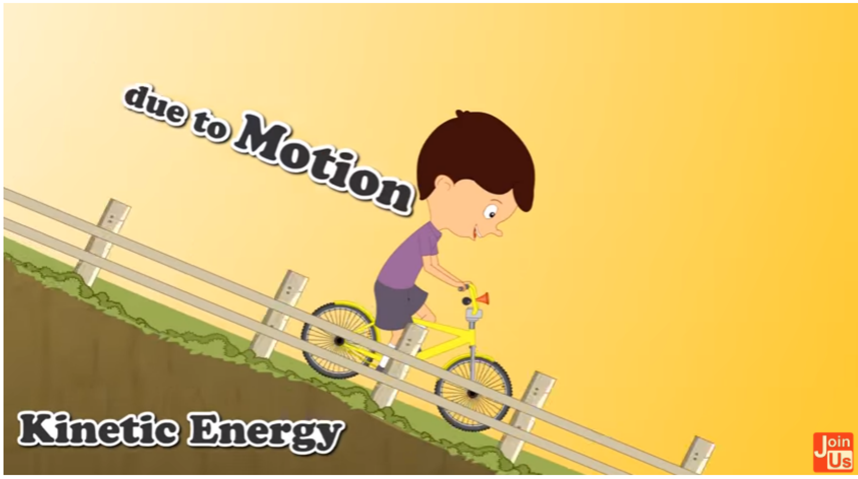
3.7: Energy

Energy is usually defined as the capability for doing work. For example, a billiard ball can collide with a second ball, changing the direction or speed of motion of the latter. In such a process the motion of the first ball would also be altered. We would say that one billiard ball did work on (transferred energy to) the other.

Kinetic Energy



Cartoon of a boy riding a bike downhill. The words "kinetic energy" and "due to motion" are also on the picture.

Image source: Smart Learning for All

Energy due to motion is called kinetic energy and is represented by E_k. For an object moving in a straight line, the kinetic energy is one-half the product of the mass and the square of the speed:

$$E_k = \frac{1}{2} m u^2 \tag{3.7.1}$$

where

- m = mass of the object
- u = speed of object

If the two billiard balls mentioned above were studied in outer space, where friction due to their collisions with air molecules or the surface of a pool table would be negligible, careful measurements would reveal that their total kinetic energy would be the same before and after they collided. This is an example of the **law of conservation of energy**, which states that *energy cannot be created or destroyed* under the usual conditions of everyday life. Whenever there appears to be a decrease in energy somewhere, there is a corresponding increase somewhere else.

Example 3.7.1 : Kinetic Energy

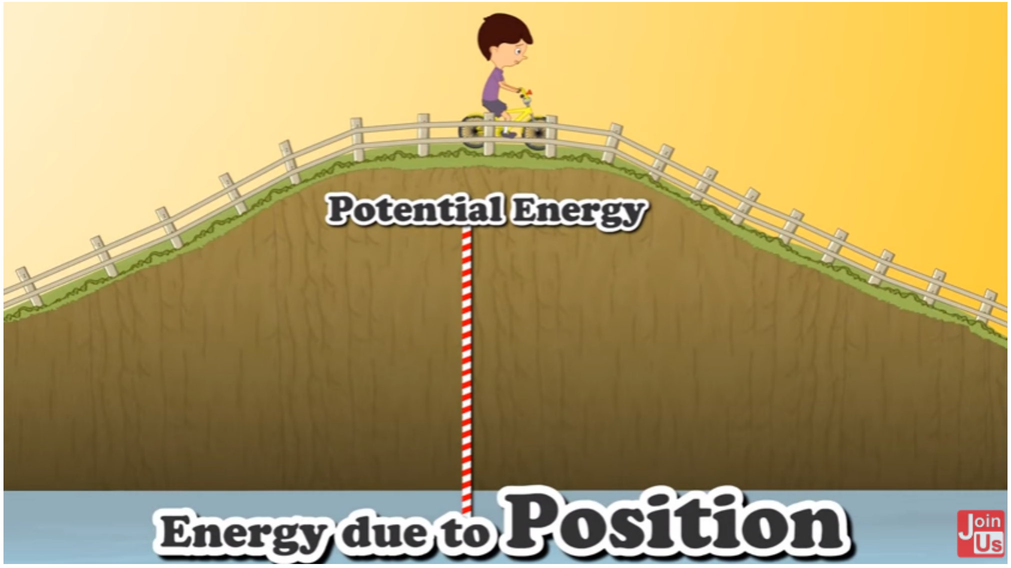
Calculate the kinetic energy of a Volkswagen Beetle of mass 844 kg (1860 lb) which is moving at 13.4 m s^{-1} (30 miles per hour).

