


Slide 1

**Friction**  
A true Slow Force

Slide 2

**Friction opposing Motion**

- Friction is generated by macro and microscopic irregularities in the surfaces of two objects in contact.

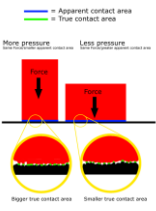


A microscopic view showing two surfaces in contact. The top surface is grey and the bottom surface is light blue. The contact interface is highly irregular and jagged, illustrating the microscopic roughness that causes friction.

Slide 3

**Friction**

- Dependent on
  - the surfaces in contact
  - Additional applied forces
- Not dependent on:
  - Surface area
  - Mass of the object
- Defined by the coefficient of friction,  $\mu$



The diagram illustrates the relationship between pressure and contact area. It shows two red rectangular blocks on a horizontal surface. The left block is taller and narrower, labeled 'More pressure' with a downward arrow. The right block is shorter and wider, labeled 'Less pressure' with a downward arrow. Below each block, a circular cross-section shows the contact area. The left block has a larger, more irregular contact area labeled 'Bigger true contact area', while the right block has a smaller, more regular contact area labeled 'Smaller true contact area'. A legend at the top indicates that a blue line represents 'Apparent contact area' and a green line represents 'True contact area'.

Slide 4

### Frictional Force

- Two basic types of Friction
  - Static
  - Kinetic
- In general it takes more force to get an object to move than to keep it moving.
- This means that the coefficient of static friction,  $\mu_s$ , is larger than the coefficient of kinetic friction,  $\mu_k$ , for most surfaces.

Slide 5

### Frictional Force

- Equation:
 
$$F_f = \mu F_N$$
- Normal force is found by finding the net vertical force.

Slide 6

### Frictional Force

If the coefficient of static friction is 0.4, what is the frictional force on the box?

$$\Sigma F_x = 0$$

$$F_{gc} - F_{static} = 0$$

$$N - (W + V) = 0$$

$$N = W + V$$

$$N = mg + 200 \sin 60$$

$$N = 22 (9.8) + 200 (.866)$$

$$N = 215.6 + 173.2 = 388.8 \text{ N}$$

$$F_f = \mu F_N$$

$$F_f = 0.4 (388.8) = 155.52 \text{ N}$$

Slide 7

### Friction Problem

- A 36 kg box is pushed by an outside force. There is a coefficient of static friction,  $\mu_s$ , of 0.3 between the box and the floor and a coefficient of kinetic friction,  $\mu_k$ , of 0.25. What is the minimum force required to get the box to begin moving and to keep it moving at a constant speed?

$\Sigma F_y = 0$   
 $F_{g^y} - F_{\text{floor}} = 0$   
 $N - W = 0$   
 $N = W$   
 $N = mg$   
 $N = 36(9.8) = 352.8$

$\Sigma F_x = 0$   
 $F_{g^x} - F_{\text{floor}} = 0$   
 $F - F_f = 0$   
 $F = F_f = \mu N$   
 $F_s = 0.3(352.8) = 106 \text{ N}$   
 $F_k = 0.25(352.8) = 88 \text{ N}$

Slide 8

### Friction Problem

- A force of 300 N causes a 50 kg box to start to move, but a 250 N force keeps the box moving at a constant speed. What is the coefficients of static and kinetic friction between the box and the floor?

$\Sigma F_y = 0$   
 $F_{g^y} - F_{\text{floor}} = 0$   
 $N - W = 0$   
 $N = W$   
 $N = mg$   
 $N = 50(9.8) = 490$

$\Sigma F_x = 0$   
 $F_{g^x} - F_{\text{floor}} = 0$   
 $F - F_f = 0$   
 $F = F_f = \mu N$   
 $300 = \mu_s(490)$   
 $\mu_s = 300/490 = 0.61$   
 $250 = \mu_k(490)$   
 $\mu_k = 250/490 = 0.51$

Slide 9

### Coefficient of Friction

- Calculated by:

Right triangle

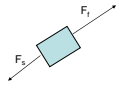
$\Sigma F_{\text{incline}} = 0$   
 $F_{g^x} - F_{\text{floor}} = 0$   
 $F_s - F_f = 0$   
 $F_s = F_f$   
 $mg \sin \theta = \mu mg \cos \theta$   
 $\sin \theta = \mu \cos \theta$   
 $\mu = \sin \theta / \cos \theta = \tan \theta$

$N = W \cos \theta = mg \cos \theta$   
 $F_s = W \sin \theta = mg \sin \theta$

Slide 10

### Friction on an Incline

- A 45 kg box is sitting on a 30 degree incline. What is the coefficient of static friction between the box and the incline? If the coefficient of kinetic friction is 80% of the coefficient of static friction, how much mass must be removed from the box in order to begin sliding down the ramp at a constant speed? With what acceleration would the box slide down the ramp?



$\Sigma F_{\text{incline}} = 0$	$\mu_s = 0.8 (0.58) = 0.46$
$F_{g\parallel} - F_{s\text{static}} = 0$	$\Sigma F_{\text{incline}} = ma$
$F_s - F_g = 0$	$F_{g\parallel} - F_{s\text{static}} = ma$
$F_s = F_g$	$F_s - F_g = ma$
$mg \sin \theta = \mu mg \cos \theta$	$mg \sin \theta - \mu mg \cos \theta = ma$
$\sin \theta = \mu \cos \theta$	$g \sin 30 - \mu g \cos 30 = a$
$\mu = \sin \theta / \cos \theta$	$9.8 (.5) - .46(9.8) = a$
$\mu = \tan 30 = 0.58$	$4.9 - 3.92 = a$
	$0.98 \text{ m/s}^2 = a$