PHYS151
Lecture 08

Ch 08 Potential Energy and Conservation of Energy

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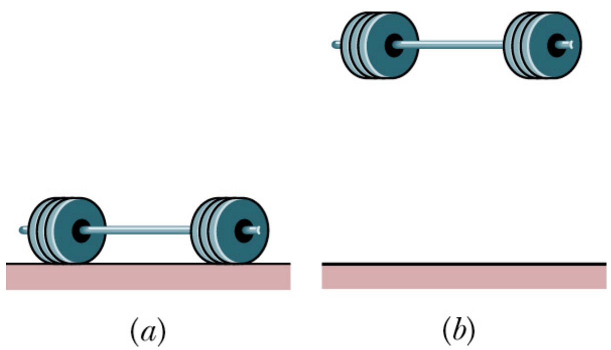
Potential Energy

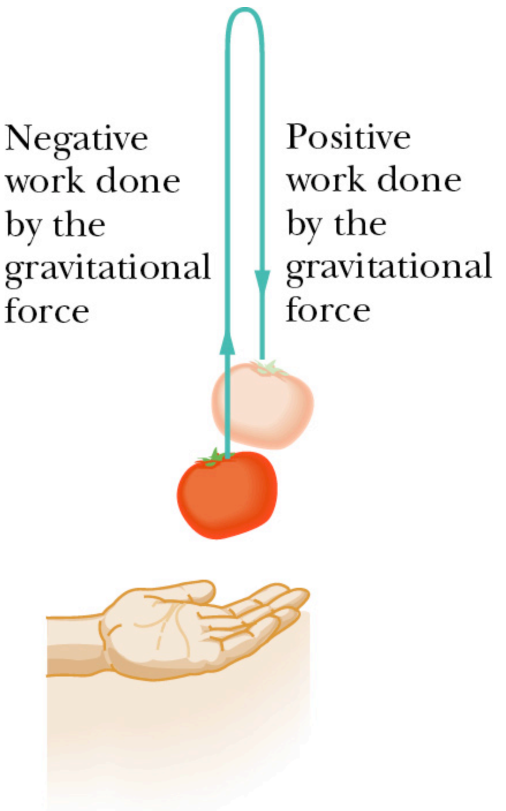
Potential energy is the energy that can be associated with the configuration



These two states has two different potential energy

ex) gravitational potential energy
elastic potential energy

Work and Potential Energy



The change ΔU in gravitational potential energy is defined to equal the negative of the work done on the tomato by gravitational force

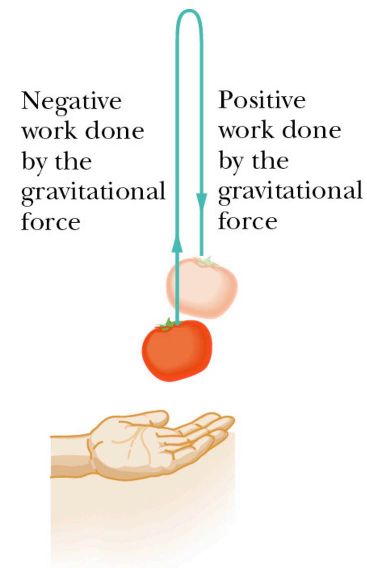
$$\Delta U = -W$$

Conservative and Nonconservative Forces

Conservative force:

Work done by a force to change configuration is same but negative to the work done to restore the configuration

