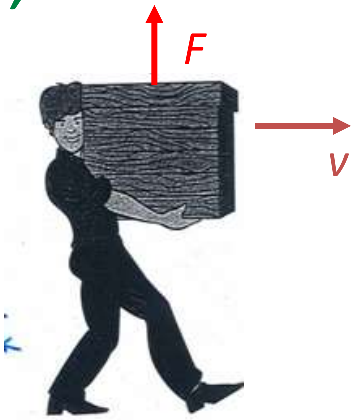
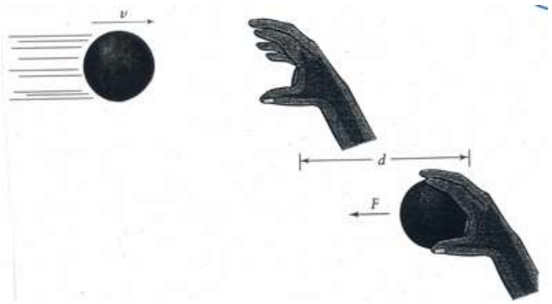
Work = force × distance

Force must be in the direction of motion

If perpendicular, no work!



If opposite, "negative work"



Energy

Amount of work an object can do

Units

Joules (J)

1 J = 1Nm

(also ft-lbs, Calories, kWh, BTU, etc.)

Clicker Question

I pick up a book from the floor, and place it on a table. The net work done on the book in this process is

A. positive.
B. zero.
C. negative.
D. imaginary.

Clicker Question

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Types of energy

- Electric and magnetic energy
- Chemical energy
- Gravitational potential energy
- Kinetic energy
- Elastic energy
- Nuclear energy
- Radiant energy (light, etc.)
- Thermal energy

Kinetic energy

The kinetic energy of an object in motion can be derived from Newton's laws:

$$\text{Work} = (\text{distance fallen}) \times (\text{force of gravity})$$
$$= (\tfrac{1}{2}\, g\, t^2) \times (m\, g)$$
$$= \tfrac{1}{2}\, m\, (g\, t)^2$$

speed after t seconds = $g\, t$

KinE = ½ × mass × the square of the speed

Thermal energy

Thermal energy is a kind of "kinetic energy at the atomic scale."

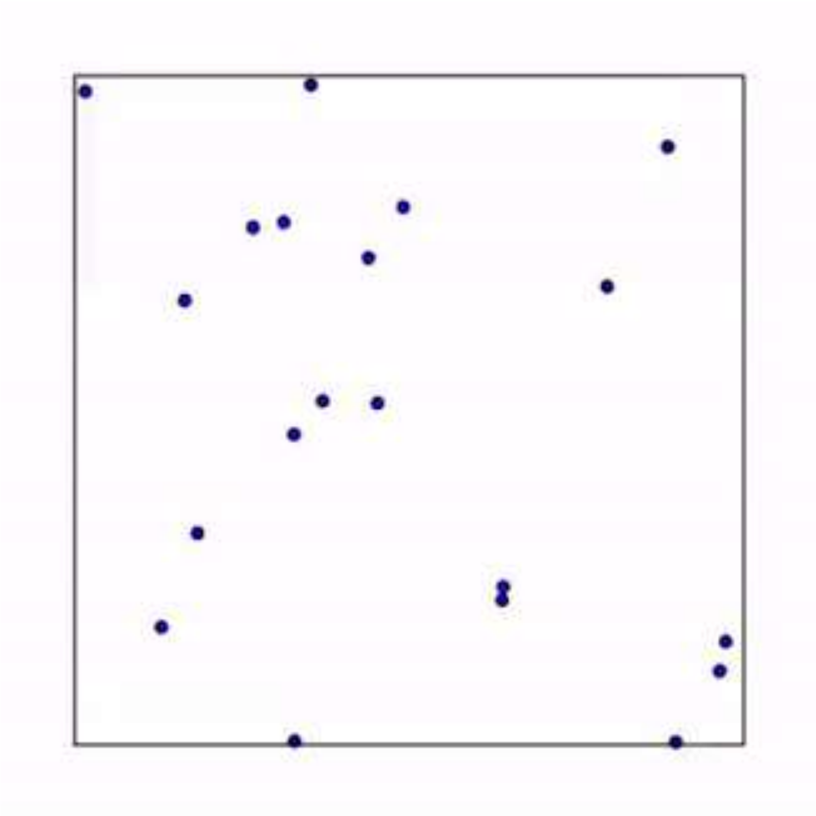
However, when we can't see the atoms jiggling around, we call it "thermal energy," not "kinetic energy."

