13 Energy transfer

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Energy is a theme that pervades all branches of science. It links a wide range of phenomena and enables us to explain them. It exists in different forms and when something happens, it is likely to be due to energy being transferred from one form to another. Energy transfer is needed to enable people, computers, machines and other devices to work and to enable processes and changes to occur. For example, in Figure 13.1, the water skier can only be pulled along by the boat if there is energy transfer in its engine from the burning petrol to its rotating propeller.

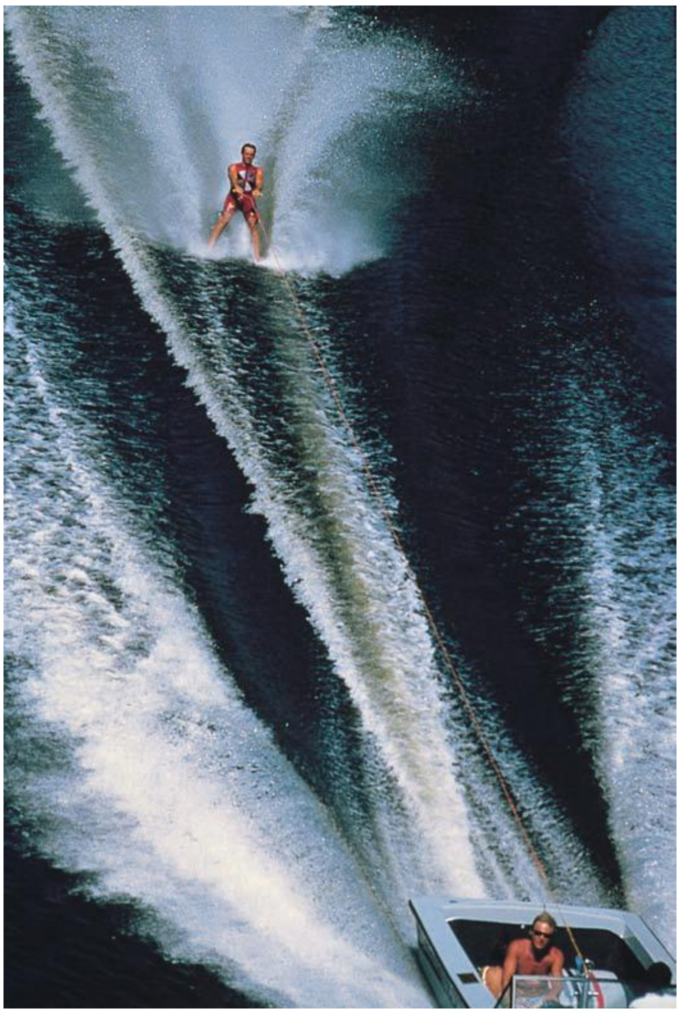

Figure 13.1 Energy transfer in action

Forms of energy

a) Chemical energy

Food and fuels, like oil, gas, coal and wood, are concentrated stores of **chemical energy** (see Chapter 15). The energy of food is released by chemical reactions in our bodies, and during the transfer to other forms we are able to do useful jobs. Fuels cause energy transfers when they are burnt in an engine or a boiler. Batteries are compact sources of chemical energy, which in use is transferred to electrical energy.

b) Potential energy (p.e.)

This is the energy a body has because of its position or condition. A body above the Earth's surface, like water in a mountain reservoir, has **potential energy** (p.e.) stored in the form of **gravitational potential energy**.

Work has to be done to compress or stretch a spring or elastic material and energy is transferred to potential energy; the p.e. is stored in the form of **strain energy** (or **elastic potential energy**). If the catapult in Figure 13.3c were released, the strain energy would be transferred to the projectile.

c) Kinetic energy (k.e.)

Any moving body has **kinetic energy** (k.e.) and the faster it moves, the more k.e. it has. As a hammer drives a nail into a piece of wood, there is a transfer of energy from the k.e. of the moving hammer to other forms of energy.

d) Electrical energy

Electrical energy is produced by energy transfers at power stations and in batteries. It is the commonest form of energy used in homes and industry because of the ease of transmission and transfer to other forms.

e) Heat energy

This is also called **thermal** or **internal energy** and is the final fate of other forms of energy. It is transferred by conduction, convection or radiation.

f) Other forms

These include **light energy** and other forms of **electromagnetic radiation**, **sound** and **nuclear energy**.

Energy transfers

a) Demonstration

The apparatus in Figure 13.2 can be used to show a battery changing **chemical energy** to **electrical energy** which becomes **kinetic energy** in the electric motor. The motor raises a weight, giving it **potential energy**. If the changeover switch is joined to the lamp and the weight allowed to fall, the motor acts as a generator in which there is an energy transfer from **kinetic energy** to **electrical energy**. When this is supplied to the lamp, it produces a transfer to **heat** and **light energy**.

