PhyzGuide: Conservation of Energy

JOULE'S CROWNING ACHIEVEMENT

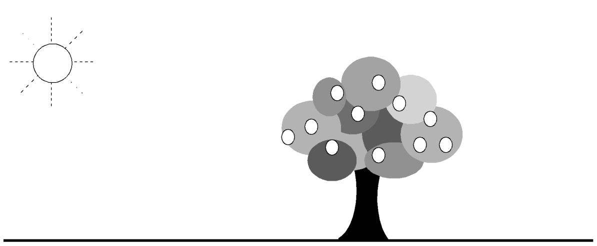
On a wintry night in 1843, a British brewer who dabbled in physics delivered a lecture at a church in Manchester, England that presented an idea as revolutionary and unifying as any discovery of Galileo or Newton. On that night, James Prescott Joule proposed the principle of the conservation of energy. The specifics of his discovery will be explored in a future unit (*stay tuned*), but the implications of his findings are here for us to take advantage of immediately.

The principle of **conservation of energy** is that energy is never created or destroyed. Energy is *always* conserved, completely and absolutely. Sounds neat, but what does it mean? On the surface, it seems to contradict many simple observations.

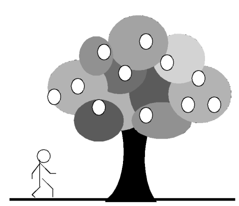
For example, isn't potential energy created when a rock is lifted, and doesn't that energy dissipate when the rock is dropped? And isn't kinetic energy created when a dart is thrown, and doesn't that energy dissipate when the dart hits the dartboard? And what about pushing a crate across the floor? The work that is done (the energy put into the system) seems to dissipate immediately—the crate neither rises to a higher elevation nor does it accelerate to a higher speed: it starts at rest and ends at rest. Are these all exceptions to the principle of conservation of energy?

They are not. And to this date, a violation of conservation of energy has yet to be found. So what's going on?

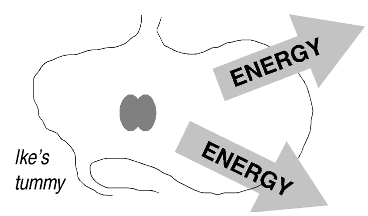
The creation or destruction of energy does not happen. Ever. But energy does undergo *transformations* from one type to another. Consider the sequence of energy transformations depicted below. (And understand that many others are possible!)



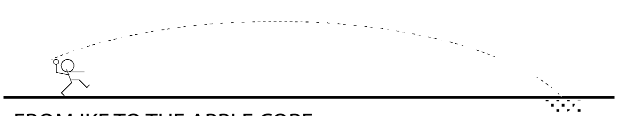
FROM THE SUN TO THE EARTH
Energy produced in nuclear fusion reactions in the sun is radiated away in all directions. About 3% of the sun's energy is "absorbed" by the earth. That energy warms the air, land, and water, and is also an integral part of photosynthesis, which makes this apple tree grow. The sun's energy is stored in the chemical bonds of the molecules produced by photosynthesis.



Our good buddy, Ike, comes along and picks an apple. He promptly eats the apple.



FROM THE APPLE TO IKE
In the digestion process, energy stored in the molecular bonds of the sugars in the apple is released as those bonds are broken. Most of that energy is used by Ike's body to maintain metabolic processes.



FROM IKE TO THE APPLE CORE
Ike then hurls the apple core as far as he can. Energy flows from Ike to the apple core as he imparts kinetic energy to it.

FROM THE APPLE CORE TO THE ENVIRONMENT
But what happens to the energy Ike gave to the apple core when the core hits the ground? Some of it dissipates as sound that gives energy to the surrounding air molecules. The rest is dissipated as thermal energy: the apple and the ground experience localized temperature increases.

PhyzExample: Conservation of Energy

The simplest conservation of energy problems involve conservation of mechanical energy. There are two forms of mechanical energy: potential and kinetic. When no work is being done on a system, total mechanical energy is conserved. That is, the sum of potential energy and kinetic energy before an event is equal to the sum of potential energy and kinetic energy after the event.

To get a sense of the analytical power of the principle of conservation of energy, consider the following numerical problem.

A popular carnival game involves striking a lever with a mallet to propel a weight up a pole. If the lever is struck with sufficient force, the weight rises to the top of the pole where a mounted bell is struck, and the contestant wins a prize. If the weight consists of a 1 kg mass, the lever propels the weight through a distance of 16 cm, and the pole is 5 m tall,

a. how much force is needed to propel the weight to the bell?
b. with what speed will the weight leave the lever if struck with that force?
Neglect retarding forces.

$m = 1$ kg $\quad h = 5$ m $\quad d = 0.16$ m

a. $W = PE$

$F \cdot d = mgh$

$F = mgh/d$

$F = 1 \text{ kg} \cdot 9.8 \text{ m/s}^2 \cdot 5 \text{ m} / 0.16 \text{ m}$

$\underline{F = 310 \text{ N}}$

b. $KE_{bottom} = PE_{top}$

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

$v = \sqrt{(2gh)}$

$v = \sqrt{(2 \cdot 9.8 \text{ m/s}^2 \cdot 5 \text{ m})}$

$\underline{v = 10 \text{ m/s}}$ (= 22 mph)