# Energy

## Energy costs *and* Energy transfer

### Ideas you have met before

Although you'll have heard and used the term 'energy' before, you may well not have explored its use in science. However, there are many things you will have investigated which use energy.

#### Materials may change

Changes such as burning result in the formation of new materials.

Some materials change state when they are heated or cooled.

#### Living things need nutrition

Plants require light and water for life and growth.

Animals need nutrition, and they cannot make their own food; they get nutrition from what they eat.

Food chains identify producers, predators and prey.

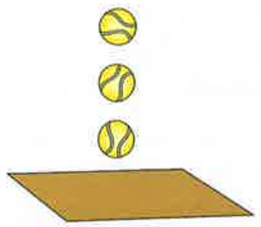
**Nutritional Information per 100 g**

| | |
|---|---|
| Protein | 18.1 g |
| Fat | 16.2 g |
| Of Which Saturates | (5.2 g) |
| Carbohydrates | 26 g |

#### Objects can move in various ways

Unsupported objects fall towards Earth because of gravity.

Air resistance, water resistance and friction act between moving surfaces.



#### Light and sound travel as waves

We see things because light travels from light sources to our eyes, or from light sources to objects and then to our eyes.

Sounds are made because of something vibrating; these vibrations travel through the air to our eyes.

#### Electricity can do useful work

Many common appliances run on electricity.

Components in a circuit can be made to function in different ways, for example lamps can be made brighter and buzzers can be made louder.



### In this chapter you will find out



#### Energy stores and transfers

- Energy is transferred when changes happen, and this transfer can happen in many different ways.
- An object stores energy if it has been raised up. This is because it is affected by the Earth's gravitational force.
- When elastic materials are stretched or squashed they have more energy stored in them.

#### Fuels are energy stores

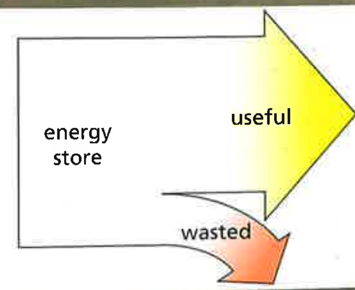
- Fuels are energy stored chemically. They include wood, fossil fuels and hydrogen.
- Fuels only burn if oxygen is present. The products of burning also store energy, but less than that in the fuel and oxygen.
- When a fuel is burned in oxygen, energy is transferred to the surroundings.

#### Energy in the home

- The quantity of energy transferred in a change can be measured.
- How quickly energy is transferred is the power and this can also be measured.
- Electricity is generated by using different energy resources, which each have advantages and disadvantages.
- We pay for our domestic electricity based on the amount of energy transferred.
- We can calculate the cost of home energy usage using the formula: cost = power (kW) × time (hours) × price (per kWh).

#### Accounting for energy

- We can describe how jobs get done using an energy model where energy is transferred from one store at the start to another store at the end.
- When energy is transferred, the energy total is conserved, but some energy is dissipated, reducing the useful energy.



# Understanding energy transfer by fuels and food

We are learning how to:

- Describe the use of fuels in the home.
- Explain that foods are energy stores and that the amount stored can be measured.
- Explain that energy is not a material and can be neither created nor destroyed.

Natural gas and electricity are used in homes to supply energy. Our bodies, too, need supplies of energy. But is energy for the body the same as energy for the home?

FIGURE 1.3.1a: Gas pipelines and electricity cables supply us with energy.

## Fuels and energy in the home

One of the places we use energy is in our homes. We need light and heat and we need to power appliances such as TVs and washing machines.

**Fuels** are a way of providing us with the energy we need.

1. Name four fuels that might be used in homes.
2. Describe how energy use in a home is measured.
3. Suggest an advantage and a disadvantage for these fuels:
   a) electricity;
   b) gas.

## Food and energy

Energy is measured in **joules** (abbreviated to J). A joule is a very small amount of energy so we sometimes use **kilojoules (kJ)**: 1000 J = 1 kJ. You may hear people talk about calories – this is an older unit of energy that scientists no longer use.

Food is fuel for our bodies. Energy stored in food is often called its 'energy content', measured in kilojoules (kJ); 1 kJ = 1000 J and this is equivalent to 240 'calories'. During digestion food is changed into chemicals that store energy in the body's cells (an **energy resource**).

### Did you know...?

The unit of energy, the joule, is named after James Joule, a Salford brewer who discovered the link between heat and work. He spent part of his honeymoon in Switzerland making measurements to show that the water at the bottom of a waterfall was slightly warmer than the water at the top.





Chemical reactions that happen in the body enable growth and reproduction, responses to the environment and keeping healthy. All rely on energy being transferred from chemical stores in the body's cells which, in turn, depends on the food eaten.

