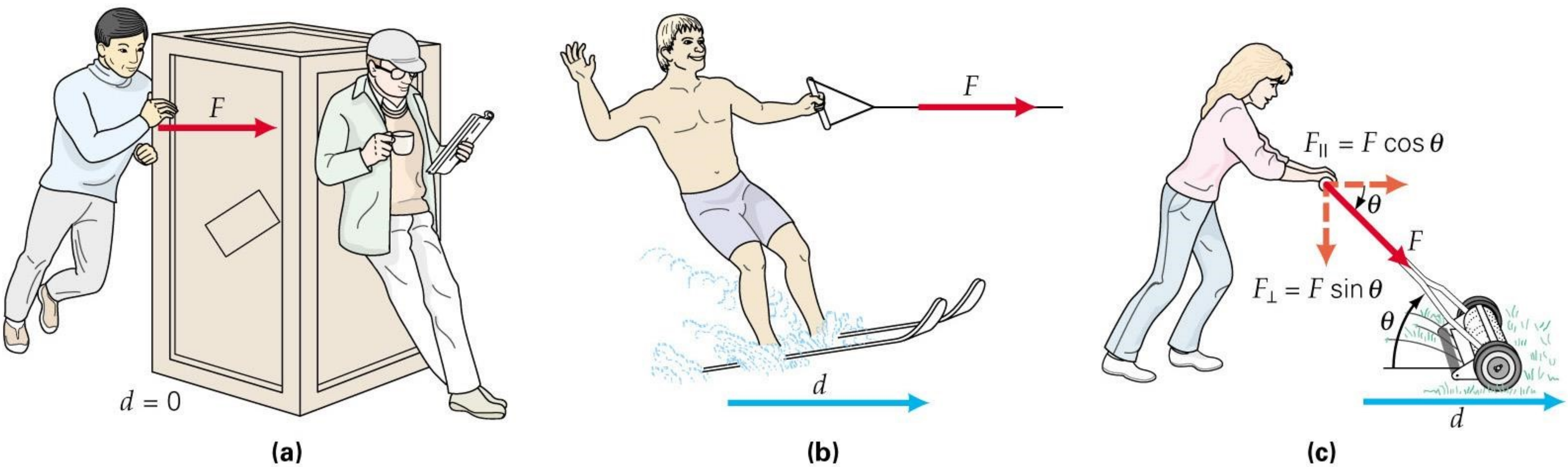
AP Physics 1 Review Session 2

Work, Energy, Power, Impulse,
Momentum, Collisions

WORK

In order for work to be done, three things are necessary:

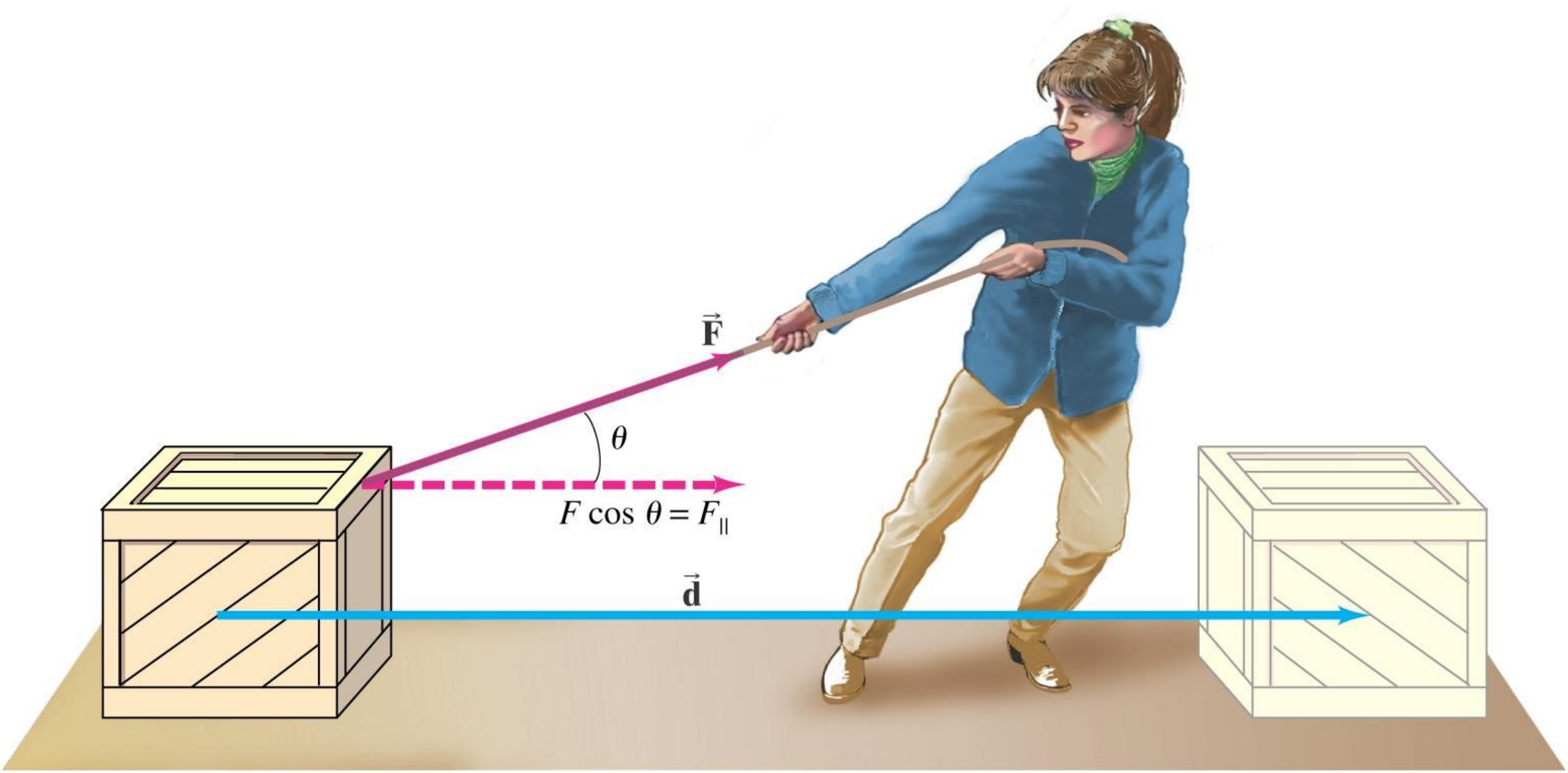
- There must be an applied force.
- The force must act through a certain distance, called the displacement.
- The force must have a component along the displacement.

