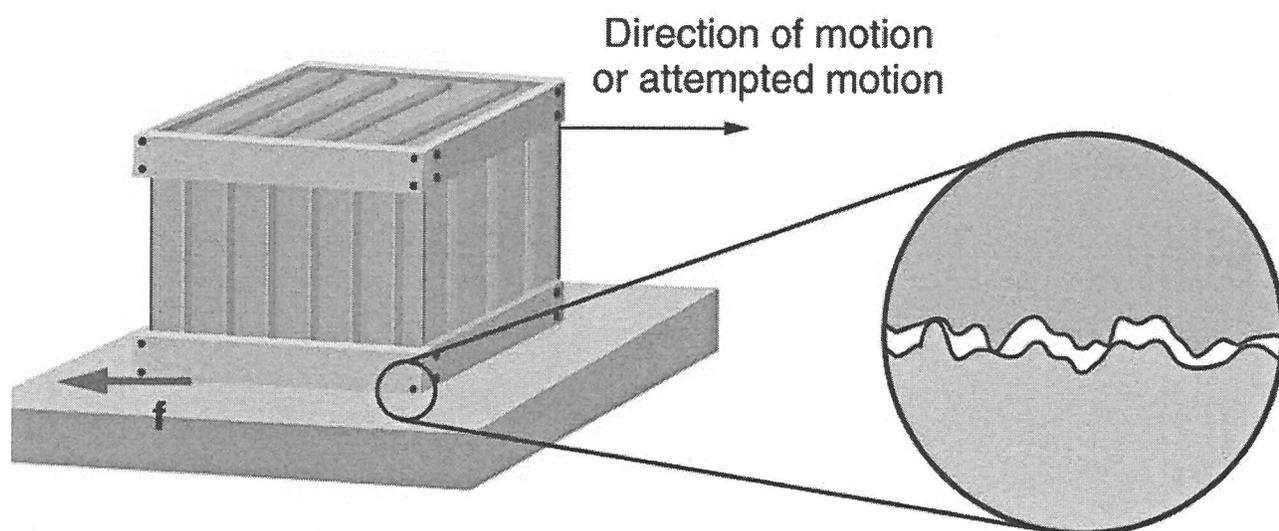


L04 - Friction in 1-Dimension



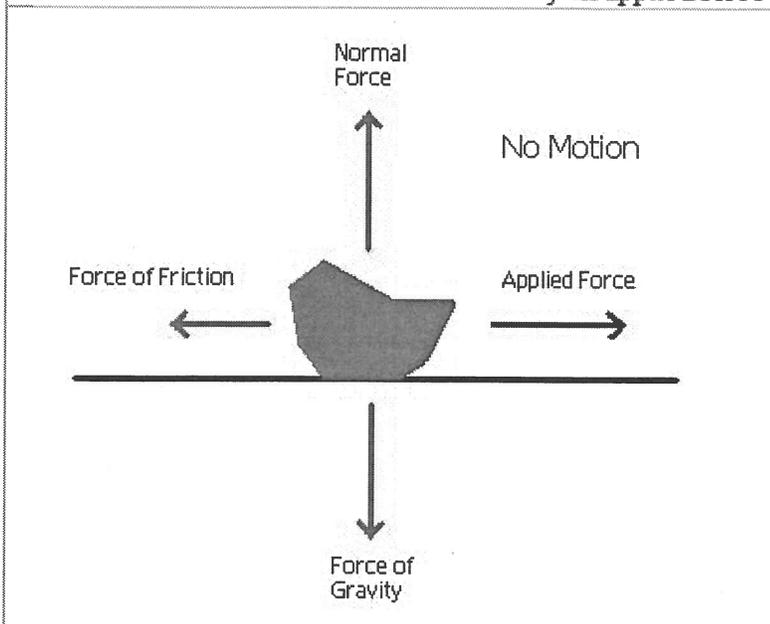
PHET Physics Simulation

Q1: From the simulation, what did you learn about friction?

Static and Kinetic Friction

M

Static Friction – The friction between two or more solid objects that are not moving relative to each other. The static friction must be overcome by an applied force before an object can move.

