Mechanics
Potential Energy
Conservative and Nonconservative Forces

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Last time

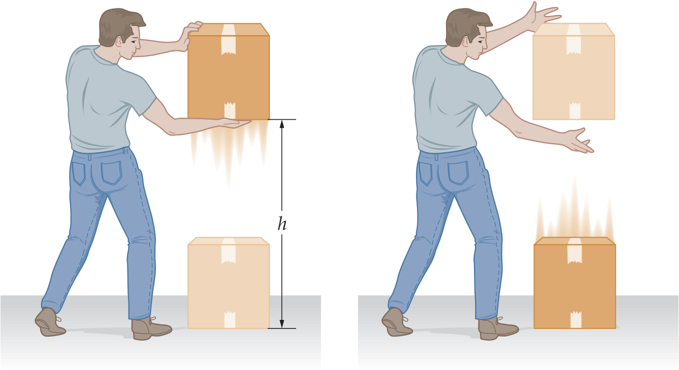
- work done by a varying force
- kinetic energy
- the work-kinetic energy theorem
- power

Overview

- concept of potential energy
- conservative and nonconservative forces
- potential energy definition
- some kinds of potential energy
- potential energy diagrams

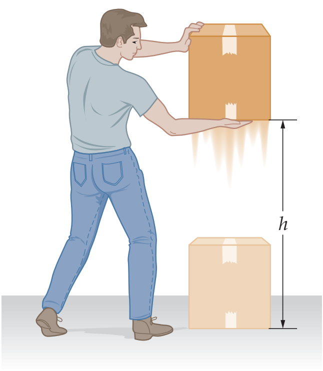
Work Done Lifting a Box

Work done by person (applied force) $W = Fd\cos(0^\circ) = mgh$.



When box falls, this energy becomes kinetic energy.
$W_{\text{net}} = mgh = \Delta K$.

Potential Energy



When the box is in the air, it has the “potential” to have kinetic energy.

The man put in work lifting it, as long as the box is held in the air, this energy is stored.

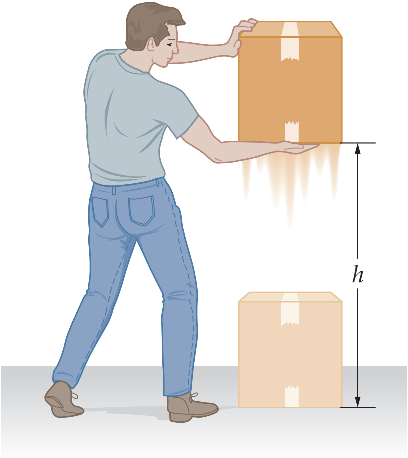
Potential Energy

This illustrates that there is another type of energy that it makes intuitive sense to assign in some systems.

That is a kind of energy that results from the configuration of the system, the **potential energy**.

Work Done Lifting a Box

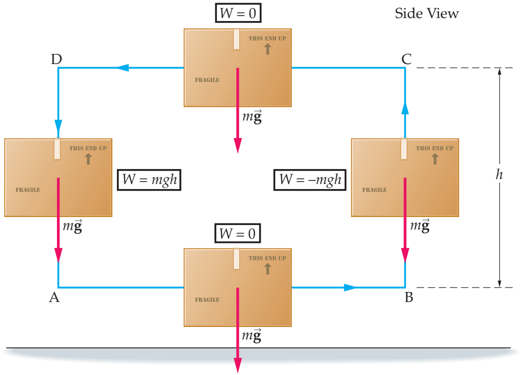
Work done by person (applied force) $W_{\text{app}} = Fd\cos(0^\circ) = mgh$.



Work done by gravity $W_g = Fd\cos(180^\circ) = -mgh$.

Conservative and Nonconservative Forces

The work done by gravity when raising and lowering an object around a closed path is zero.

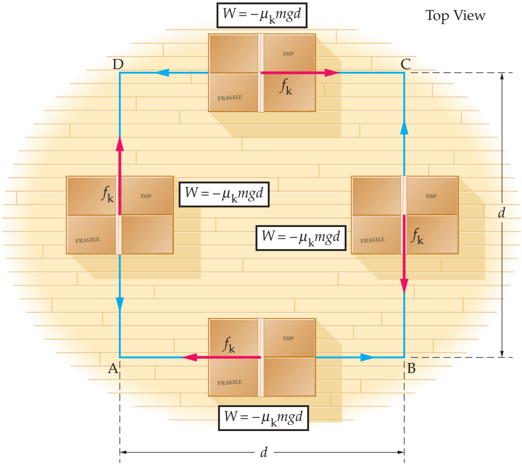


The path taken doesn't matter; if it comes back to the start, the work done is zero.