4. Explain how the body builds up stores of energy.
5. Explain why information about energy stored in food is useful.
6. Calculate the energy content of 100 g of the food product shown in Figure 1.3.1b.

## Transfers and stores

Energy is stored in various ways, such as in a battery or in a tank of water that has been heated up. This energy can then be transferred and will end up in another store.

For example, when a fuel burns in air, energy stored in the fuel and in oxygen is transferred to the surroundings, which warm up. The energy stored in the products of combustion and the warmer surroundings equals the energy stored in the fuel and oxygen.

Similarly, warming a room with an electric heater causes a change that results in energy being transferred to the surroundings (air, walls, ceiling, furniture and so on). The total amount of energy remains the same, even though it is more spread out.

When we eat food, energy stored in food is transferred to energy stored in our bodies. This stored energy is transferred further during body processes.

When these changes happen, energy is not used up but is transferred to different places.

**Nutritional Information per 100 g**

| | |
|---|---|
| Protein | 18.1 g |
| Fat | 16.2 g |
| Of Which Saturates | (5.2 g) |
| Carbohydrates | 26 g |
| Of Which Sugars | (7.2 g) |
| Sodium | 0.468 g |
| Potassium | 906 mg |
| Salt | 1.2 g |
| Fibre | 4.7 g |
| kCalories | 322 kCal |
| kJoules | 1347 kJ |

FIGURE 1.3.1b: Energy content is given as part of the nutritional data on a food label. This shows what is contained in a 100 g serving of food.

7. Give two other examples of changes taking place that involve energy transfer, and explain where you think the energy has been transferred to.
8. When a candle is burning:
   a) How is energy being transferred?
   b) Where is it being transferred from and to?

### Know this vocabulary

**fuel**
**joule**
**kilojoule (kJ)**
**energy resource**

# Comparing rates of energy transfers

We are learning how to:

- Describe what is meant by 'rate of energy transfer'.
- Recall the correct units for rate of energy transfer.
- Calculate quantities of energy transferred.

Chinese food is often cooked in a wok. Using a frying pan instead never seems to produce the same flavours. The reason is speed of cooking – woks are thinner than frying pans (about one-third the thickness). Energy is transferred much more quickly through them and the food is cooked more quickly – essential to create that authentic Chinese taste. How do we measure how quickly energy is transferred?

FIGURE 1.3.2a: The design of a wok speeds up the energy transfer to the food.

## Energy and power

Sometimes energy is transferred very quickly and other times it takes much longer. When we talk about how quickly energy is transferred we use the word **'power'**.

Power is measured in **watts** (W). Transferring one joule every second would mean 1 W of power. 1 W is a small amount of power so we often use **kilowatts** (kW): 1 kW = 1000 W.

If the change can be controlled, so can the rate at which energy is transferred. For example, to make a lamp transfer energy more quickly it would need a more powerful light bulb.

FIGURE 1.3.2b: Warm clothes slow the rate of energy transfer from the children's bodies to the cold air, helping to keep them warm.

1. How many watts are there in 2 kW?
2. Of the appliances shown in Figure 1.3.2c:
   a) Which has the highest power rating?
   b) Which has the lowest power rating?
3. How many joules of energy does a 100 W bulb transfer every second?



FIGURE 1.3.2c: Some typical power ratings.





## Calculating power

We can calculate power by using the formula:

$$\text{power} = \frac{\text{energy transferred}}{\text{time taken for transfer}}$$

For example, if a light bulb transfers 1000 J of energy in 10 seconds, the power is:

$$\frac{1000}{10} = 100\,\text{W}$$

When we talk about how quickly something happens, we sometimes refer to the rate. This is the amount per second.

4. Why does a toaster have a much higher power output than a laptop computer?
5. What is the power of a bulb that transfers 600 J per minute?
6. What is the rate of energy transfer in joules per second for a 20 W laptop?


FIGURE 1.3.2d: The power rating of the electric fan heater is shown on the label. It is 2000 W.

## Quantities of energy transferred

When a change happens and energy is transferred, the quantity of energy transferred can be calculated in joules (J) or kilojoules (kJ) using:

energy transferred (J or kJ) = power (W or kW) × time (s)

- A 20 W laptop computer transfers 20 J/s.
  So if it is used for one hour (1 × 60 × 60 = 3600 s), it transfers 20 × 3600 = 72 000 J = 72 kJ.
- A 2.15 kW electric oven transfers 2.15 kJ of energy per second.
  So if it is used for one hour (1 × 60 × 60 = 3600 s), it transfers 2.15 × 1000 × 3600 = 7 740 000 J = 7.74 MJ.

7. How much energy is transferred when a 1.2 kW toaster runs for three minutes?
8. Calculate the energy transferred when one store transfers energy to another store by heating it for five minutes at a rate of 15 J/s.
9. a) Calculate the energy transferred when a 10 W bulb is left on for three days.
   b) Calculate the energy saved if the same light bulb is turned off every day for eight hours.