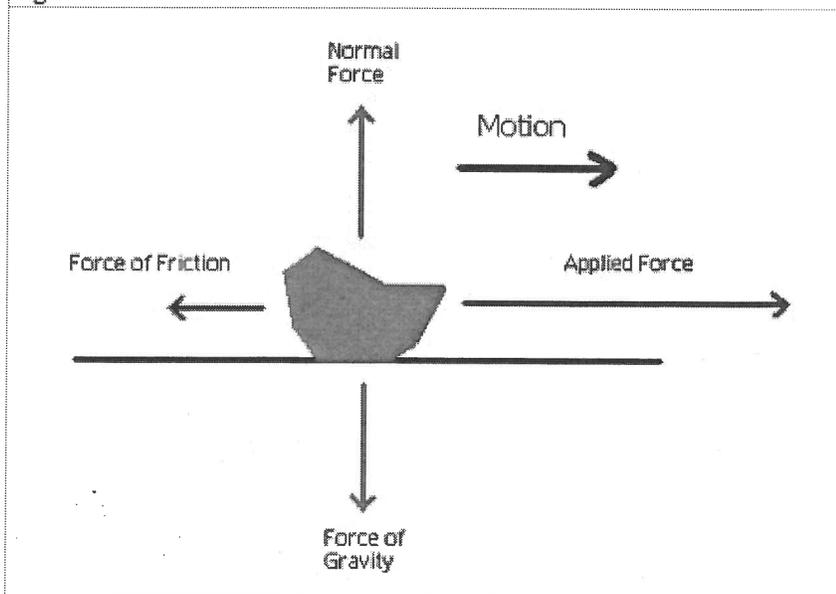


$$F_{f_s} \leq \mu_s F_N$$

$$F_{f_{s_{max}}} = \mu_s F_N$$

↓
Coefficient of Static Friction

Kinetic Friction – The friction that occurs when two objects are moving relative to each other and rub together.



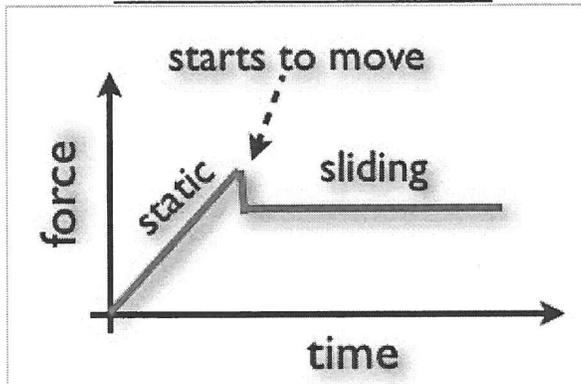
$$F_{f_k} = \mu_k F_N$$

↓
Coefficient of Kinetic Friction

$$|\vec{F}_f| = \mu |\vec{F}_N|$$

When a force is applied to an object, the force must first exceed the maximum possible ~~static~~ frictional force. If it does, the object starts to slide, and kinetic friction takes over. **static**

Force of Friction versus Time



$$F_{f\text{ static}} \leq \mu_s F_N \quad F_{f\text{ kinetic}} = \mu_k F_N$$

The *Coefficient of Static Friction* is always larger or equal to the *Coefficient of Kinetic Friction*.

Surfaces	μ (static)	μ (kinetic)
Steel on steel	0.74	0.57
Glass on glass	0.94	0.40
Metal on Metal (lubricated)	0.15	0.06
Ice on ice	0.10	0.03
Teflon on Teflon	0.04	0.04
Tire on concrete	1.00	0.80
Tire on wet road	0.60	0.40
Tire on snow	0.30	0.20

Table 3.4 Approximate Coefficients of Friction for Some Materials

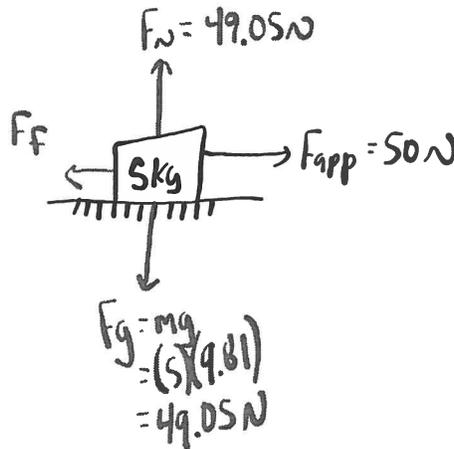
Material	Coefficient of Static Friction μ_s	Coefficient of Kinetic Friction μ_k
Copper on copper	1.6	1.0
Steel on dry steel	0.41	0.38
Steel on greased steel	0.15	0.09
Dry oak on dry oak	0.5	0.3
Rubber tire on dry asphalt	1.2	0.8
Rubber tire on wet asphalt	0.6	0.5
Rubber tire on dry concrete	1.0	0.7
Rubber tire on wet concrete	0.7	0.5
Rubber tire on ice	0.006	0.005
Curling stone on ice	0.003	0.002
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
Synovial fluid on joint	0.01	0.01