Example: I am sitting still. Do I have any kinetic energy?

Let's demonstrate thermal energy…

Phet Simulation

Thermal energy



Average kinetic energy of an atom:

KE = 3/2 k T

T = absolute temperature

k = a proportionality constant

Clicker Question

A mixture of gases A and B is in thermal equilibrium. The molecules of B have four times the mass of those of A. What is the average kinetic energy of the molecules of type A, compared to the average kinetic energy of the B-type molecules?

A. Four times larger.
B. Twice as large.
C. The same.
D. Half as large.
E. One quarter as large.

Clicker Question

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Clicker Question

A mixture of gases A and B is in thermal equilibrium. The molecules of B have four times the mass of those of A. What is the typical speed of the molecules of type B, compared to that of the A-type molecules?

A. Four times larger.
B. Twice as large.
C. The same.
D. Half as large.
E. One quarter as large.

Clicker Question

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Average kinetic energy of an atom:

KE = 3/2 k T

T = absolute temperature

k = a proportionality constant

KE = ½ m v^2

Clicker Question

If you put a helium balloon in liquid nitrogen to cool it, what will happen?

A. The balloon will shrink and drop.
B. The balloon will expand and rise.
C. The balloon will expand and drop.
D. The balloon will shrink and rise.

Clicker Question

If you put a helium balloon in liquid nitrogen to cool it, what will happen?

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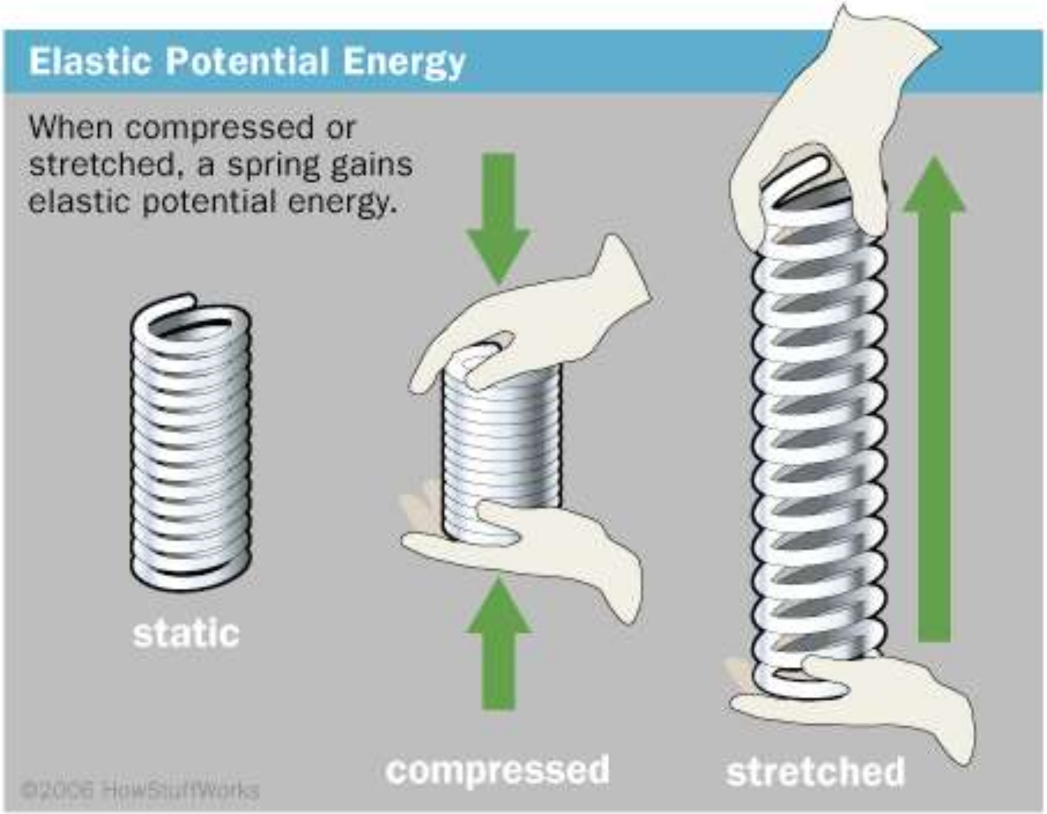
Elastic energy



