Newton's second law

$$\mathbf{F} = m\,\mathbf{a}$$

Types of forces:

Fundamental	Approximate	Empirical
Gravitational	$F = -mg\,\mathbf{j}$	Friction
Electrical		Support
Magnetic		Elastic
Elementary particles		

$$\mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{v}}{dt} = m\frac{d^2\mathbf{r}}{dt^2}$$

Examples (one dimension):

$F = F_0$ (constant) => $x(t) = x_0 + v_0 t + \frac{1}{2}\frac{F_0}{m}t^2$

$F = F_0 \sin\omega t$ => $x(t) = x_0 + v_0 t - \frac{F_0}{m\omega^2}\sin\omega t$

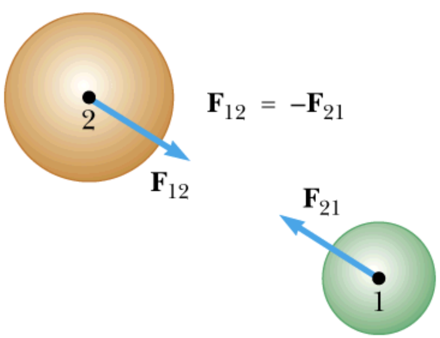
$F = -kx$ => $x(t) = x_0 \cos\sqrt{\frac{k}{m}}t$

$F = F_0 - mbv$

Newton's third law

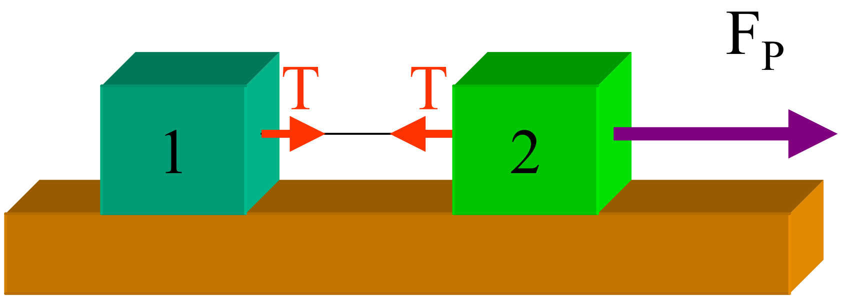
$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

Serway, Physics for Scientists and Engineers, 5/e
Figure 5.6a



(a)

Harcourt, Inc.



$T = m_1 a$

$F_P - T = m_2 a$

$a = F_P/(m_1 + m_2)$

$T = F_P\,(m_1/(m_1 + m_2))$

On line quiz

For this exercise, you should ride the elevator from the first floor of Olin Physical Laboratory up to the second or third floor. While in the elevator, stand on the scale and record the scale readings to answer the following questions.