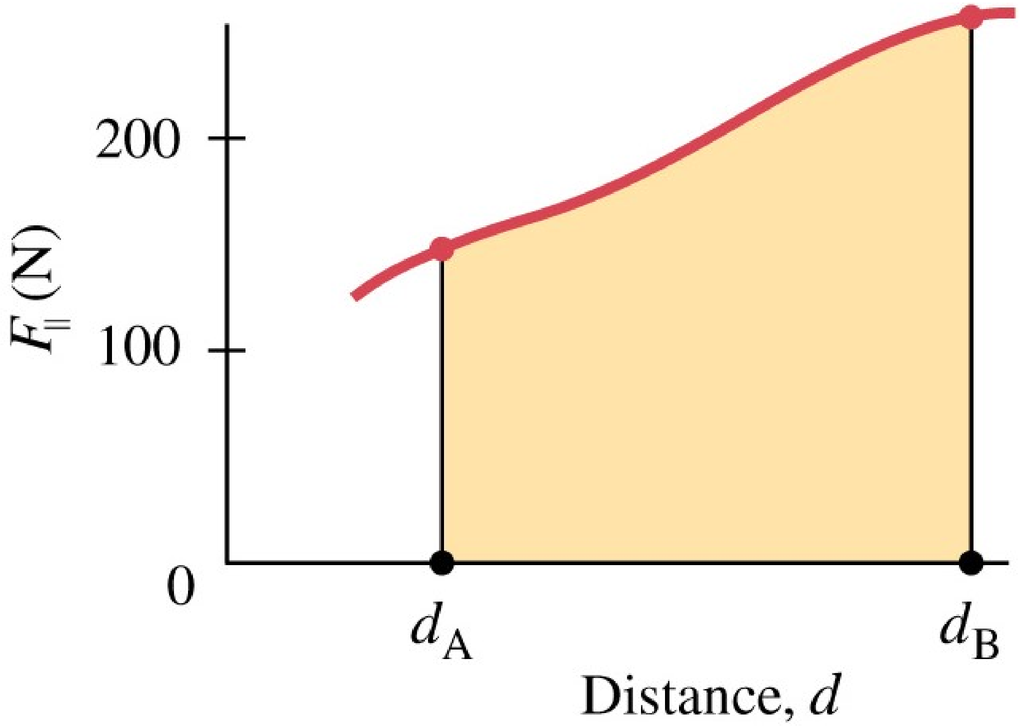


Work is a *scalar* quantity equal to the product of the magnitudes of the displacement and the component of the force in the direction of the displacement.

