to find examples that refute this. As we saw in the acceleration experiments where we found that the acceleration of a ball rolling down a ramp is independent of its mass, some students hand on to old but incorrect intuitive ideas for a long time.]
3. What is the relationship between the coefficient of friction and the amount of surface area in contact with the table top? [They are independent of each other.]

CONCEPT EXTENSION

A. Place the blocks on an inclined plane ($\angle = 10^{\circ}$).
1. Attach the spring balance to each block. Predict whether the frictional force will be larger than, smaller than, or equal to the frictional force when the same block was being pulled on the horizontal table top.
2. Pull the block up the plane maintaining constant velocity and read the amount of force required.
3. Remember friction always acts in a direction opposite to the motion. Therefore, the frictional force is the equal and opposite force directed down the plane to the force pulling the block up the plane.



4. The force of the surface pushing upon the object is equal to the entire weight of the object only when the supporting surface is horizontal. When the object is on an incline, this force is less than the object's weight. Because of our definition of μ we see that the force of friction, F_f, depends on μ and this normal force. (If we broke F_W into its two components, we would see that F_N = the Y component of the object's weight. From basic geometry we can see that this component must be less than F_W.



$$\frac{\text{Frictional Force}}{\text{Weight}} = \mu \quad \text{or} \quad \text{Frictional Force} = \mu \text{ (Normal Force).}$$

5. Because the frictional force decreases on an inclined plane and the normal force also decreases in the same proportion, the coefficient of friction on the inclined plane is the same as on the horizontal table.

B. What do you think would happen to the frictional force and the coefficient of friction if the angle of the inclined plane increased? [The frictional force will decrease (but the normal force will also decrease in the same proportion), and the coefficient of friction will remain constant.]

1. What would happen if the angle became 90° ? [F_N = 0 ; F_f = 0 ; the object is no longer sliding down the table but is in free-fall.)
2. What will happen if the mass of the block is increased:
   a. to the frictional force? [Increase]
   b. to the μ ? [Remain the same]
   c. to the normal force ? [Increase]