1. What is the scale reading when the elevator is stationary? x

2. What is the scale reading when the elevator just starts moving upward? $>x$

3. What is the scale reading when the elevator is coming to a stop just before your destination floor? $<x$

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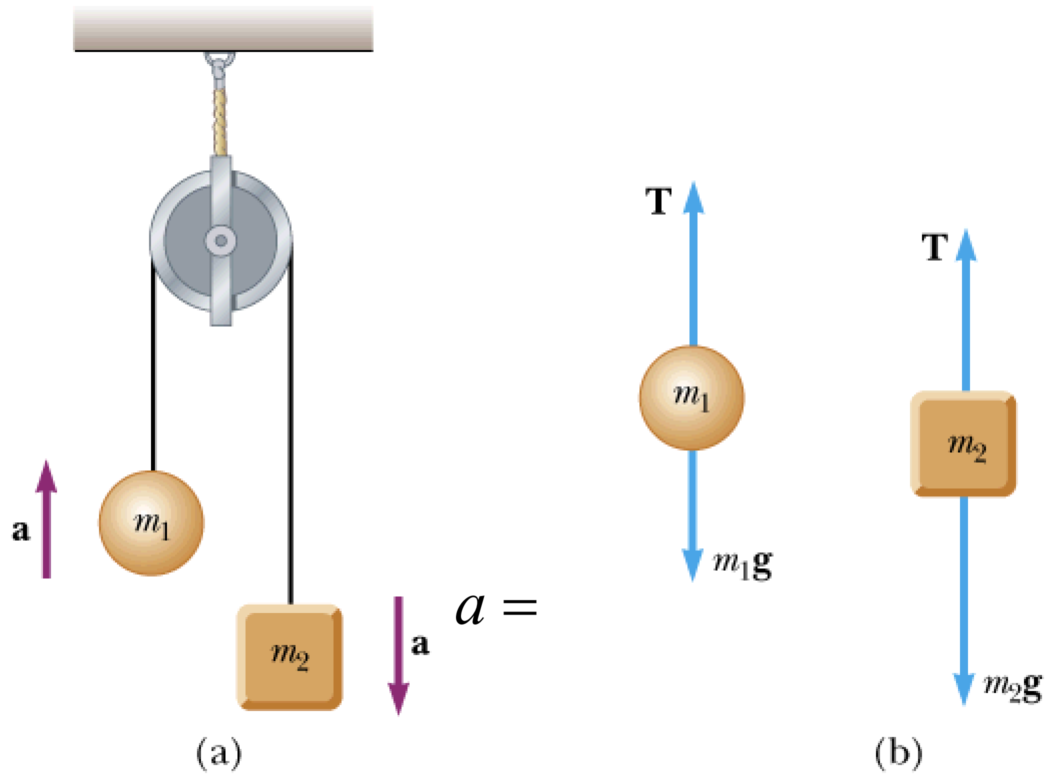
Figure 5.15



$T - m_1 g = m_1 a$ $\quad$ $T - m_2 g = -m_2 a$ $\quad$ => after some algebra:

$$a = \frac{m_2 - m_1}{m_2 + m_1} g$$

$$T = \frac{2 m_1 m_2}{m_2 + m_1} g$$

Friction forces

The term “friction” is used to describe the category of forces that *oppose* motion. One example is surface friction which acts on two touching solid objects. Another example is air friction. There are several reasonable models to quantify these phenomena.

Peer instruction question

Suppose that the forces on a soap bubble falling through the air can be described by: $F = -mg - mbv$ If at t=0 v(t)=0, what will be its velocity at a later time?

(a) v(t)=–gt (The bubble will accelerate under the effects of gravity and air friction (the "b" term) has a negligible effect.)

(b) v(t)=0 (Air friction will eventually stop the bubble from moving.)

(c) v(t)=(Constant) (The magnitude of the air friction force will increase with time, eventually balancing the force of gravity.)

(d) |v(t)|>gt (Air friction makes the bubble move faster than gravity alone.

$$\mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{v}}{dt} = m\frac{d^2\mathbf{r}}{dt^2}$$

Examples (one dimension):

$F = F_0$ (constant) => $x(t) = x_0 + v_0 t + \frac{1}{2}\frac{F_0}{m}t^2$

$F = F_0 \sin\omega t$ => $x(t) = x_0 + v_0 t - \frac{F_0}{m\omega^2}\sin\omega t$