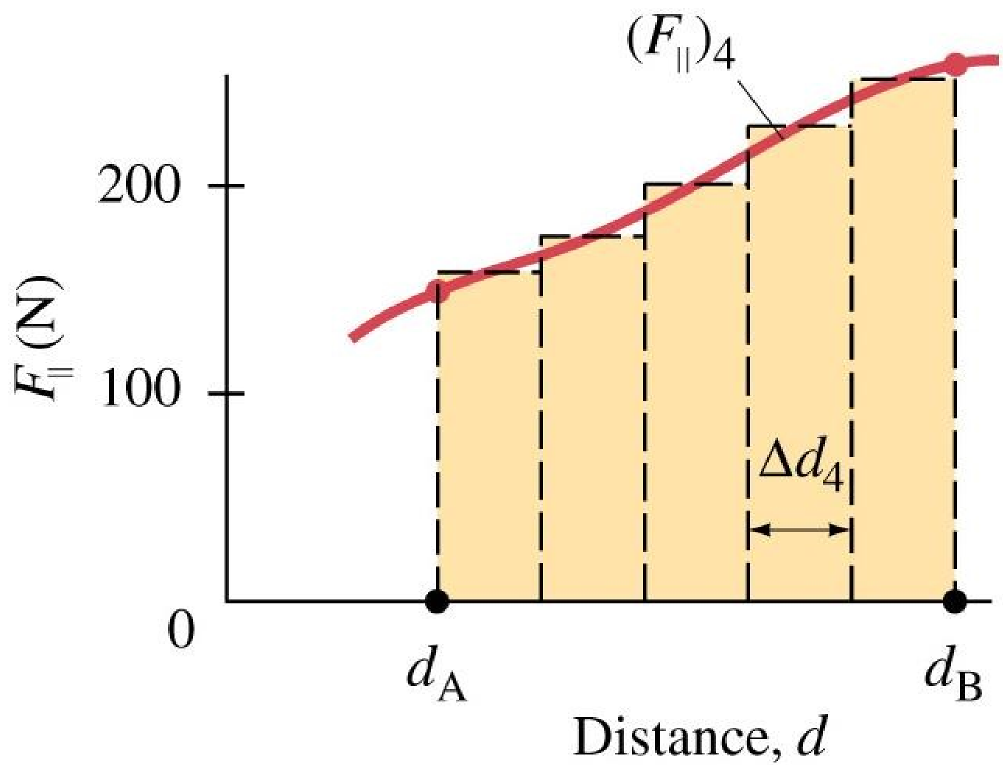
$W = F \cdot x$ **or** $W = F \cos\theta \; x$

UNITS: N.m this unit is called a Joule (J)





200
100
0
F∥ (N)
dA
dB
Distance, d

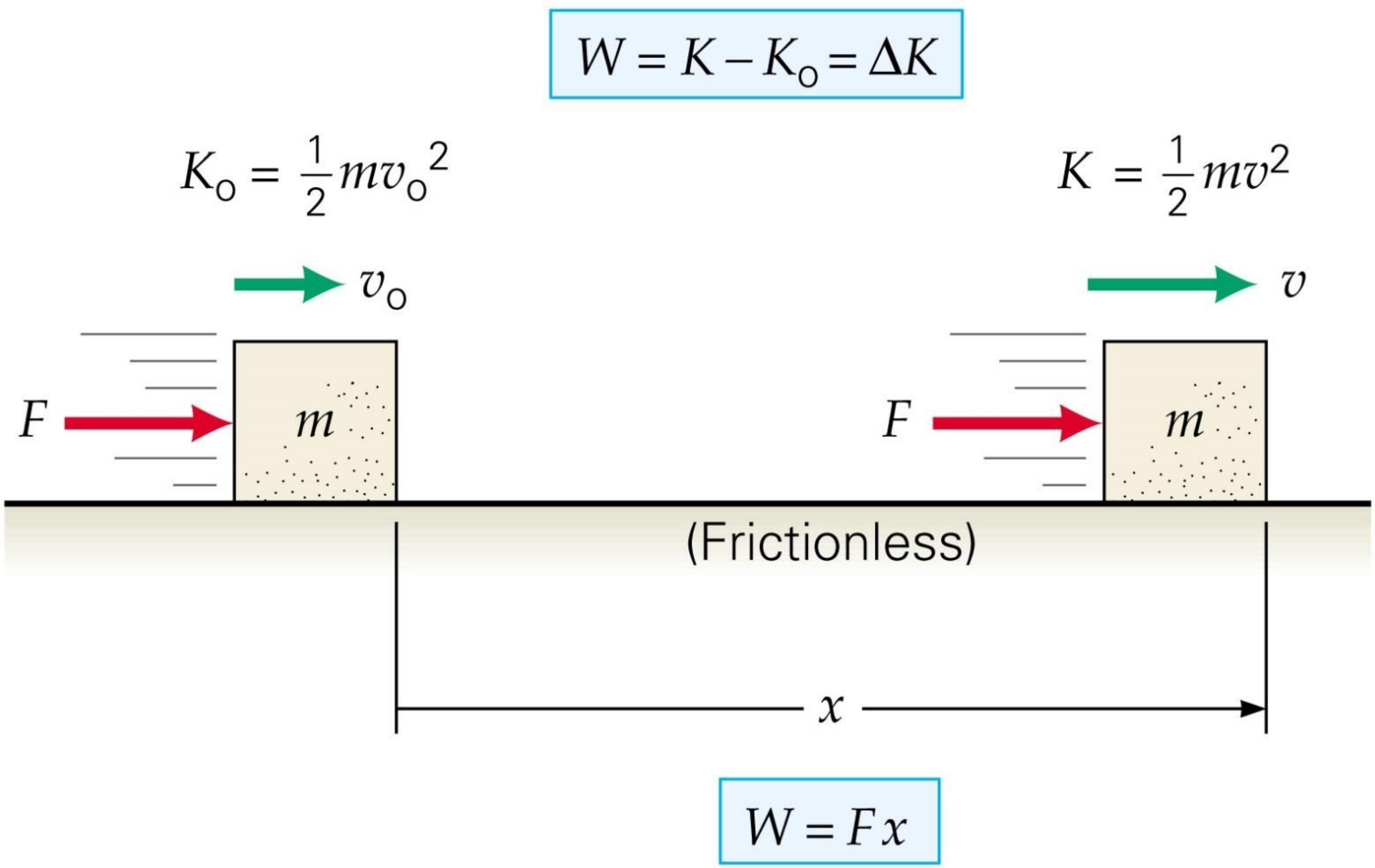


(F∥)4
200
100
0
F∥ (N)
Δd4
dA
dB
Distance, d

WORK-ENERGY PRINCIPLE:

The work of a resultant external force on a body is equal to the change in kinetic energy of the body.

