

Name: \_\_\_\_\_

Period: \_\_\_\_\_

# Surface Friction



**Friction ( $F_f$ )** - Friction opposes motion. If you are moving left, friction tries to stop you by pulling right and vice versa. We will be studying only the two types of surface friction.

### Increasing Surface Friction

If you wanted to increase the friction on an object you could either put the object on a rougher surface or push down on the object, grinding it into the surface.

$\mu$  (pronounced "me-oo") is the coefficient of friction. Rougher surfaces have higher  $\mu$ 's.

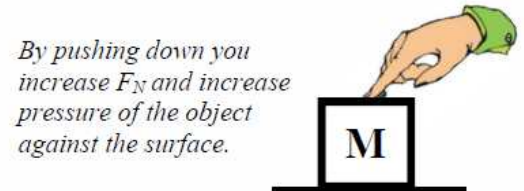
The greater  $F_N$  is, the more the object is being ground into the surface, causing more friction.



Ice has a very low coefficient of static friction of 0.1, so you slip easily.



Rubber on concrete has a high coefficient of friction of 1.0, so tires grip well.



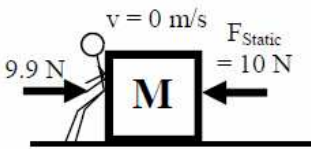
By pushing down you increase  $F_N$  and increase pressure of the object against the surface.

### Static Friction ( $F_s$ )

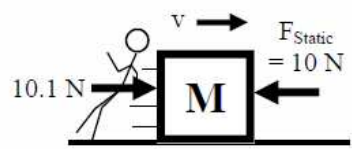
Static friction is gripping friction.  $F_s$  tries to keep an object sticking to a surface. You must apply a force just greater than  $F_s$  to start the object sliding.

### Kinetic Friction ( $F_k$ )

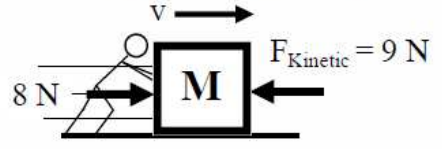
Kinetic friction is slipping friction.  $F_k$  tries to stop an object from slipping, to make it stop. Kinetic friction is usually less than static friction.



Since  $9.9\text{ N} < 10\text{ N}$ ,  $M$  won't slide.



Since  $10.1\text{ N} > 10\text{ N}$ ,  $M$  breaks free and starts to slide.



$8\text{ N} < 9\text{ N}$ , so  $M$  will slow down and eventually stop.

Use  $F_s$  to decide if the object slides.

If  $F > F_s$  it starts to slide.  
If  $F < F_s$  it doesn't slide.

Remember:  $F_s$  never causes an object to start sliding on its own.



Use  $F_k$  to calculate acceleration, since an object must be moving to be accelerating.

If  $F > F_k$  it keeps sliding and accelerates.  
If  $F < F_k$  it will slow down and stop.  
If  $F = F_k$  it will stay moving at constant speed.

Static Friction (in N)      Normal Force (in N)

$$F_s \leq \mu_s F_N$$

Coefficient of static friction (no units)

Kinetic Friction (in N)      Normal Force (in N)

$$F_k = \mu_k F_N$$

Coefficient of kinetic friction (no units)

Example: Calculate static and kinetic friction for a 4 kg mass sitting on a table where  $\mu_s = 0.45$  and  $\mu_k = 0.25$ .

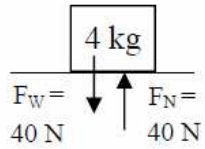
$\mu_s = 0.45$      $\mu_k = 0.25$     4 kg

Solution:

**Step 1) Calculate Normal Force**  
(see "Normal Force" notes)

Since  $a_y = 0\text{ m/s}^2$  and there are no other vertical forces, the normal force equals the weight of the object.

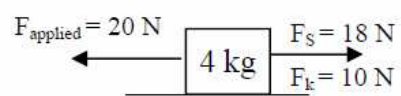
$F_N = F_W = 4(10) = 40\text{ N}$



**Step 2) Calculate Static and Kinetic Friction**

$F_s = \mu_s F_N$	$F_k = \mu_k F_N$
$F_s = 0.45(40)$	$F_k = 0.25(40)$
$F_s = 18\text{ N}$	$F_k = 10\text{ N}$

It takes 18 N to start  $M$  sliding.      It takes 10 N to keep  $M$  sliding.



$\Sigma F = ma$        $-10 = 4a$       Use  $F_k$  because it is slipping when it accelerates.  
 $-20 + 10 = 4a$        $a = -2.5\text{ m/s}^2$

1. Static ( $F_s$ ) or Kinetic ( $F_k$ ) Friction?

- |  |   |
|--|---|
| <input type="checkbox"/> Tries to stop an object when it's moving.     | <input type="checkbox"/> On a playground slide.   |
| <input type="checkbox"/> How much force to keep an object sliding.     | <input type="checkbox"/> Sliding friction.        |
| <input type="checkbox"/> Slows down a sliding object.                  | <input type="checkbox"/> Car tires normally.      |
| <input type="checkbox"/> How much it takes to start an object sliding. | <input type="checkbox"/> Is greater.              |
| <input type="checkbox"/> Car tires when they "spin out".               | <input type="checkbox"/> Gripping friction        |
| <input type="checkbox"/> Requires $F_N$ to calculate.                  | <input type="checkbox"/> Calculate with $\mu_s$ . |
| <input type="checkbox"/> Calculate with $\mu_k$ .                      |   |

2. More or less friction?

- A.  On a rougher surface.  
 B.  If  $F_N$  increases.  
 C.  If the surface is smoother.  
 D.  If  $\mu$  is less.  
 E.  If the object has more mass.  
 F.  If you push down on the object.  
 G.  If you pull up on the object.  
 H.  If  $\mu$  increases.



3. An object is moving to the left. Which way does friction act?

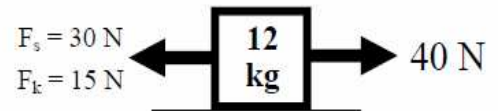
4. A force is pulling on an object to the left. Draw an arrow showing the direction of static friction.



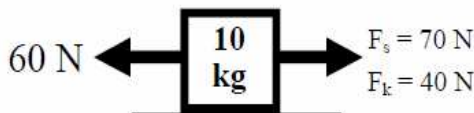
5. If  $F_N = 50 \text{ N}$  and  $\mu_s = .26$ , find the force of static friction.

6. If  $F_N = 25 \text{ N}$  and  $\mu_k = .13$ , calculate kinetic friction.

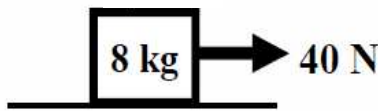
7. A. How much force is necessary to start the 12 kg object moving?  
 B. How much force is necessary to keep it moving?  
 C. If it starts at rest, will it start sliding?  
 D. Calculate the acceleration of the object.



8. A. Does the object start sliding?  
 B. If not, how much extra force is necessary?  
 C. If it is moving calculate the acceleration of the object?



$\mu_s = .4$   $\mu_k = .25$



9. A. Calculate the normal force on the object.  
 B. Calculate both static and kinetic friction.  
 C. Does the object start moving?  
 D. Calculate the acceleration if it is moving.

$\mu_s = .6$   $\mu_k = .3$



10. A. Calculate  $F_N$ .  
 B. Using  $F_N$ , calculate  $F_s$  and  $F_k$ .  
 C. Will the object slide?  
 D. Calculate the acceleration of the object if it does slide.