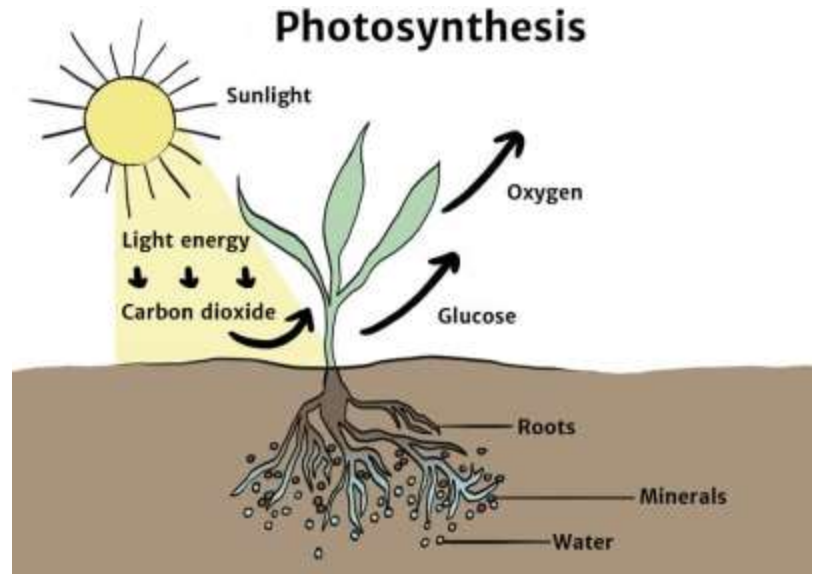
Hooke's law: Force $\propto$ distance stretched or compressed

Let's demonstrate this ….

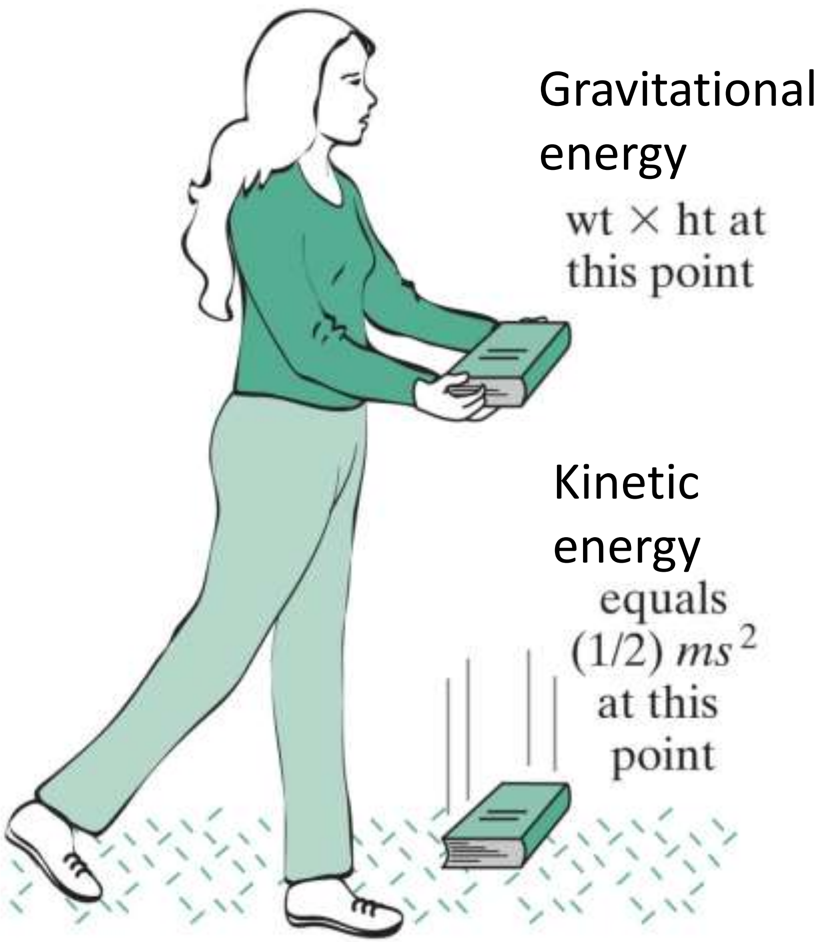
[Phet simulation]