$W = \Delta K$ **Units: Joules (J)**



In mechanics we are concerned with two kinds of energy:

KINETIC ENERGY: ***K*****, energy possessed by a body by virtue of its motion.**

$$K = \frac{1}{2}mv^2$$ **Units: Joules (J)**

POTENTIAL ENERGY: ***PE*****, energy possessed by a system by virtue of position or condition.**

$$PE = m\,g\,h$$ **Units: Joules (J)**

CONSERVATIVE AND NON-CONSERVATIVE FORCES

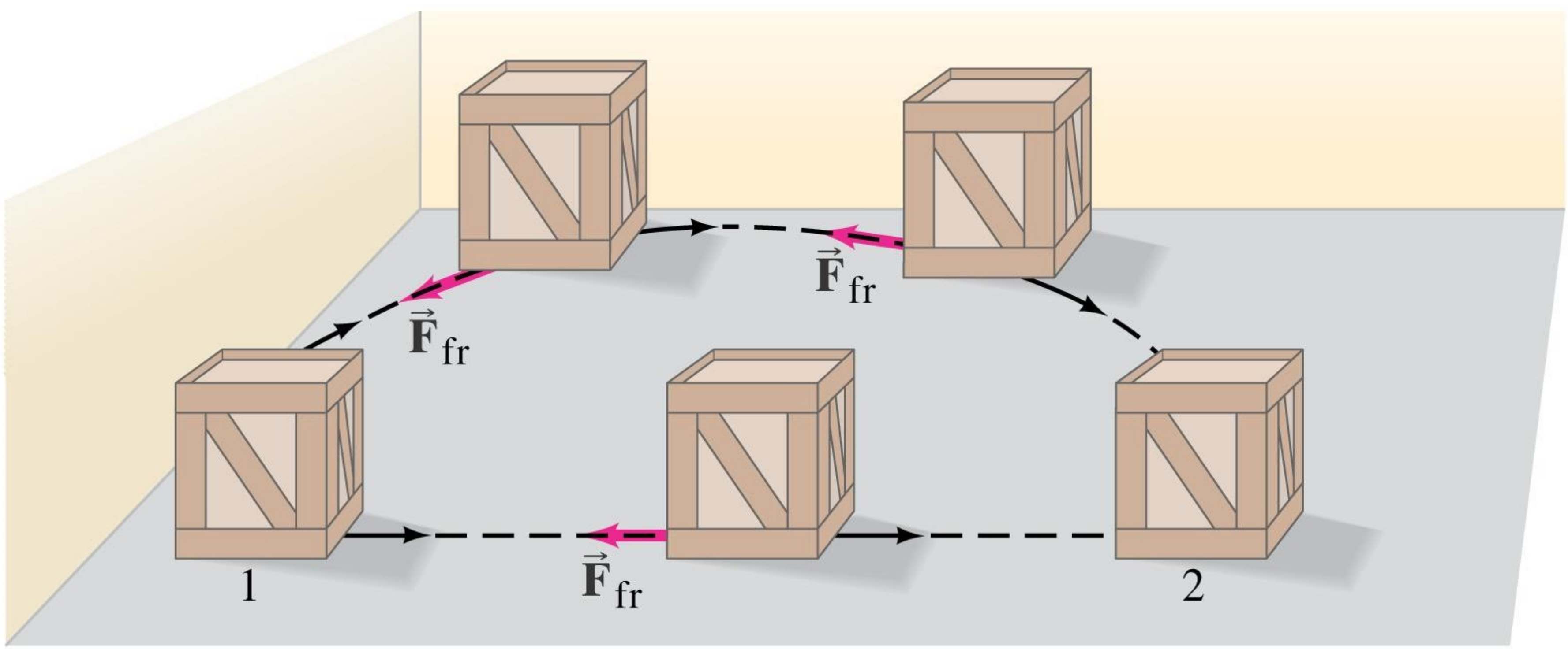
The work done by a *conservative force* depends only on the initial and final position of the object acted upon. An example of a conservative force is gravity.

The work done equals the change in potential energy and depends only on the initial and final positions above the ground and NOT on the path taken.

TABLE 6–1 Conservative and Nonconservative Forces

Conservative Forces	Nonconservative Forces
Gravitational	Friction
Elastic	Air resistance
Electric	Tension in cord
	Motor or rocket propulsion
	Push or pull by a person

Friction is a *non-conservative* force and the work done in moving an object against a non-conservative force depends on the path. For example, the work done in sliding a box of books against friction from one end of a room to the other depends on the path taken.