Unit 2 - Dynamics

$$\vec{F}_{net} = m\vec{a} \quad \vec{F}_g = m\vec{g} \quad \vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \dots \quad F_{f\ static} \leq \mu_s F_N \quad F_{f\ kinetic} = \mu_k F_N$$

Q2: A glass object of mass 5kg has a force of 50N applied to it. If the object rests on a glass surface, will the object move? If it does, how quickly will it accelerate?

Surfaces	μ (static)	μ (kinetic)
Steel on steel	0.74	0.57
Glass on glass	0.94	0.40
Metal on Metal (lubricated)	0.15	0.06
Ice on ice	0.10	0.03
Teflon on Teflon	0.04	0.04
Tire on concrete	1.00	0.80
Tire on wet road	0.60	0.40
Tire on snow	0.30	0.20



(A) Will it move?

$$F_{f\ s\ max} = \mu_s F_N \\ = (0.94)(49.05) \\ = 46.107\text{N}$$

Yes! F_{app} will overcome $F_{f\ s}$.

(B) What is $F_{f\ k}$?

$$F_{f\ k} = \mu_k F_N \\ = (0.4)(49.05) \\ = 19.62\text{N}$$

(C) Accel?

$$\vec{F}_{net} = \vec{F}_{app} + \vec{F}_{f\ k} \\ = +50 + (-19.62) \\ = 30.38\text{N}$$

$$\vec{a} = \frac{F_{net}}{m} = \frac{30.38}{5} = 6.076\text{m/s}^2 \text{ (forward)}$$

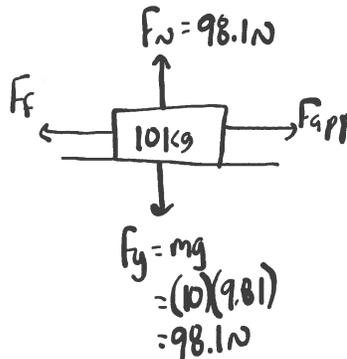
Unit 2 - Dynamics

$\vec{F}_{net} = m\vec{a}$ $\vec{F}_g = m\vec{g}$ $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \dots$ $F_{f\ static} \leq \mu_s F_N$ $F_{f\ kinetic} = \mu_k F_N$

Q3: A copper block of mass 10kg is sitting stationary on a copper surface. How much force is required to accelerate this object? If 170 N is applied, how fast will it accelerate?

Table 3.4 Approximate Coefficients of Friction for Some Materials

Material	Coefficient of Static Friction μ_s	Coefficient of Kinetic Friction μ_k
Copper on copper	1.6	1.0
Steel on dry steel	0.41	0.38
Steel on greased steel	0.15	0.09
Dry oak on dry oak	0.5	0.3
Rubber tire on dry asphalt	1.2	0.8
Rubber tire on wet asphalt	0.6	0.5
Rubber tire on dry concrete	1.0	0.7
Rubber tire on wet concrete	0.7	0.5
Rubber tire on ice	0.006	0.005
Curling stone on ice	0.003	0.002
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
Synovial fluid on joint	0.01	0.01



(A) $F_{f\ s\ max} = \mu_s F_N$
 $= (1.6)(98.1)$
 $= 156.96\ N$
 $F_{app} > 156.96\ N$

(B) $F_{f\ k} = \mu_k F_N$
 $= (1.0)(98.1)$
 $= 98.1\ N$
 $\vec{F}_{net} = \vec{F}_{app} + \vec{F}_f$
 $= (+170) + (-98.1)$
 $= 71.9\ N$
 $\vec{a} = \frac{\vec{F}_{net}}{m} = \frac{71.9}{10} = 7.19\ m/s^2 [f]$