Forces (like gravity) that behave this way are called **conservative forces**.

Conservative and Nonconservative Forces

The work done by friction when pushing an object around a closed path is **not** zero.

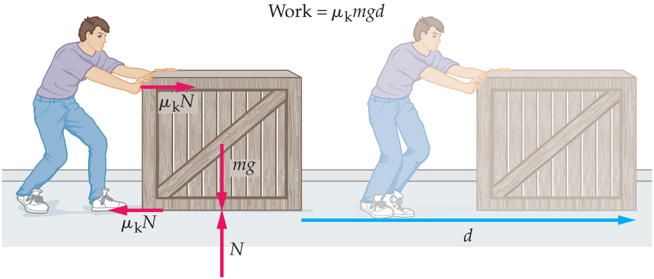


Forces (like friction) where the work done over a closed path is not zero are called **nonconservative forces**.

Nonconservative Forces: Friction

The work done by kinetic friction is always negative.

Kinetic friction points in the opposite direction to the velocity / instantaneous displacement.



$$W_{\text{fric}} = -f_k d = -\mu_k N d$$

where d is the distance the object moves along the surface.

Nonconservative Forces: Friction

Air resistance is another nonconservative force.

When a force does negative work on a system, **energy is transferred out** of the system.

In the case of kinetic friction, this energy increases the **temperature** of the two surfaces that rub on each other, and may also leave as **sound** waves.

This energy is lost to the system, but not to the universe.

Conservative Forces: Work Done Lifting a Box

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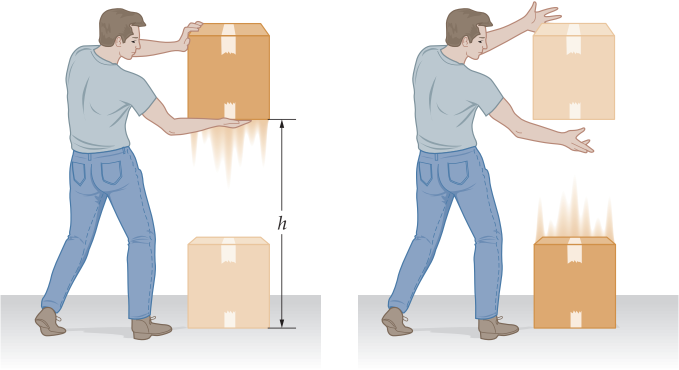

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Conservative Forces: Potential Energy

Any box that has been lifted a height h has had the same work done on it: mgh.

The path the box took to get to that height doesn't matter.

This is because gravity is a **conservative force**.

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Potential energy

energy that system has as a result of its configuration. Is always the result of the effect of a **conservative force**.

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The “configuration” of the system refers to how close the box is to center of the Earth.

To have a potential energy, we must *include the Earth* in the system and make the weight of the box an **internal force**.

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Any time a potential energy is introduced, the source of the conservative force becomes part of the system.

Potential Energy

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energy that system has as a result of its configuration. Is always the result of the effect of a conservative force.

$$\Delta U = -W_{\text{cons}}$$

Only conservative forces can have associated potential energies!

If a nonconservative force acts, any work done to displace the system (at constant velocity) leaves the system again as heat and sound.

That energy isn't stored $\Rightarrow$ no potential energy.

Gravitational Potential Energy

The change of potential energy when lifting an object of mass m near the Earth's surface:

$$\Delta U = mg(\Delta h)$$

If we choose the convention that $U = 0$ at the Earth's surface, then an object (mass m) at a height h has gravitational potential energy:

$$U = mgh$$

The Earth (which creates the gravitational force on the box) is **part of our system** description.

Gravitational Potential Energy

42. A 400-N child is in a swing that is attached to a pair of ropes 2.00 m long. Find the gravitational potential energy of the child–Earth system relative to the child's lowest position when (a) the ropes are horizontal, (b) the ropes make a 30.0° angle with the vertical, and (c) the child is at the bottom of the circular arc.

W

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(c) $U = 0$.

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Spring Force: Another Conservative Force

The spring force is also a conservative force.

If we stretch a spring, we can say that the spring stores the energy.

That energy is converted to kinetic energy when the end of the spring is released.

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There is also spring potential energy!