$m_1 = 0.04$ kg
$m_2 = 0.500$ kg
$h = 0.045$ m

$$K_0 = PE_f$$

$$PE_f = (m_1 + m_2)\, g h_f$$
$$= (0.04+0.500)(9.8)(0.045)$$
$$= 0.24 \text{ J}$$

$$K_0 = PE_f = 0.24 \text{ J}$$

$$K_0 = \frac{1}{2} m_T v_0^2$$

$$v_0 = \sqrt{\frac{2K_o}{m_T}} = \sqrt{\frac{2(0.24)}{0.54}} = 0.94 \text{ m/s}$$

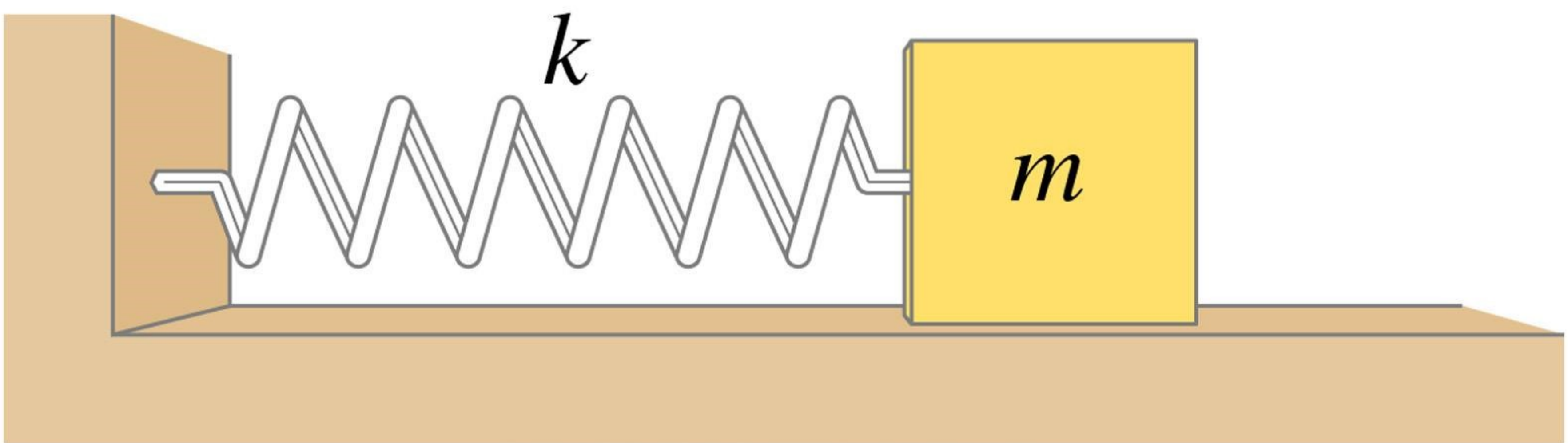
ELASTIC FORCE

The force F_s applied to a spring to stretch it or to compress it an amount x is directly proportional to x.