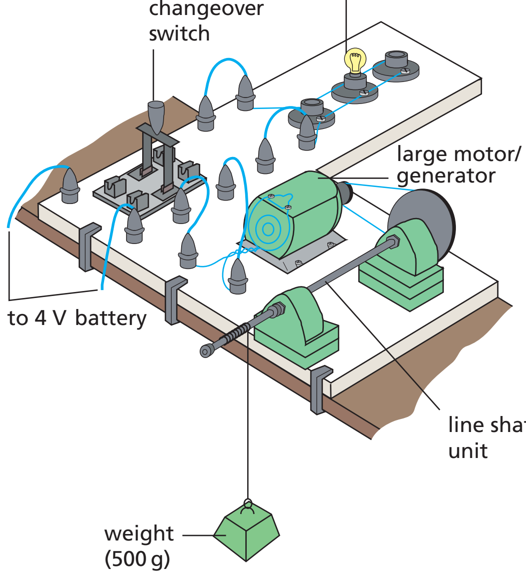

Figure 13.2 Demonstrating energy transfers

b) Other examples

Study the energy transfers shown in Figures 13.3a to d. Some devices have been invented to cause particular energy transfers. For example, a **microphone** changes sound energy into electrical energy; a **loudspeaker** does the reverse. Belts, chains or gears are used to transfer energy between moving parts, such as those in a bicycle.

a Potential energy to kinetic energy

b Electrical energy to heat and light energy

c Chemical energy (from muscles in the arm) to p.e. (strain energy of catapult)

d Potential energy of water to kinetic energy of turbine to electrical energy from generator

Figure 13.3 Some energy transfers

Energy measurements

a) Work

In science the word **work** has a different meaning from its everyday use. **Work is done when a force moves.** No work is done in the scientific sense by someone standing still holding a heavy pile of books: an upward force is exerted, but no motion results.

If a building worker carries ten bricks up to the first floor of a building, he does more work than if he carries only one brick because he has to exert a larger force. Even more work is required if he carries the ten bricks to the second floor. The amount of work done depends on the size of the force applied and the distance it moves. We therefore measure work by

$$\text{work} = \text{force} \times \text{distance moved in direction of force} \qquad (1)$$

The unit of work is the **joule** (J); it is the work done when a force of 1 newton (N) moves through 1 metre (m). For example, if you have to pull with a force of 50 N to move a crate steadily 3 m in the direction of the force (Figure 13.4a), the work done is $50\,\text{N} \times 3\,\text{m} = 150\,\text{N m} = 150\,\text{J}$. That is

$$\text{joules} = \text{newtons} \times \text{metres}$$

If you lift a mass of 3 kg vertically through 2 m (Figure 13.4b), you have to exert a vertically upward force equal to the weight of the body, i.e. 30 N (approximately) and the work done is $30\,\text{N} \times 2\,\text{m} = 60\,\text{N m} = 60\,\text{J}$.

Note that we must always take the distance in the direction in which the force acts.

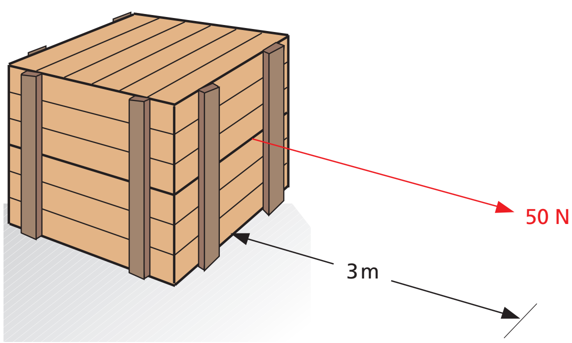

Figure 13.4a

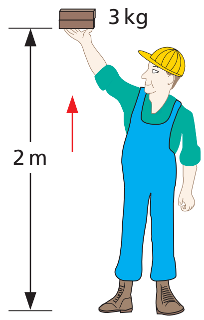

Figure 13.4b

b) Measuring energy transfers

In an energy transfer, work is done. **The work done is a measure of the amount of energy transferred.** For example, if you have to exert an upward force of 10 N to raise a stone steadily through a vertical distance of 1.5 m, the work done is 15 J. This is also the amount of chemical energy transferred from your muscles to potential energy of the stone. All forms of energy, as well as work, are measured in joules.

c) Power

The more powerful a car is, the faster it can accelerate or climb a hill, i.e. the more rapidly it does work. The **power** of a device is the work it does per second, i.e. the rate at which it does work. This is **the same as the rate at which it transfers energy from one form to another.**

$$\text{power} = \frac{\text{work done}}{\text{time taken}} = \frac{\text{energy transfer}}{\text{time taken}} \qquad (2)$$

The unit of power is the **watt** (W) and is **a rate of working of 1 joule per second**, i.e. 1 W = 1 J/s. Larger units are the **kilowatt** (kW) and the **megawatt** (MW):

$$1\,\text{kW} = 1000\,\text{W} = 10^3\,\text{W}$$

$$1\,\text{mW} = 1\,000\,000\,\text{W} = 10^6\,\text{W}$$

If a machine does 500 J of work in 10 s, its power is $500\,\text{J}/10\,\text{s} = 50\,\text{J/s} = 50\,\text{W}$. A small car develops a maximum power of about 25 kW.