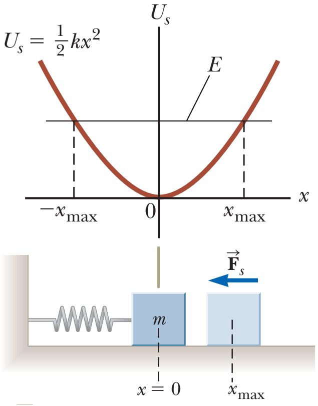
Choosing $U = 0$ when the spring is at its natural length (relaxed):

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

(The spring must be part of our system.)

Potential Energy Diagrams

Potential energy can be plotted as a function of position. *eg.* potential energy of a spring:



$$F_{sp} = -kx$$

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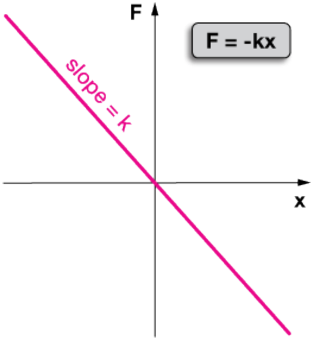
Potential Energy Diagrams

Recall that the work done by a force is the area under the force-displacement curve.



The work done *by the spring* relates to the change in the spring potential:

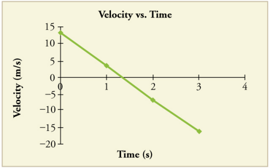
$$W_{\text{sp}} = -\Delta U_{\text{sp}}$$

So the area is also equal to $-\Delta U_{\text{sp}}$.

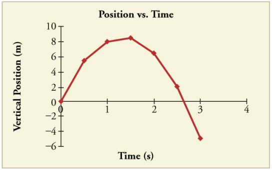
Potential Energy Diagrams

Comparison:

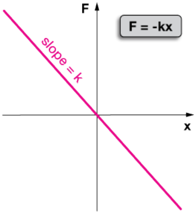
Area under v-t graph $= \Delta x$.



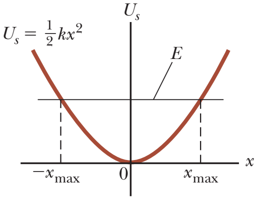
Slope of x-t curve $= v$. ($v = \frac{dx}{dt}$)



Area under F-x graph $= -\Delta U$.

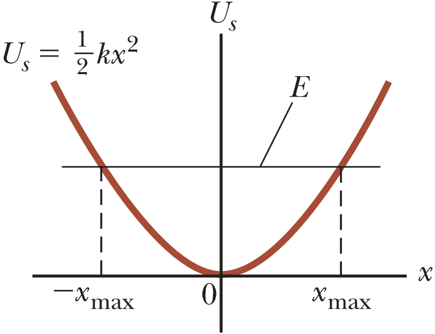


Slope of U-x curve $= -F$. ($F = -\frac{dU}{dx}$)



Potential Energy, Conservative Force, & Equilibrium

The value of a conservative force **F** at a particular point can be found as the **slope** of the potential energy curve:

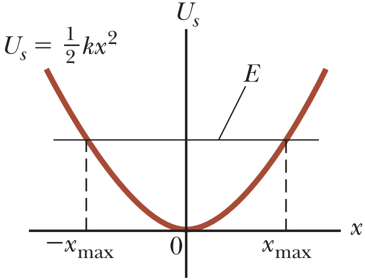


$$F_{\text{sp}} = -(\text{slope of } U(x)) = -kx$$

If F is the only force acting on the particle, stationary points (slope $= 0$) are force equilibrium points.

Energy Diagrams and Equilibrium

System is in equilibrium when $F_{\text{net}} = F_{\text{sp}} = 0$.

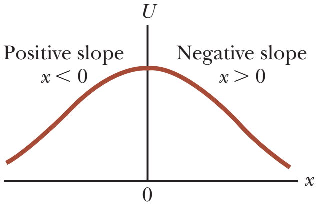


In this case, the force is always back toward the $x = 0$ point, so this is a **stable equilibrium**.

Examples:

- spring force
- ball inside a bowl

Energy Diagrams and Equilibrium



In this case, the force is always away from the $x = 0$ point, so this is a **unstable equilibrium**.

Examples:

- ball on upside-down a bowl

Neutral Equilibrium

A system can also be in **neutral equilibrium**.

In this case, no forces act, even when the system is displaced left or right.

Example:

- ball on a flat surface

Summary

- potential energy
- conservative and nonconservative forces

Quiz given out tomorrow.

Homework

- Ch 8 Probs: 1, 3, 5, 7