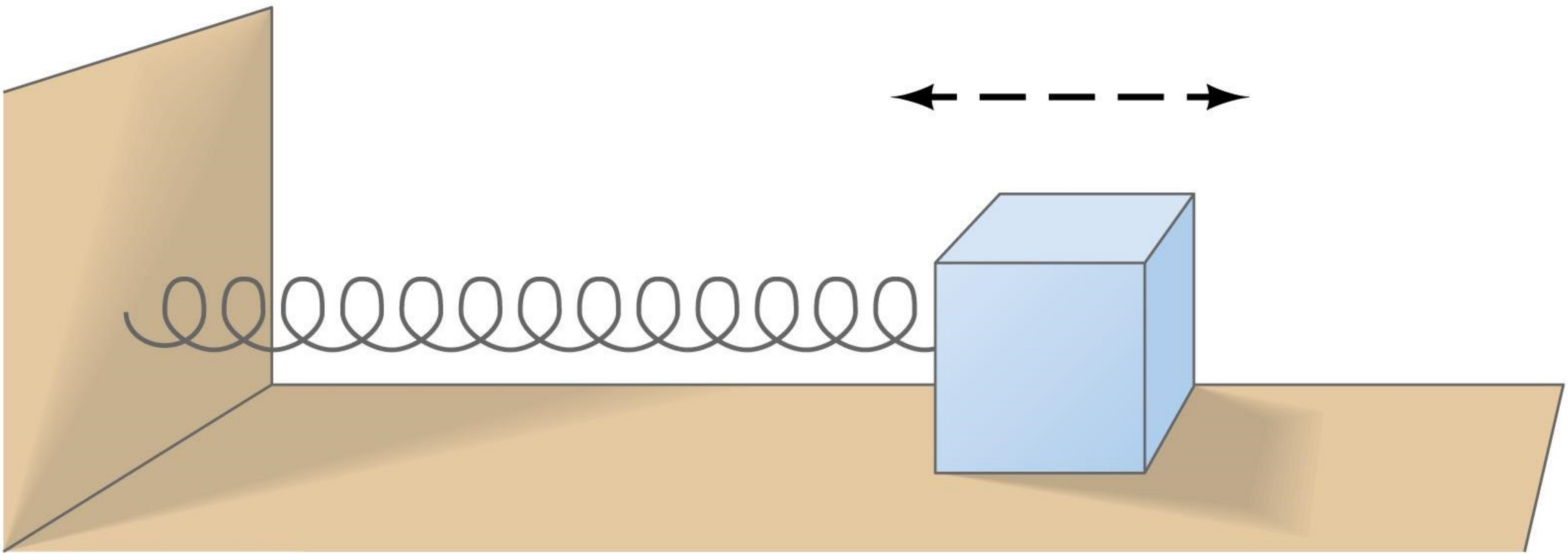
$$F_s = - k\,x$$

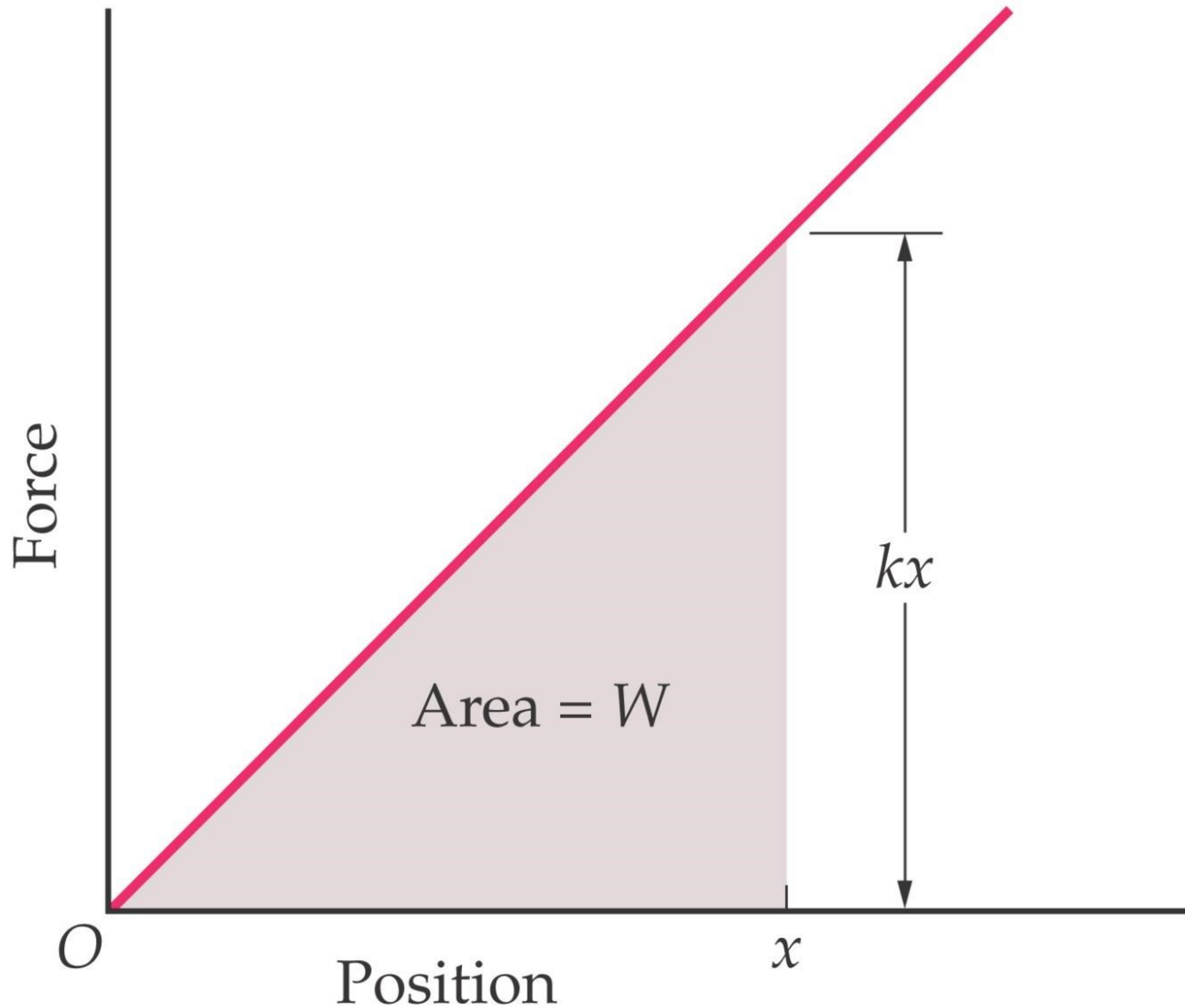
Units: Newtons (N)

Where k is a constant called the ***spring constant*** and is a measure of the **stiffness** of the particular spring. The spring itself exerts a force in the *opposite* direction:



This force is sometimes called *restoring force* because the spring exerts its force in the direction opposite to the displacement. This equation is known as the *spring equation* or *Hooke's Law.*





$$A = \frac{1}{2}bh$$

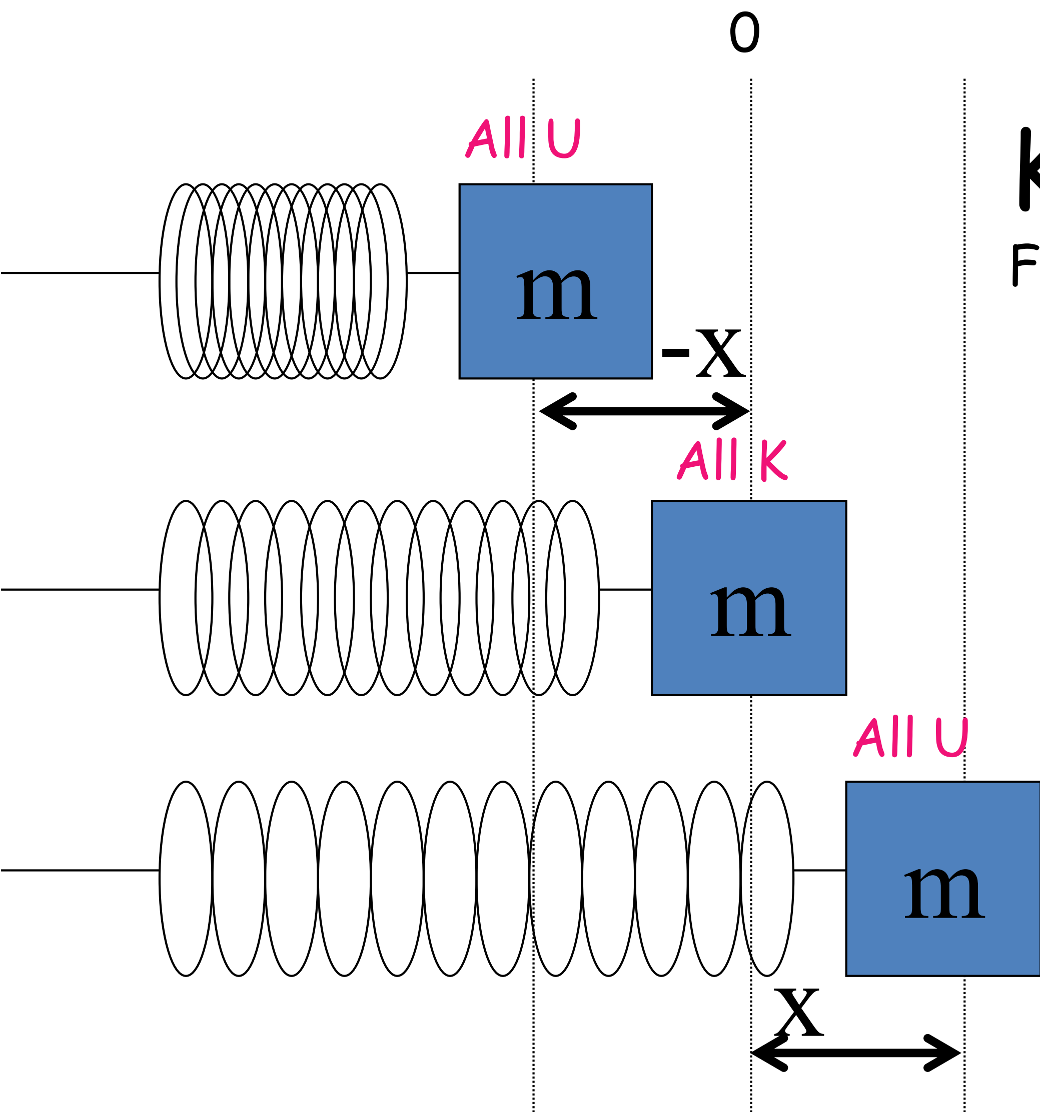
$$= \frac{1}{2}(x)(kx)$$

$$= \frac{1}{2}kx^2$$

Springs and Energy Conservation

- Transforms energy back and forth between K and U.
- When fully stretched or extended, all energy is U.
- When passing through equilibrium, all its energy is K.
- At other points in its cycle, the energy is a mixture of U and K.

Spring Energy



$$K_1 + U_1 = K_2 + U_2 = E$$

For any two points 1 and 2

$$\tfrac{1}{2}kx_{max}^2 = \tfrac{1}{2}mv_{max}^2$$

For maximum and minimum displacements from equilibrium

Conservation of Energy

$$ME_0 = ME_f + E_{th}$$

$$K_0 + U_{g0} + U_{s0} = K_f + U_{gf} + U_{sf} + E_{th}$$

Equations Provided

$$K = \frac{1}{2}mv^2$$

$$\Delta E = W = F_{||}d = Fd\cos\theta$$

$$\Delta U_g = mg\Delta y$$

$$\left|\vec{F}_s\right| = k\left|\vec{x}\right|$$

$$U_s = \frac{1}{2}kx^2$$

Power

- The *rate* of which work is done.
- When we run upstairs, t is small so P is big.
- When we walk upstairs, t is large so P is small.

Power

in Equation Form

- P = W/t
  - work/time
- P = F V
  - (force)(velocity)

Unit of Power

- SI unit for Power is the Watt.
- 1 Watt = 1 Joule/s
- Named after the Scottish engineer James Watt (1776-1819) who perfected the steam engine.

POWER

Is the rate at which work is performed. ***P*** **= work/time**

$$P = \frac{W}{t} = \frac{Fr}{t} = Fv$$

UNITS: $\frac{\mathrm{J}}{\mathrm{s}} = \mathrm{W}$ **= Watt**

The difference between walking and running up these stairs is power.