ex) gravitational force



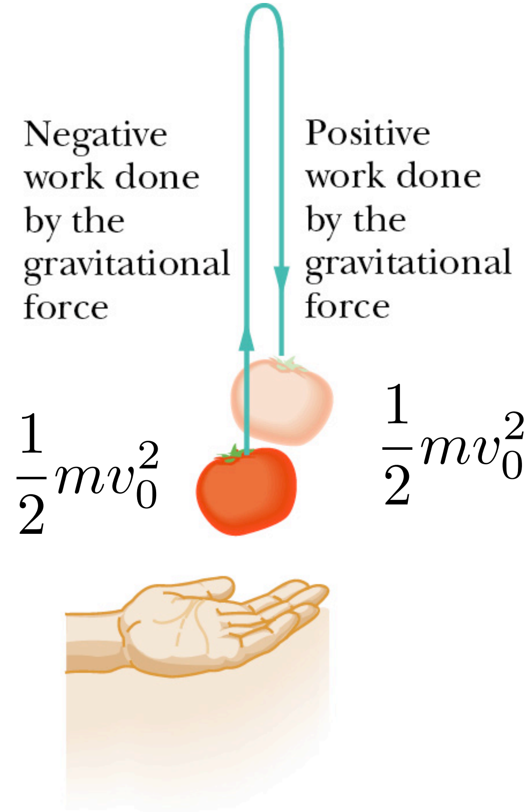
Nonconservative force:

A force that is not conservative

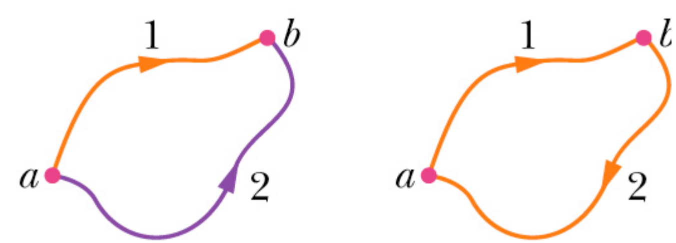
ex) kinetic frictional energy (thermal energy cannot be transferred back to kinetic energy)

Path Independence of Conservative Forces

The net work done by a conservative force on a particle moving around every closed path is zero



The work done by a conservative force on a particle moving between two points does not depend on the path taken by the particle



(a) (b)

$$W_{ab,1} + W_{ba,2} = 0$$

$$W_{ab,1} = -W_{ba,2} = W_{ab,2}$$

Potential Energy Values

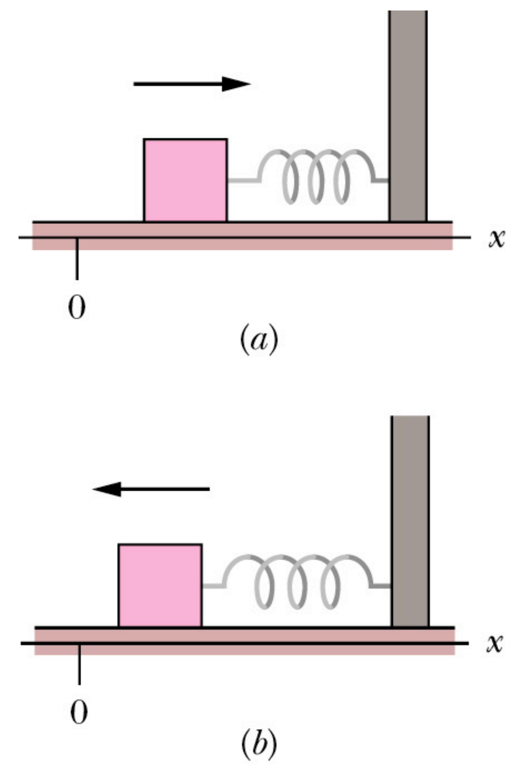
Consider a particle with a conservative force $W = \int_{x_i}^{x_f} F(x)dx$ or $\Delta U = -\int_{x_i}^{x_f} F(x)dx$

Gravitational Potential Energy:

$$\Delta U = -\int_{y_i}^{y_f} (-mg)dy = mg\int_{y_i}^{y_f} dy = mg(y_f - y_i)$$

$U(y) = mgy$ (if we take $U_i = y_i = 0$)

Elastic Potential Energy:



$$\Delta U = -\int_{x_i}^{x_f} (-kx)dx = k\int_{x_i}^{x_f} x\ dx = \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2$$