Chemical Energy: Combustion

Chemical Energy w/o combustion



Energy transformations



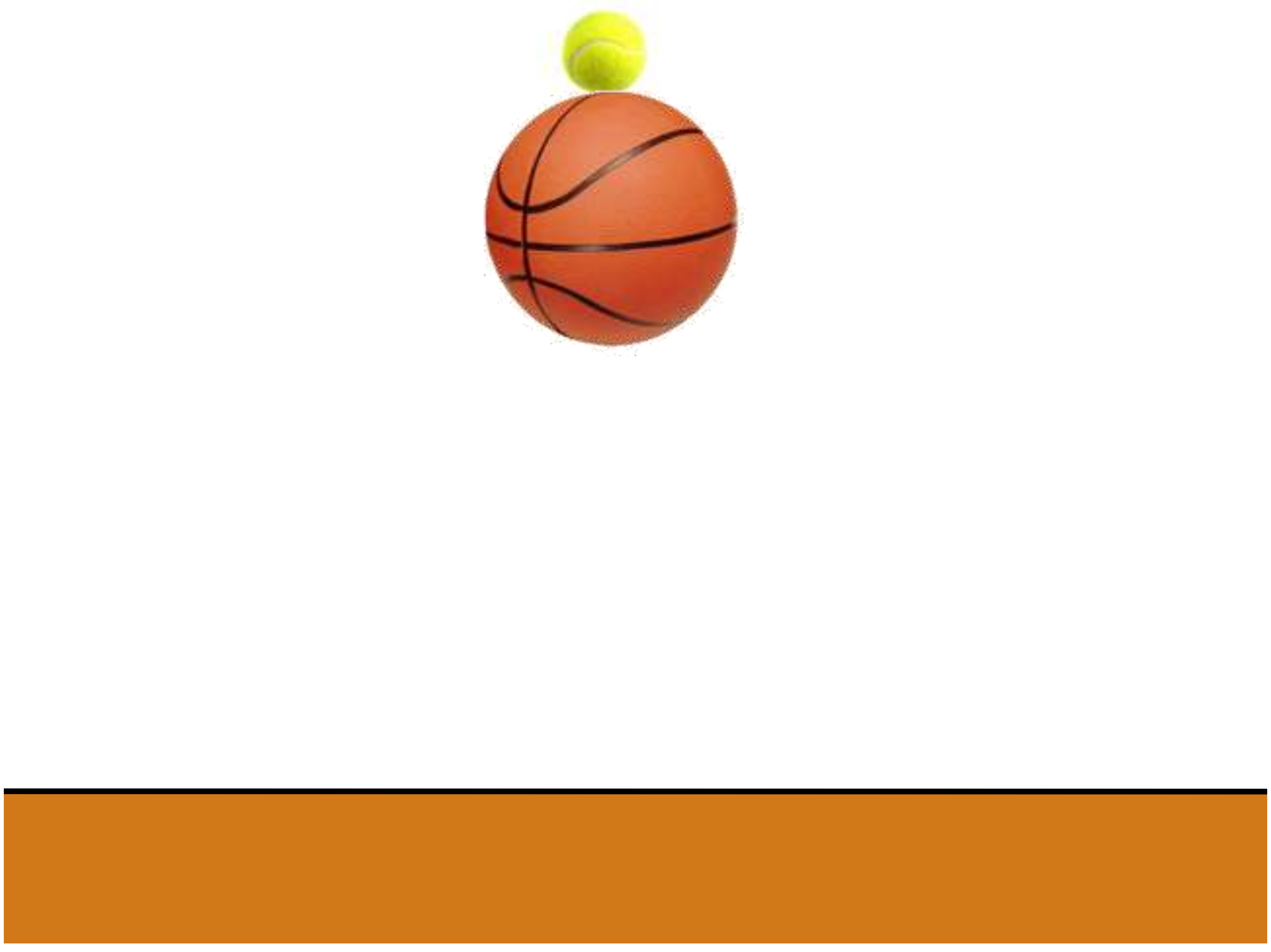
If you drop a book, its gravitational energy when you let it drop is the same as its kinetic energy just before it hits the floor.