### Did you know...?

Some of the ways energy is transferred by a device are more useful than others. Getting light from a bulb is great but heat less so. The more of the energy output that is useful, the more efficient we say the device is.

### Know this vocabulary

**power**
**watt**
**kilowatt**

# Looking at the cost of energy use in the home

We are learning how to:

- Describe the information a typical fuel bill provides.
- Explain and use the units used on a fuel bill.
- Explain how the costs of energy used can be calculated.

When you look at your gas or electricity bill there are two charges. One is for the amount used, and the other is a fixed charge. Why do energy providers make a fixed charge on top of the cost of the electricity or gas used?

## Fuel bills

Electricity and gas for the home are bought from energy suppliers. Users receive energy bills that show:

- the 'standing charge' – a fixed amount regardless of how much energy is used
- the price of each unit of energy and the number of units used.

**Meter readings** (E = estimate, C = customer, A = actual)

**Electricity readings**

| Period | Meter no. | Previous | Present | Rate | kilowatt-hours |
|---|---|---|---|---|---|
| 4 Sept to 12 Nov | S08B 06654 | 12549 E | 12757 C | Normal | 208 |

**Gas readings**

| Period | Meter no. | Previous | Present | Units | kilowatt-hours |
|---|---|---|---|---|---|
| 30 Aug to 12 Nov | 674215 | 02938 A | 02954 C | 16 m³ | converts to 178 |

**Charges**

**Electricity charges**

| | | |
|---|---|---|
| 4 Sept to 12 Nov | | £43.69 |
| 208 kilowatt-hours (kWh) used at 12.66p each | £26.33 | |
| Standing charge – 69 days at 25.16p per day | £17.36 | |

**Gas charges**

| | | |
|---|---|---|
| 30 Aug to 12 Nov | | £26.33 |
| Gas 178 kilowatt-hours (kWh) used at 3.981p each | £7.09 | |
| Standing charge – 69 days at 27.89p per day | £19.24 | |

**Total charges**

| | |
|---|---|
| Total electricity and gas charges (excluding VAT) | £70.02 |

FIGURE 1.3.3a: This energy bill shows the quantities and charges for electricity and gas used in a home.

The amount of electricity used in a home is measured in a unit called **kilowatt-hours (kWh)** by an electricity meter. The quantity of gas is shown on a gas meter in cubic metres ($m^3$). This will probably be converted into kilowatt-hours (kWh) on an energy bill.

1 kWh = 3 600 000 J or 3600 kJ

A typical home might use several hundred kilowatt-hours (kWh) of energy every month (see Figure 1.3.3a) – in other words, hundreds of millions of joules.

1. Suggest why electricity bills do not show energy usage in joules.
2. What are the standing charges shown in the energy bill in Figure 1.3.3a for the following?
   **a)** electricity **b)** gas
3. Explain the difference between a standing charge and the cost of energy used. (Hint: As well as the fuel used, what else needs to be paid for?)

**Did you know...?**

About half of the household cost for gas and electricity is for heating the home. Double glazing can reduce heating bills, but it is expensive to install. It has been estimated that it can take 80 years before the savings balance out the cost of the double glazing.





## Calculating the energy used by domestic appliances

Remember that the rate at which energy is transferred is called power, measured in watts (W) – 1 watt = 1 joule per second (1 W = 1 J/s). The amount of energy used by an appliance is calculated by multiplying its power by the time for which it was used. Electricity supply companies use the energy unit kilowatt-hour (kWh), so we need to use hours, not seconds, in the calculation.

energy used (kWh) = power (kW) × time (h)

An appliance with a power rating of 500 W running for five hours transfers 0.5 × 5 = 2.5 kWh. Choosing an electrical appliance with the optimum power rating for the intended purpose is important. A more powerful electric kettle will use more energy per second but it will take less time to do the job.

4. How much energy would be used by:
   **a)** A 2 kW oven in 30 minutes?
   **b)** A 1 kW microwave in 6 minutes?
   **c)** A 30 W bulb in an hour?
5. Explain the difference between 'energy' and 'power'.

FIGURE 1.3.3b: The cost of 1 kWh of energy from electricity is roughly three times that of 1 kWh of energy from gas.