$U(x) = \frac{1}{2}kx^2$ (if we take $U_i = x_i = 0$)

Conservation of Mechanical Energy

The mechanical Energy E_{mec} $$E_{mec} = K + U$$

When a conservative force does work W on an object, it transfers energy between K and U

$$\Delta K = W = -\Delta U$$

from the top, we find that

$$K_2 - K_1 = -(U_2 - U_1)$$

and becomes

$$K_2 + U_2 = K_1 + U_1$$

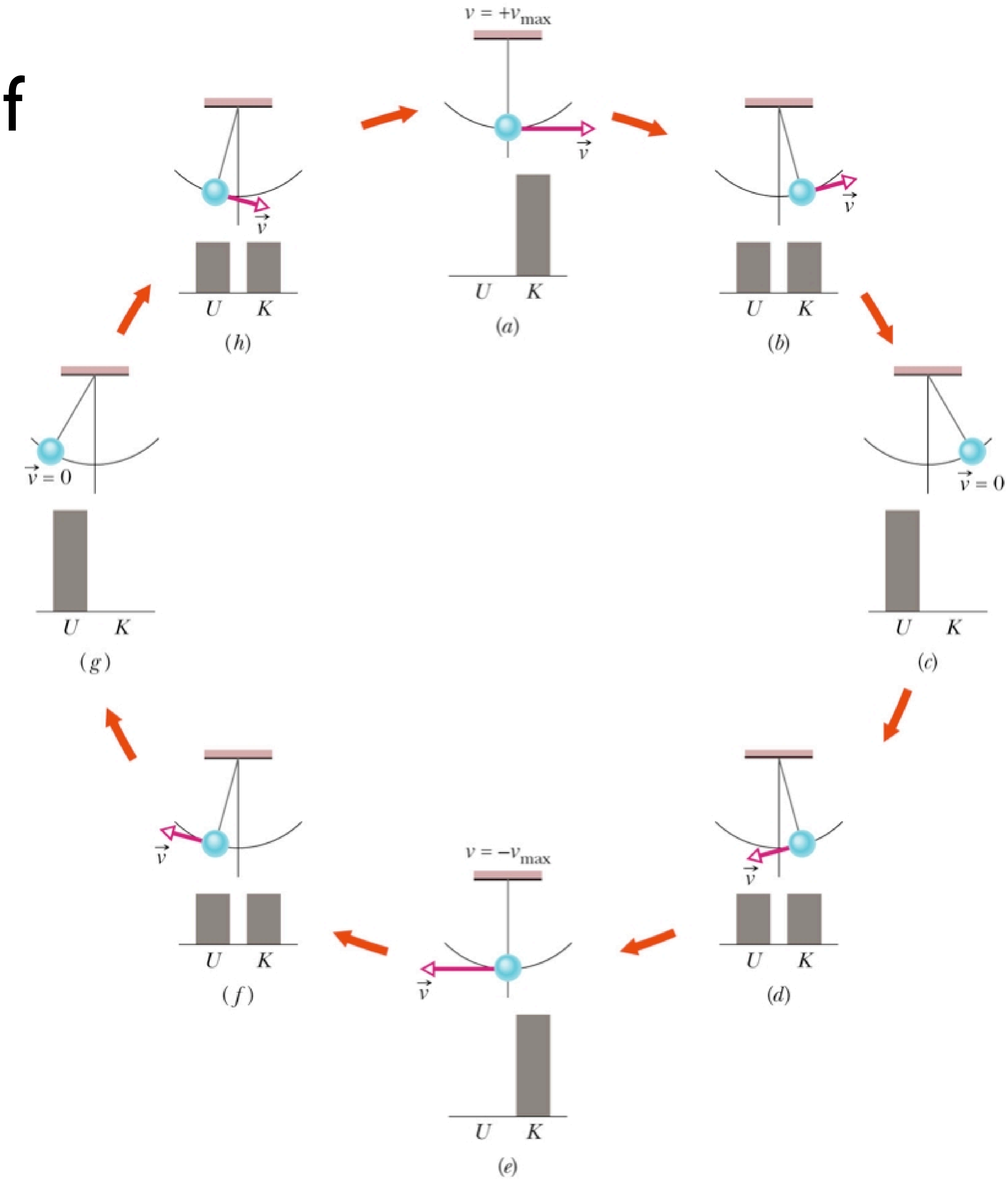
Principle of conservation of mechanical energy:

$$\Delta E_{mec} = \Delta K + \Delta U = 0$$

Conservation of Mechanical Energy

ex) a pendulum

K + U is constant all the time



Potential Energy Curve

We had this before: $\Delta U = -\int_{x_i}^{x_f} F(x)dx$

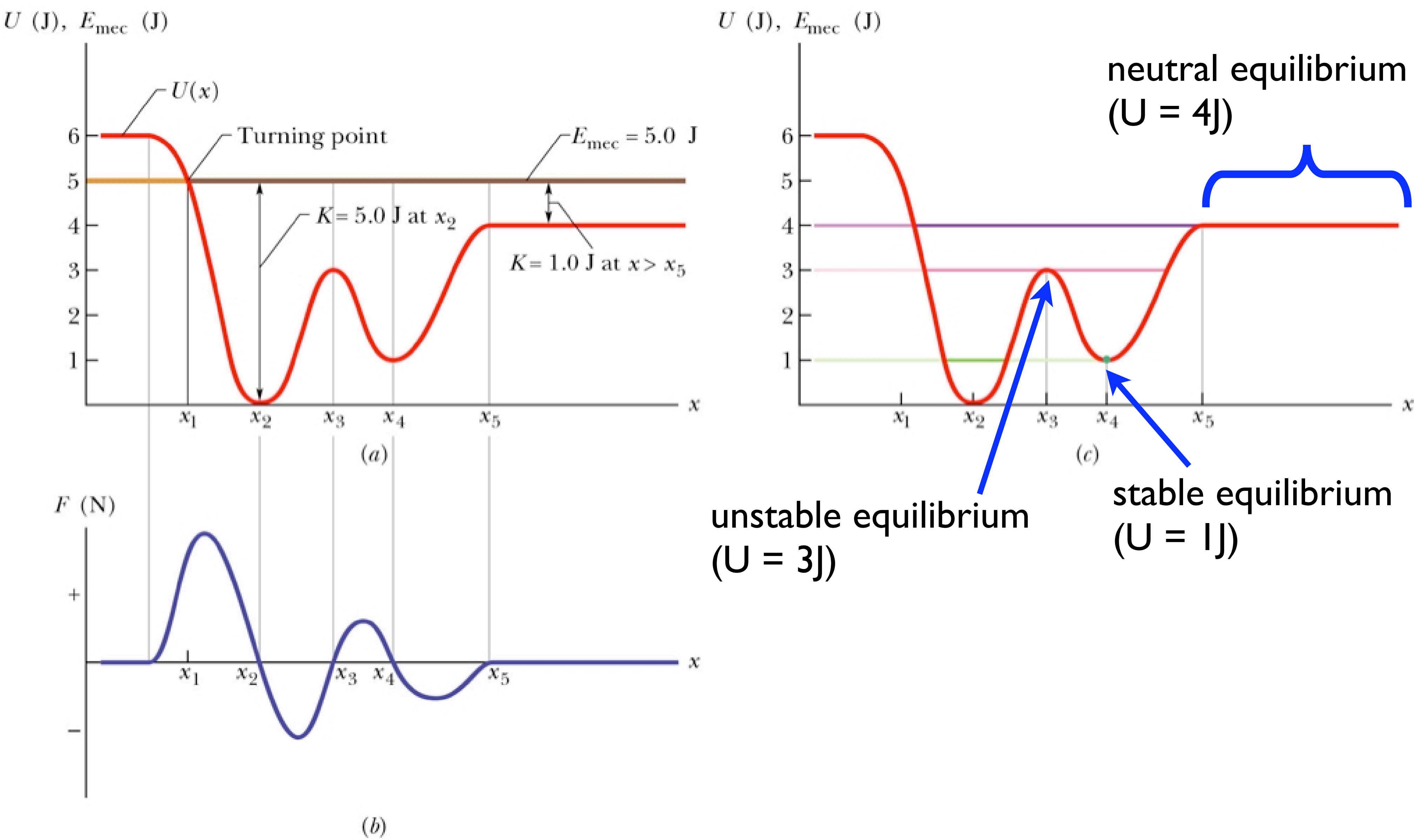
and it becomes at the differential limit: $F(x) = -\frac{dU(x)}{dx}$ (obtaining the force from the potential)