$F = -kx$ => $x(t) = x_0 \cos\sqrt{\frac{k}{m}}t$

$F = F_0 - mbv$ => $v(t) = -\frac{g}{b} + \frac{g}{b}e^{-bt}$

Models of surface friction forces

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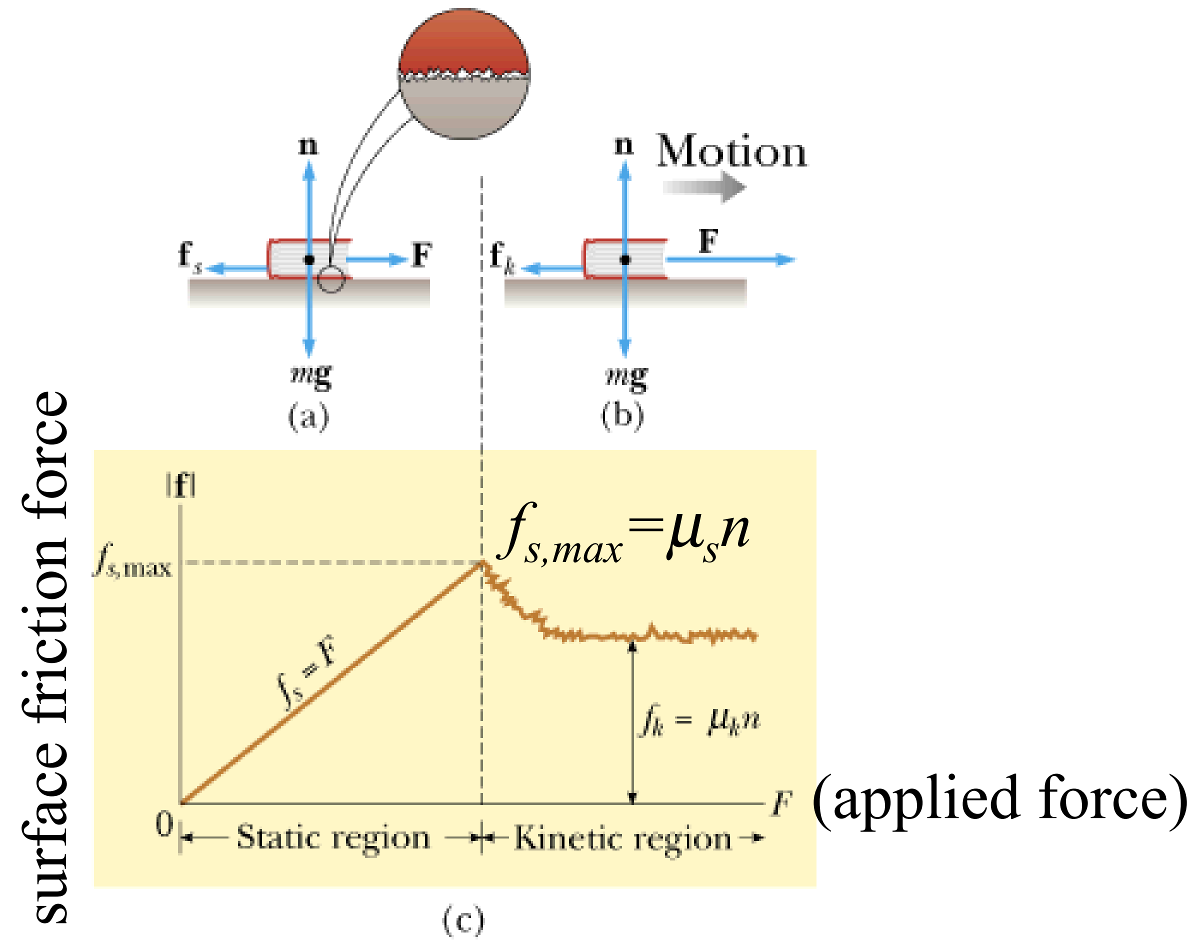
Figure 5.17

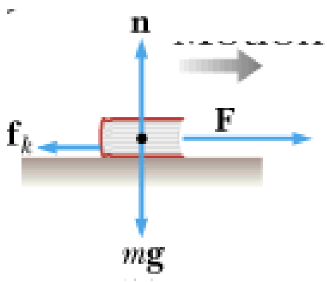


Coefficients of friction μ_s , μ_k depend on the surfaces; usually, $\mu_s > \mu_k$

Some estimates of static and kinetic friction:

Material	μ_s	μ_k
Rubber on concrete	1.0	0.8
Wood on wood	0.3	0.2
Steel on steel with lubrication	0.09	0.05
Teflon on teflon	0.04	0.04

Surface friction:



$F\text{-}f_s = 0$ if $F<\mu_s n=\mu_s mg$

if $F>\mu_s n=\mu_s mg$, then $F\text{-}f_k=ma \quad (f_k= \mu_k mg)$

$$a = \frac{F - \mu_k mg}{m}$$