Law of Conservation of Energy

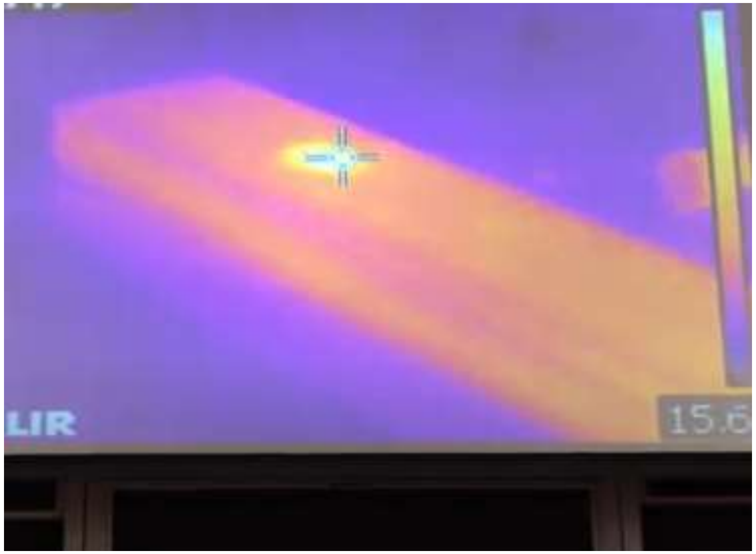
- The total energy of all the participants in a process remains unchanged throughout the process.
- Energy cannot be created or destroyed, only transferred from one object to another, or changed from one form into another.

Energy transformations

Energy can be transformed from one kind into another…



[Wrecking ball pendulum]

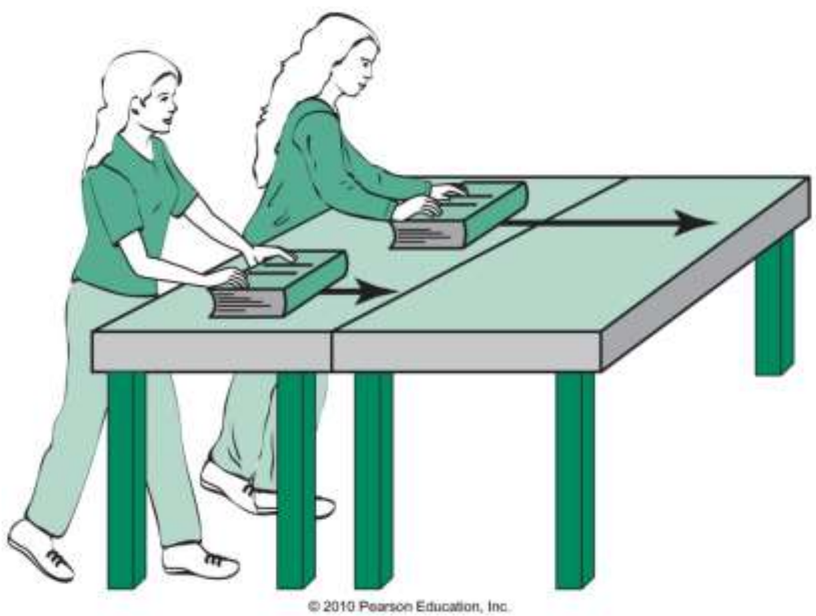


[Infrared imaging of hammer impact]