ex) elastic potential $U(x) = \frac{1}{2}kx^2 \longrightarrow F(x) = -kx$

gravitational potential $U(y) = mgy \longrightarrow F = -mg$

Potential Energy Curve

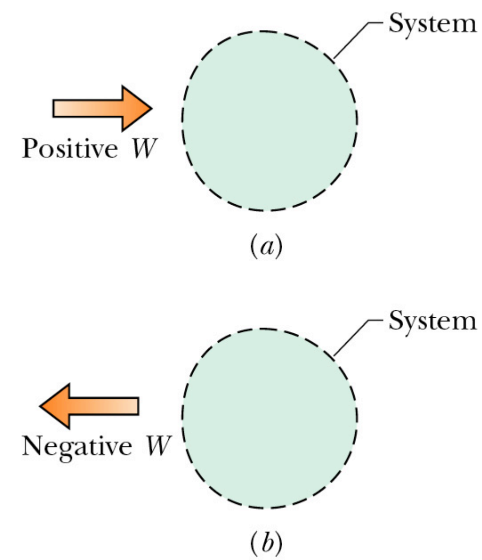
Potential Energy Curve



Work Done on a System by an External Force

Definition of work with external force:

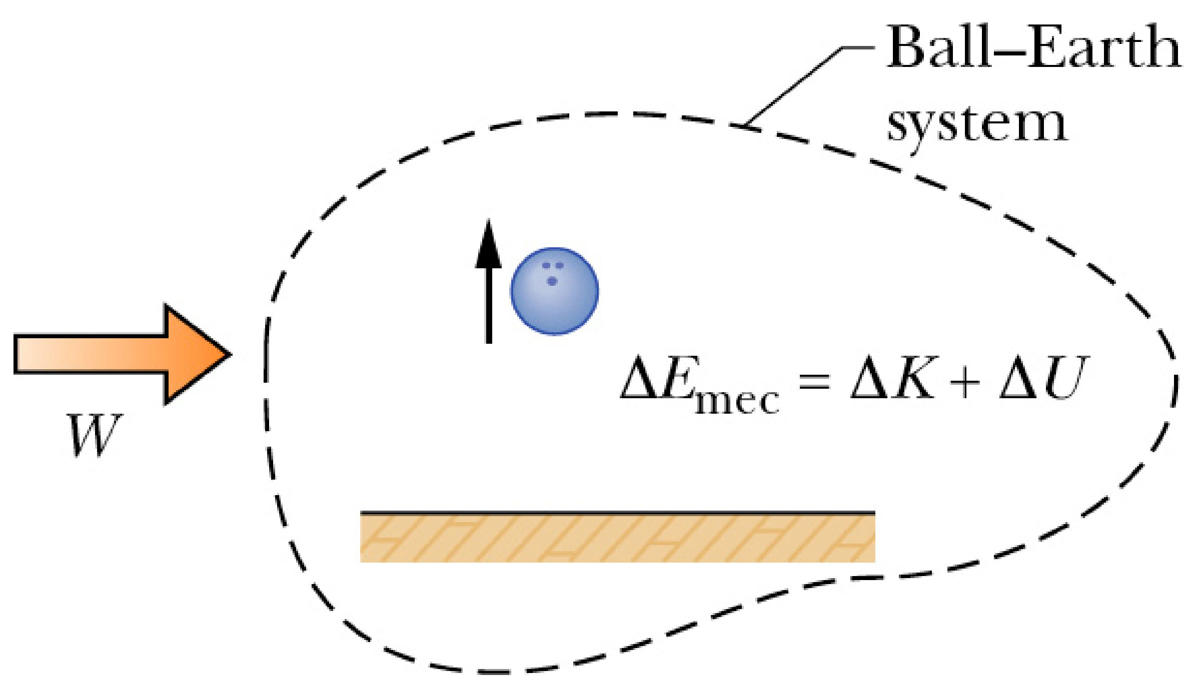
Work is energy transferred to or from a system by means of an external force acting on that system