Solution:

$E_k = \frac{1}{2} m u^2 = \frac{1}{2} \times 844 \text{ kg} \times (13.4 \text{ m s}^{-1})^2 = 7.58 \times 10^4 \text{ kg m}^2 \text{ s}^{-2}$

In other words the units for energy are derived from the SI base units kilogram for mass, meter for length, and second for time. A quantity of heat or any other form of energy may be expressed in kilogram meter squared per second squared. In honor of Joule's pioneering work this derived unit 1 kg m^2 s^{-2} called the **joule**, abbreviated J. The Volkswagen in question could do nearly 76 000 J of work on anything it happened to run into.

Potential Energy



Boy on a bike on the peak of a hill. The words "potential energy" and "energy due to position" are also on the picture.

Image source: Smart Learning for All

Potential Energy is energy that is stored by rising in height, or by other means. It frequently comes from separating things that attract, like rising birds are being separated from the Earth that attracts them, or by pulling magnets apart, or pulling an electrostatically charged balloon from an oppositely charged object to which it has clung. Potential Energy is abbreviated E_P and gravitational potential energy is calculated as follows:

$$E_P = mgh \tag{2}$$

where

- m = mass of the object in kg
- g = gravitational constant, 9.8 m s^2
- h = height in m

Notice that E_P has the same units, kg m^2 s^{-2} or ***Joule*** as kinetic energy.

✔ Example 3.7.2: Kinetic Energy Application

How high would the VW weighing 844 kg and moving at 30 mph need to rise (vertically) on a hill to come to a complete stop, if none of the stopping power came from friction?

Solution:

The car's kinetic energy is 7.58 × 10^4 kg m^2 s^{-2}(from EXAMPLE 3.7.1), so all of this would have to be converted to E_P. Then we could calculate the vertical height:

$$E_P = mgh = 7.58 \times 10^4 \text{ kg m}^2 \text{ s}^{-2} = 844 \text{ kg} \times 9.8\text{ms}^{-2} \times h$$
$$h = 9.2 \text{ m}$$

Even when there is a great deal of friction, the law of conservation of energy still applies. If you put a milkshake on a mixer and leave it there for 10 min, you will have a warm, rather unappetizing drink. The whirling mixer blades do work on (transfer energy to) the milkshake, raising its temperature. The same effect could be produced by heating the milkshake, a fact which suggests that heating also involves a transfer of energy. The first careful experiments to determine how much work was equivalent to a given quantity of heat were done by the English physicist James Joule (1818 to 1889) in the 1840s. In an experiment very similar to our milkshake example, Joule connected falling weights through a pulley system to a paddle wheel immersed in an insulated container of water. This allowed him to compare the temperature rise which resulted from the work done by the weights with that which resulted from heating. Units with which to measure energy may be derived from the SI base units of Table 1 from The International System of Units (SI)(opens in new window) by using Eq. 3.7.1.

Another unit of energy still widely used by chemists is the **calorie**. The calorie used to be defined as the energy needed to raise the temperature of one gram of water from 14.5°C to 15.5°C but now it is defined as exactly 4.184 J.