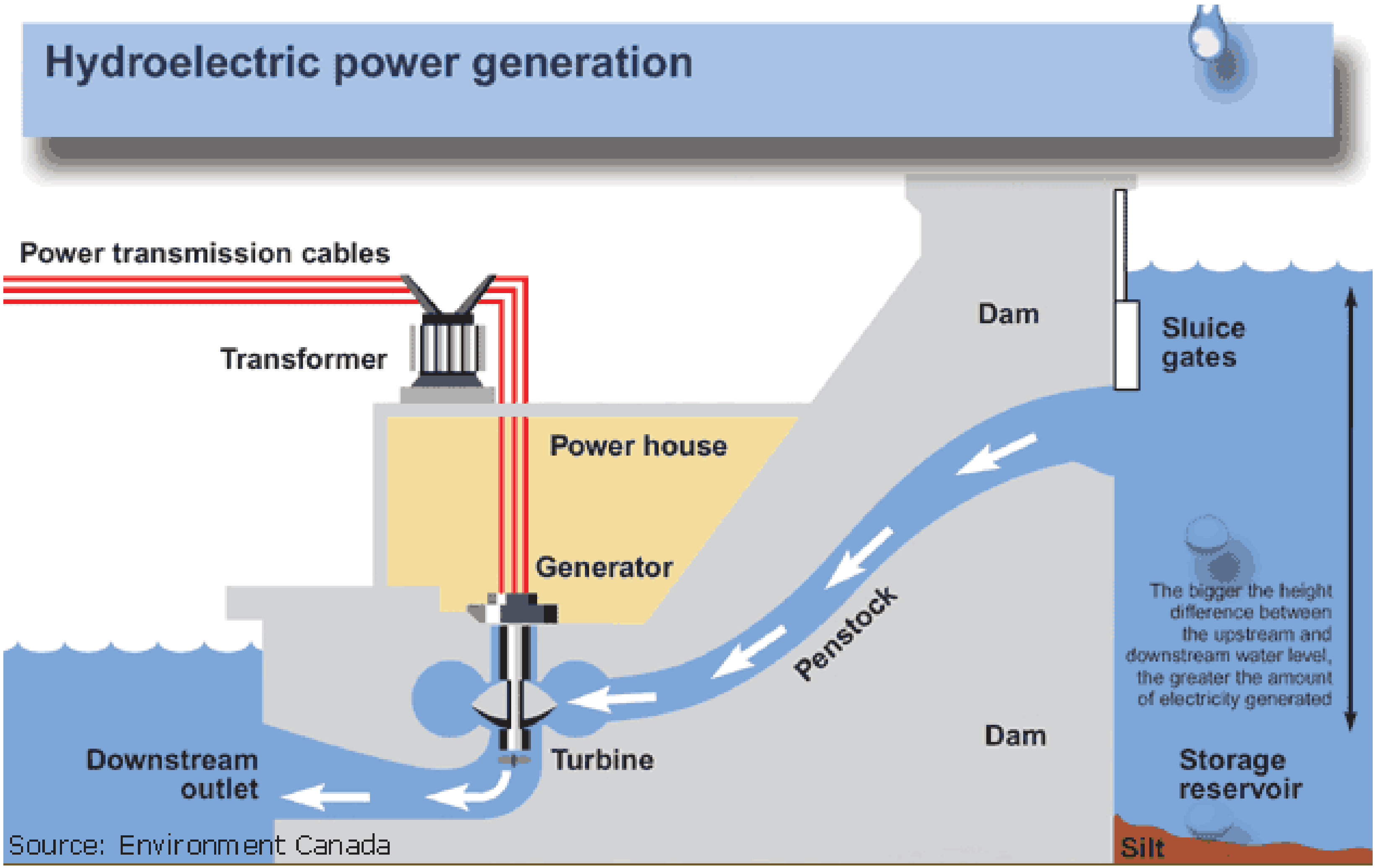
Work-Energy Principle

- Work is a form of energy transfer.
- Work reduces the energy of the object doing the work, while increasing the energy of the object on which the work is done, by an equal amount.