The change in gravitational potential energy is the same.

5.6 A 1100-kg car starting from rest, accelerates for 5.0 s. The magnitude of the acceleration is 4.6 m/s². What power must the motor produce to cause this acceleration?

$m = 1100$ kg
$v_o = 0$ m/s
$t = 5$ s
$a = 4.6$ m/s²

$F = ma$
$= (1100)(4.6)$
$= 5060$ N

$v_f = v_o + at$
$= 0 + 4.6\,(5)$
$= 23$ m/s

The average velocity is: 23/2 = 11.5 m/s

$P = Fv$
$= (5060)(11.5)$
$= 5.82\times10^{4}$ W

Equations Provided

$$P = \frac{\Delta E}{\Delta t}$$

Momentum

- Inertia in motion

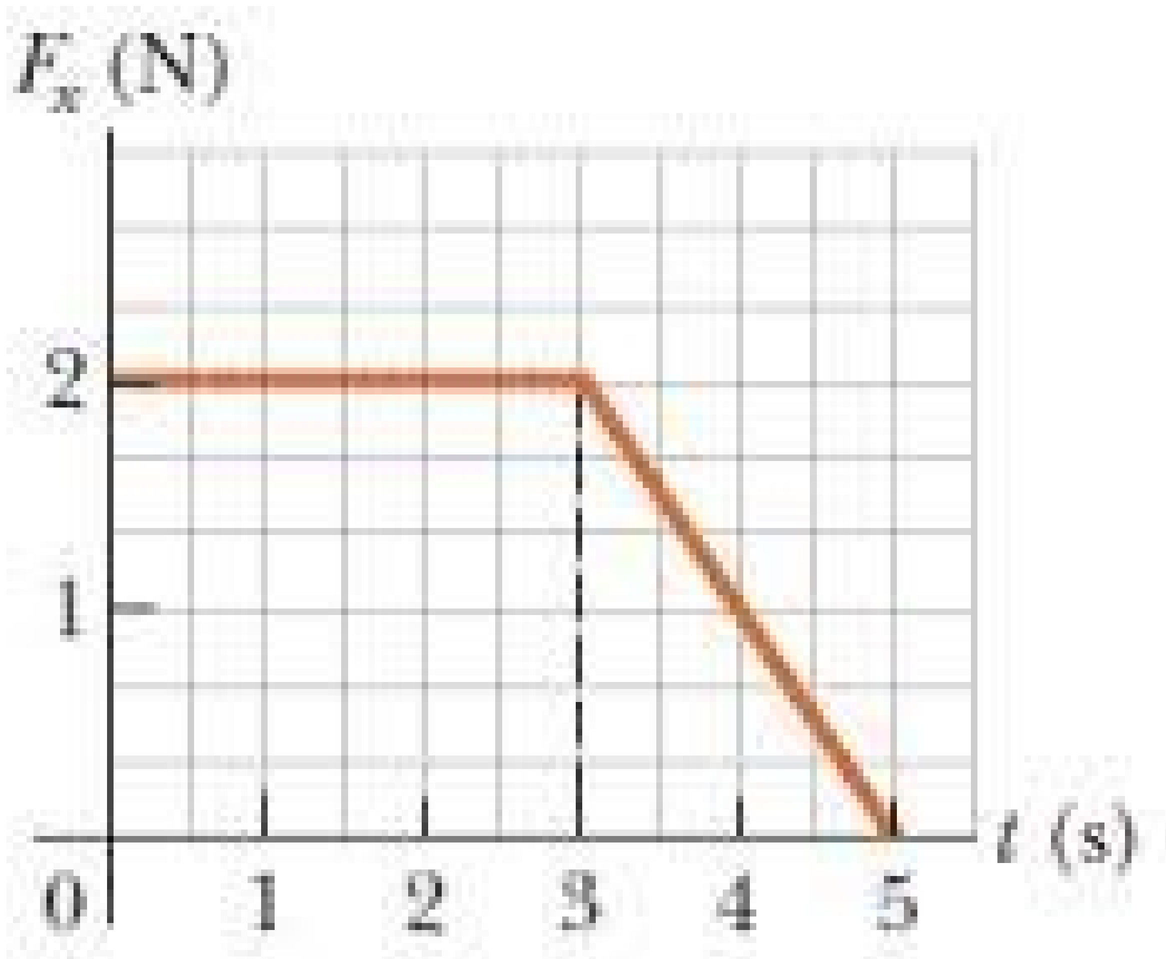
$$p = mv$$

Impulse

- Change in momentum

$$J = \Delta p = mv_f - mv_0 = Ft$$

Impulse Graphically



Conservation of Momentum

- Momentum is always conserved in all collisions
  - Newton's 3rd law application!

Conservation of Momentum

- For a closed system, i.e., no outside forces

$$p_0 = p_f$$

- For 2-D collisions, momentum is conserved in each direction

Collisions

- Elastic
  - Both momentum & energy are conserved
  - No compression or deformation
- Inelastic
  - Only momentum is conserved
  - Energy lost to deformation
  - Same final velocity

Equations Provided

$$\vec{p} = m\vec{v}$$

$$\Delta\vec{p} = \vec{F}\,\Delta t$$