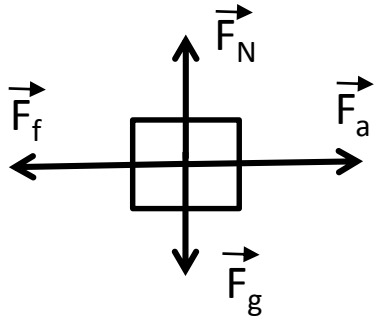
Friction

- Friction: A force that resists the motion of an object across a surface.



- Factors That Affect Friction:
  1. The Normal Force applied by the surface on the object.
  2. The types of materials in contact.

Note: Factors such as surface area and shape do not affect the force of friction.

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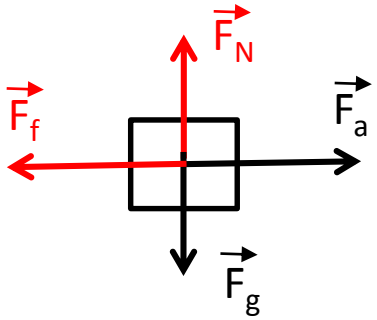

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  1. The Normal Force applied by the surface on the object.
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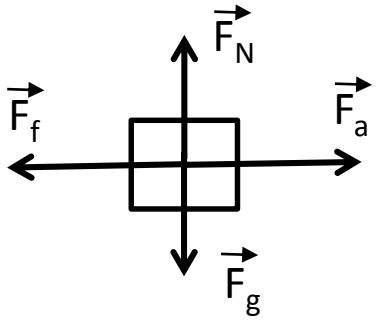
Coefficient of Friction

- μ is the Coefficient of Friction

$$F_f = \mu F_N$$



- The Coefficient of Friction is a physical property of the two materials in contact
  - Each combination of materials has a different value of μ
  - The value of μ is determined by experiment

Coefficient of Friction

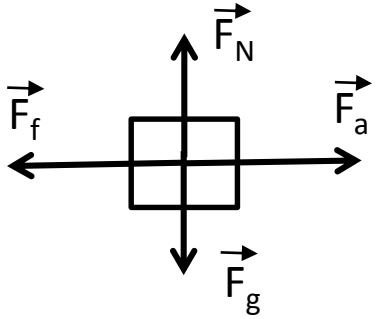
Table: Coefficients of Friction

Materials	Coefficient of Static Friction μ_s	Coefficient of Kinetic Friction μ_k
Steel on greased steel	0.15	0.09
Steel on dry steel	0.41	0.38
Oak on oak	0.50	0.30
Rubber on dry asphalt	1.20	0.80
Rubber on wet asphalt	0.60	0.50
Rubber on dry concrete	1.00	0.70
Rubber on wet concrete	0.70	0.50
Rubber on ice	0.006	0.005
Teflon on Teflon	0.04	0.04
Waxed hickory skis on dry snow	0.06	0.04
Waxed hickory skis on wet snow	0.20	0.14

Kinetic Friction

- Kinetic Friction: A force of friction that resists the motion of an object while the object is moving.

- μ_k is the Coefficient of Kinetic Friction



$$F_K = \mu_K F_N$$

- If force of friction (F_f) equals F_K as long as the object is moving.
- F_K does not depend on the applied force (F_a)
- F_K and F_S cannot be acting at the same time
- μ_k and μ_s are usually different for the same combination of materials

Kinetic Friction – Sample Problem

1. A motorcycle and rider have a mass of 230 kg. Calculate the force of kinetic friction between the rubber tires of the motorcycle and dry concrete when the cycle skids with both wheels locked.

a) Find the normal force (F_N)

b) Determine if it is static or kinetic fiction

c) Look up the coefficient of friction (μ)

d) Use: $F_f = \mu F_N$

Kinetic Friction – Sample Problem

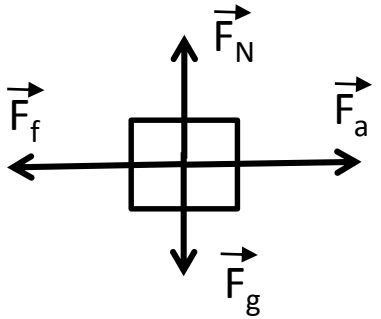
1. A motorcycle and rider have a mass of 230 kg. Calculate the force of kinetic friction between the rubber tires of the motorcycle and dry concrete when the cycle skids with both wheels locked.

a) Find the normal force (F_N)
   - $F_N = mg$ $F_N = (230)(9.81) = 2260$ N
b) Determine if it is static or kinetic fiction
   - Kinetic (*** Note: *Skidding* tires are *kinetic*)
c) Look up the coefficient of friction (μ)
   - $\mu = 0.70$ (Rubber on Dry Concrete)
d) Use: $F_f = \mu F_N$
   - $F_f = (0.70)(2260) = 1580$ N

Static Friction

- Static Friction: A force of friction that prevents an object at rest from starting to move.

- μ_s is the Coefficient of Static Friction



$$F_S(max) = \mu_s F_N$$

- If the applied force (F_a) is *equal or less* than F_s
  - Then F_f is equal but opposite to F_a
  - And *the object does not move*.

- If the applied force (F_a) is *greater* than F_s
  - Then the object begins to move
  - Static Friction no longer applies

Static Friction – Sample Problem

2. The total weight of a little girl and her sled is 545 N. Her older brother, pulling her to the tobogganing hill, finds that it takes a horizontal force of 88 N just to start the sled moving. Find the coefficient of static friction between the sled and the snow.

a) Find the normal force (F_N)

b) Determine if it is static or kinetic fiction

c) Calculate the coefficient of friction (μ)
   - μ = ? (Asked to calculate Wood on Dry snow)

d) Use: $F_f = \mu F_N$

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a) Find the normal force (F_N)
   - $F_N = mg$ $F_N = 545$ N
b) Determine if it is static or kinetic fiction
   - Static (**** Note: "just starting to move")
c) Calculate the coefficient of friction (μ)
   - μ = ? (Asked to calculate Wood on Dry snow)
d) Use: $F_f = \mu F_N$
   - $\mu = F_f / F_N$ $\mu = 88 / 545 = 0.16$

Some Final Thoughts

Note that μ_k is usually less than μ_s

1. Can μ_k be *exactly equal* to μ_s?
   - Describe the motion as you start pulling on an object initially at rest.

2. Can μ_k be *greater* than μ_s?
   - Describe the motion as you start pulling on an object initially at rest.