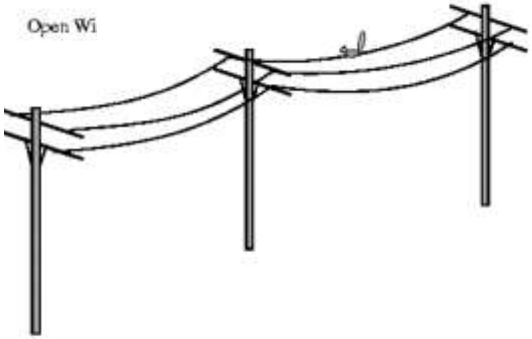
Energy transformations

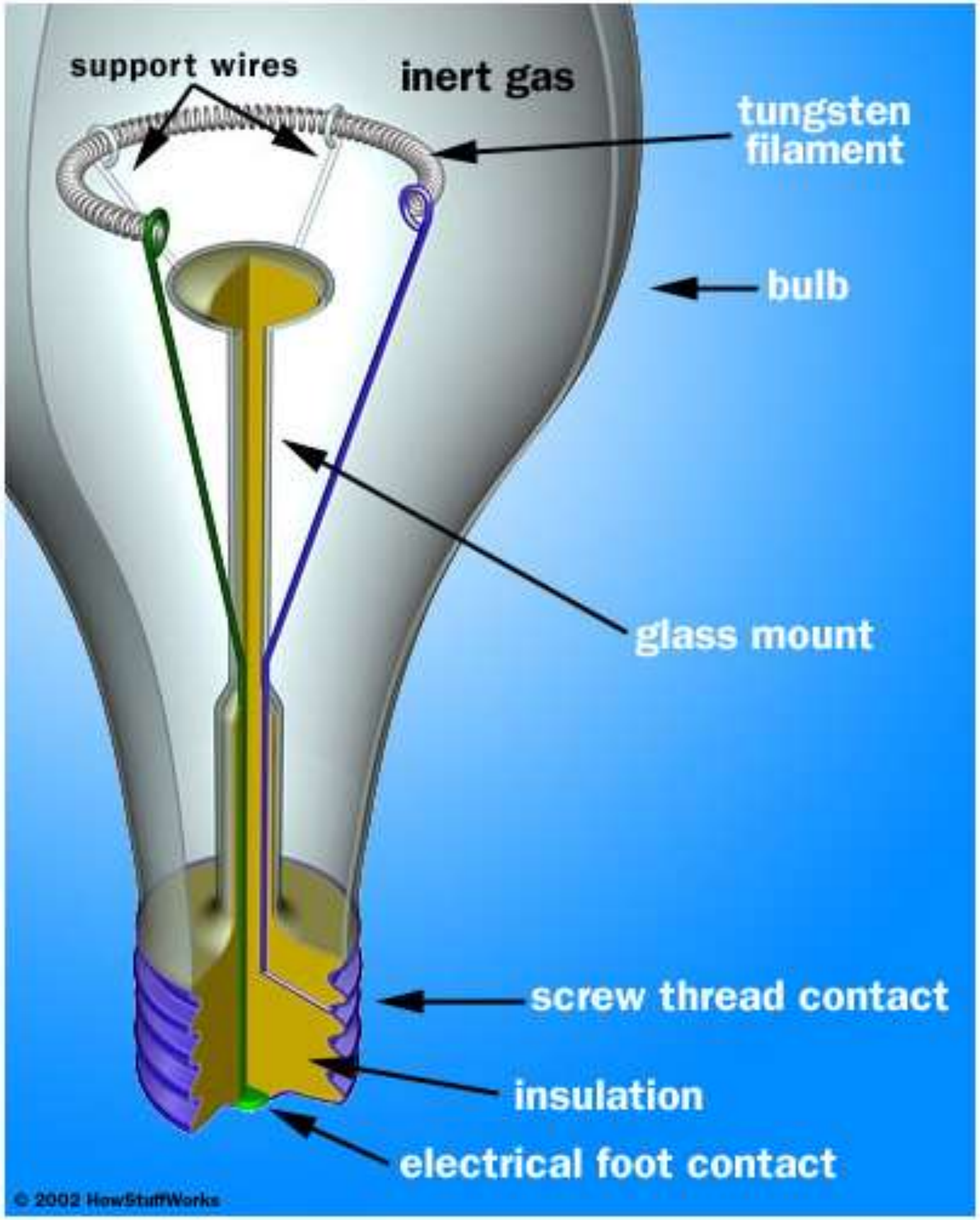


Energy transformations



Energy transformations





support wires
inert gas
tungsten filament
bulb
glass mount
screw thread contact
insulation
electrical foot contact
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Estimations and magnitudes

1 Calorie = 1 kcal = 4200 J

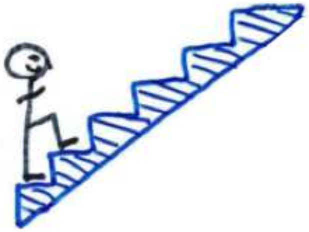
1 Boston Creme Donut = about 250 Calories

1 Boston Creme Donut = about 10^6 J

1 lb of TNT = about 10^6 J, too!

10^6 J can lift 500 N person about 2 km

10^6 J allows 110 lb person to climb ~ 6000 ft



Estimations and magnitudes

1 speck of ^{235}U the size of a grain of sand

= 10^9 J of nuclear energy

= 1000 lbs of TNT

= allows you to climb 1000 mountains

Other forms of energy transfer

Question: Is work the only kind of energy transfer?

No, there are forms of heating that also accomplish energy transfer.

convection

radiation

Energy Transformations

Clicker Question

Which of the following converts some form of energy into chemical energy?

A. Walking upstairs
B. Dropping a tennis ball
C. Chemiluminescence
D. Respiration
E. Photosynthesis

Clicker Question

Which of the following converts some form of energy into chemical energy?

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