No friction involved:

$$W = \Delta E_{mec}$$

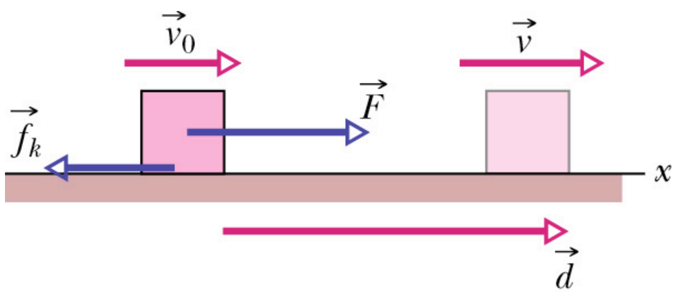
Work done on the system is equal to the change in the mechanical energy



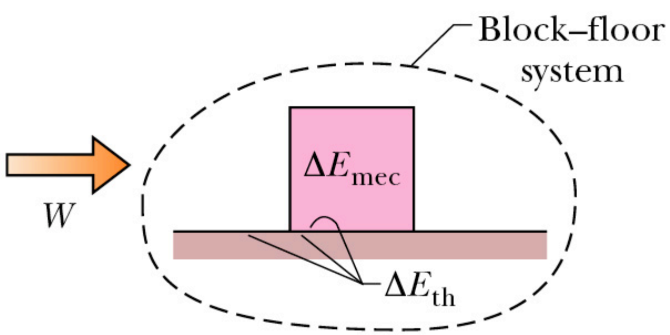
Work Done on a System by an External Force

Friction involved:

A constant force F pulls a block, increasing the block's velocity from v_0 to v



(a)



(b)

From Newton's 2nd law, we write

$$F - f_k = ma$$

acceleration is constant as forces are constant, so we can use the following equation

$$v^2 = v_0^2 + 2ad \quad \text{and,} \quad a = \frac{1}{2d}(v^2 - v_0^2)$$

$$Fd = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 + f_k d$$

it becomes $Fd = \Delta K + f_k d$

(if we include the vertical motion as well) $Fd = \Delta E_{mec} + f_k d$

(increase in thermal energy by sliding) ΔE_{th}

Conservation of Energy

The total energy E of a system can change only by amounts of energy that are transferred to or from the system

$$W = \Delta E = \Delta E_{mec} + \Delta E_{th} + \underbrace{\Delta E_{int}}_{\text{(internal Energy)}}$$

Isolated system: there can be no energy transfers to or from the isolated system

→ The total energy E of an isolated system cannot change

$$\Delta E_{mec} + \Delta E_{th} + \Delta E_{int} = 0$$

Summary

Potential energy is the energy that can be associated with the configuration

Work and Potential Energy $\Delta U = -W$

Principle of conservation of mechanical energy:

$$\Delta E_{mec} = \Delta K + \Delta U = 0$$

Force and potential energy: $$F(x) = -\frac{dU(x)}{dx}$$

Conservation of energy:

$$W = \Delta E = \Delta E_{mec} + \Delta E_{th} + \Delta E_{int}$$