# ENERGY AND POWER

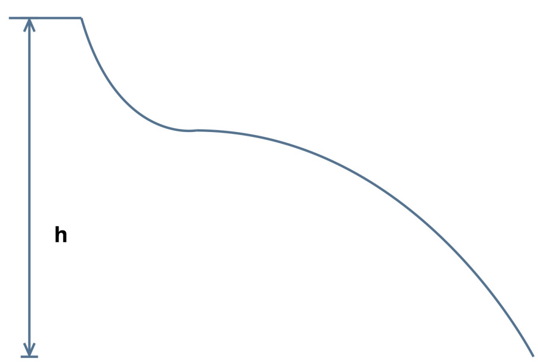
## Energy

In modern language, the terms energy and power often get confused. In physics, each term has a very specific meaning. It is important to understand the difference between both terms clearly in order to assist in analyses.

Energy refers to the capacity of a physical system to perform work. It is the amount of “stuff” in a system. It can refer to kinetic energy, potential energy, electrical energy, along with several other classifications. The units of energy include joules (J), calories (cal), kilocalories (kcal or Cal), kilowatt hours (kWh), British Thermal Units (BTU), electron volts (eV), along with other units.

In the bulletin titles “Work and Energy”, the statement of the conservation of mechanical energy was discussed. This is a very useful concept in that it allows a means to solve a complicated problem easily. It deals with the initial state and the final state of a system and does not itself with the intermediate states of a system.

For example, consider a situation in which an object is sliding down a frictionless surface with uneven elevations as follows:




Given such a path, it would be very difficult to determine the speed of the falling object at the base of the path through the use of Newton’s second law given that the acceleration of the object varies along every point. However, using the statement of conservation of energy, we could easily determine the speed of the object at the base as follows:

$U_0 = mgh$

$K_0 = 0$

$K_0 + U_0 = mgh$

$K = \frac{mv^2}{2}$

At the bottom of the path, all of the potential energy would have been converted into kinetic energy. Therefore,

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

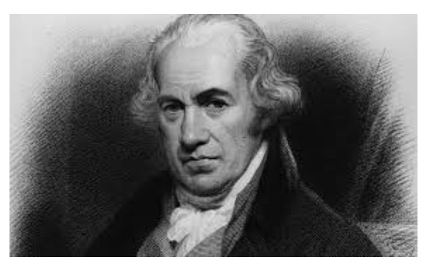
Solving for "v", we obtain,

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

The above equation solves for the speed of the object at the bottom of the hill for any height "h". Note that the shape of the path does not matter. Any path with the same height "h" would have resulted in the same speed.

# Power

In physics, power is defined as the rate of doing work, or using, generating, or transferring energy. The units of power include the watt (W), horsepower (hp), and million barrels of oil equivalent per day (MBOE/day). All power units involve units of energy and units of rate.



James Watt

The watt is likely the most frequently used unit of power in the SI system. The concept of the watt and that of horsepower were developed by James Watt (1736-1819). In his childhood, Watt exhibited superior manual dexterity, engineering skills, and an aptitude for mathematics. In 1757, he set up a small workshop at the University of Glasgow. While working on steam engines, he determined that there was a significant waste of energy in the operation of the contemporary steam engines. He realized that a energy was being dissipated as heat as opposed to mechanical energy. In the course of studying steam engines, the unit of watt was developed and was defined as 1 joule per second (1W = 1J/sec).

Since are studies are concerned with collision reconstruction, it may be of benefit to recognize that one horsepower is equivalent to 746 watts.

In order to better understand the application of power in an analysis, consider the following scenario.

<u>Scenario:</u>

A cyclist is peddling up an incline with a grade of approximately 10% (6 degrees) at approximately 14 kph. The mass of the cyclist and the bicycle combined is 80 kg. What is the minimum power required?

*Answer:*

The word required to rise an elevation “h” is defined as,

$$W = mgh$$

Since power is the rate of doing work,

$$P = \frac{W}{\Delta t}$$

$$P = \frac{mgh}{\Delta t}$$

The above equation is mathematically equivalent to the following,

$$P = mg\frac{\Delta h}{\Delta t}$$

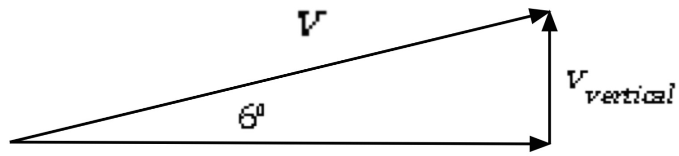
However, the change in height divided by the change in time is the definition of the vertical component of the speed of the cyclist. Therefore,

$$\frac{\Delta h}{\Delta t} = v_{vertical}$$

As a result, the equation for power can be rewritten as follows,

$$P = mgv_{vertical}$$

The relationship between the velocity of the cyclist and the vertical component of that velocity can is as follows:




In our case, the cyclist in travelling at approximately 14 kph. This is approximately equal to 4 m/s. Therefore, the vertical component of the cyclist's velocity can be determined as follows:

$v_{vertical} = v \sin 6$

$v_{vertical} = 4 \sin 6$

$v_{vertical} = 0.4 \text{ m/s}$

As a result, the power exerted by the cyclist is:

$$P = mgv_{vertical}$$

$$P = (80)(9.81)(0.4)$$

$$P = 314 \text{ W}$$

This is approximately the same power required to light 3 100W light bulbs.

Interesting Factoid

Another measure of energy is the calorie (cal). This unit was defined by Nicolas Clement (1779-1842). Professor Clement held the chair of chemistry at the Conservatoire des Arts Metiers in Paris. Clement clearly understood the concept of a mechanical equivalent of heat and emphasized the thermodynamics of steam in powering steam engines.

The word "calorie" was derived from the latin "calor" meaning "heat." The calorie (cal) is defined as the amount of energy needed to raise the temperature of one gram of water by one degree celsius at one atmosphere of pressure. However, the common unit of measure is the kilocalorie (Cal). This is the unit usually referred to dietary measures.

One kilocalorie (Cal) is equivalent to about 4200 joules.

The typical human diet contains approximately 2000 Cal per day. Once the units are converted, this is equivalent to about 100 W.