3 Energy

3.1. Types of energy

What do you understand by the term “**energy**”?

Energy is rather an abstract concept, but it helps us to understand and predict the outcome of physical processes. It can be quantified, although not measured directly. To calculate the energy of a system, you will need to know other, measurable properties, such as temperature, pressure or speed. Sometimes it is helpful to think of it as the capacity to do work.

Make a list of all the different types of energy you have heard of or know about.

You may have thought of energy types such as mechanical energy, electrical energy, thermal energy or nuclear energy.

In this module we will be considering two main classes of energy – **mechanical** and **thermal**. But there are different types of mechanical energy, some of which you may have listed. These are:

(a) **kinetic energy**, E_k – the energy a body possesses by virtue of its motion:

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

where m is the mass (kg)

v is the velocity (or speed) (ms^{-1})

(b) **gravitational potential energy**, E_p – the energy a body possesses by virtue of its height above a datum (usually the ground).

$$E_p = mgh$$

where g is the acceleration due to gravity, 9.81 ms^{-2}

h is the height above a datum (defined zero level) (m)

(c) **strain energy** (or stored elastic energy) but this is not considered in this module.

(d) **"pressure" energy** – if a fluid has a higher pressure at one point than at another, then it will tend to flow from the high pressure to the low pressure. Whenever there are viscous forces (friction) then there must be a pressure difference within the fluid to overcome the friction if the fluid is going to flow at all. So, we can consider pressure to be a form of energy, in that a fluid at pressure has the capacity to flow, thereby gaining kinetic energy.

Thermal energy is usually called **internal energy**, and given the symbol, *U* - this is the energy a body possesses due to its temperature.

Everything around us is made of molecules, and these molecules are in constant motion. This means they have kinetic energy. As the temperature of a body rises, the molecules move faster and faster, and therefore their kinetic energies increase. You can think of the internal energy as being the sum of all the molecules' kinetic energies. As the temperature rises, the internal energy increases. In fact, we can define internal energy so that it is directly proportional to the temperature. For a thermally perfect substance,

$$U = mc_vT$$

where c_v is the specific heat at constant volume ($Jkg^{-1}K^{-1}$)

T is the absolute temperature (K).

A system may possess many types of energy, and its total energy will be the sum of them all.

For example, a spinning cricket ball sent into the air by Nasser Hussein on a lovely summer's day, will have kinetic energy because it is moving, gravitational potential energy because it is high in the air, and internal energy, because its temperature is way above absolute zero. Its total energy, $E = E_k + E_p + U$.

3.2 The First Law of Thermodynamics

Detailed experiments performed over the last century have shown that energy is conserved – that is, it can neither be created nor destroyed; it can only be transformed from one type into another.

For the energy of a system to change, a **process** must take place (1.6). During a process, work is done, heating is exchanged, or both of these occur. Working and heating are the ways in which energy is transferred from one system to another. The resulting change in the energy of the system is manifest by the change of its properties.

For example, when you boil water in an electric kettle, what energy transfers are taking place? How do you know that an energy transfer has occurred?

Have you ever felt the tip of an electric drill, after drilling a hole in a wall? What energy transfer has taken place to change the properties of the drill?

The **First Law of Thermodynamics** is essentially a statement of the law of conservation of energy. (A physical "law" is a rule which has not been shown to be broken.) It states that the change in the energy of a system is equal to the energy transferred to it by working and heating.

Mathematically we write this as:

$$Q + W = \Delta E$$

where Q is the energy transferred by heating (J)

W is the energy transferred by working (J)

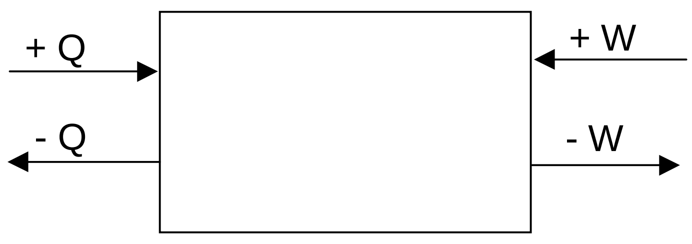
ΔE is the *change* in the total energy of the system (J)

A cycle is a series of processes after which the system is returned to its original state. There is, therefore, no overall change in energy. We write this as:

$$\Sigma Q + \Sigma W = 0$$

Sign conventions

Whenever energy is transferred to a system it is given a positive sign. So if the system is *heated*, Q is *positive*, while if it is *cooled* Q is *negative*. If work is done *on* the system, so that its energy is increased, W is *positive*, but if work is done *by* the system (such as when a gas expands against a piston), then W is *negative*.



Further reading:

Bacon and Stephens, Mechanical Technology	23.1-23.4
Rogers, G and Mayhew, Y, Engineering Thermodynamics Work and Heat Transfer	Chs 1 – 2
The Open University, T236 Introduction to thermofluid mechanics	Block 4