## Calculating the cost of energy used

The cost of home energy usage is calculated using the formula:

cost = energy used (kWh) × price of energy per kWh

The typical price of 1 kWh of electricity is about 13p, and the typical price of 1 kWh of gas is about 4p. If you used 900 kWh of electricity and 700 kWh of gas, the cost would be:

electricity: 900 × 13 = 11 700 p = £117.00

gas: 700 × 4 = 2800 p = £28.00

So the total energy cost = £117.00 + £28.00 = £145.00

6. Alex is working out how much it will cost to cook a frozen curry using a microwave oven compared with a gas cooker.
   **a)** How much will it cost to use a 1 kW microwave if it takes 5 minutes and electricity is 13p/kWh?
   **b)** How much will it cost to use a 2 kW gas oven if it takes 30 minutes and gas is 4p/kWh?
   **c)** Comment on the difference in the costs.
7. Jo has just received her gas and electricity bill (Figure 1.3.3a) and has decided to find ways of reducing what she has to pay. Suggest three things she could consider doing to reduce her energy consumption.

**Know this vocabulary**

**kilowatt-hour (kWh)**

# Getting the electricity we need

We are learning how to:

- Describe ways of generating electricity.
- Explain advantages and disadvantages of different methods.
- Evaluate the consequences of using different generating methods.

There are many different ways of generating electricity – anything that will make a magnet rotate inside a coil of wire will make a current flow. You could even use a hamster in a wheel, though you wouldn't get much of an output. We use vast amounts of electricity so supplying it cheaply and reliably is a big challenge.

## Generating electricity

There are three main ways of generating electricity. The first is to burn a **fossil fuel**, such as coal, to heat water and turn it into steam. The steam drives a turbine (rather like a water wheel) which powers the generator. These are **non-renewable** energy sources. Fossil fuels are formed from animal and plant material over millions of years and contain a lot of energy, which is released upon combustion. The process releases polluting gases and supplies are running out.

The second is to use a nuclear reactor to heat water and produce steam, which then drives a turbine generator. Nuclear power is non-renewable as it uses fuel such as uranium, which has to be mined. Reactor waste remains dangerous for many years, and leaks can contaminate large areas of land.

The third way is a whole group of methods, referred to as **renewable** generation. Unlike fossil fuel and nuclear-powered generation, these methods don't use up fuels. They include:

- solar power, which produces electricity from sunlight;
- wind power, which uses the wind to turn blades and drive a generator;
- hydroelectric power, which uses falling water from a dam to drive a generator;
- wave farms, which extract energy from water waves;
- biomass, producing gas from decomposing animal or plant matter;
- geothermal, using heat from under the ground;
- tidal, extracting energy from the motion of water as the tide comes in and goes out.

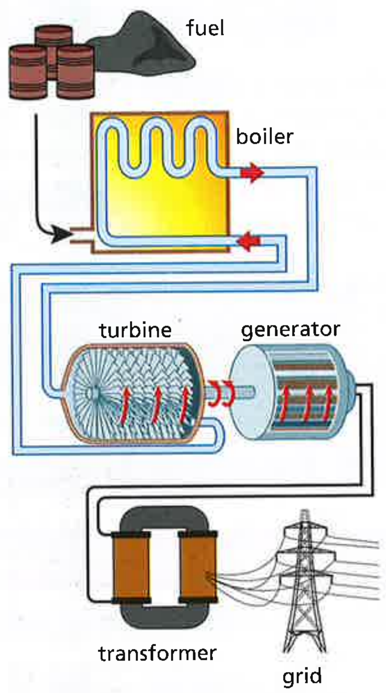



FIGURE 1.3.4a: The process of generating electricity.

**Did you know...?**

Renewable energy sources are not necessarily very efficient. Wind turbines, for example, only extract about 30% of the available energy from the wind. However, as the wind is free and there are no waste products this doesn't cause any problems. You could research other energy resources to see how they compare.





1. What other types of fossil fuel are there apart from coal?
2. What are the disadvantages of:
   a) Fossil fuel power stations? b) Nuclear power stations?

## Making decisions about which generating method to use

Governments have to decide how to produce the electricity that people need. They have to think about various factors such as:

- cost of construction;
- cost of operation;
- effect on the environment;
- availability of fuel (or sun, wind, etc.);
- reliability of the supply;
- safety of operation.

Sometimes there are difficult choices to be made. A hydroelectric power station, for example, needs no fuel and produces no waste materials but is expensive to build and affects a large area of land, flooding a valley and damaging habitats.

3. What problems are caused by burning lots of fossil fuels?
4. Quite a few people are not happy at the thought of using nuclear power stations. Why might this be?
5. The supply of power needs to be reliable. Why might solar power and wind power not be suitable as a sole energy source?

## Using evidence to make a decision

Table 1.3.4 shows how much it costs to produce electricity by different methods in the UK. It shows how much it costs to produce 1 MWh (this is 1000 kWh; 1 kWh will run a small electric fire for an hour). As this shows, the costs vary quite a lot and they aren't fixed for one particular energy resource but vary over a range. Nevertheless, it's clear that some methods are cheaper than others.

| Type of power station | Cost: £/MWh |
|---|---|
| Gas | 80 |
| Coal | 102 |
| Coal with carbon capture | 122 |
| Nuclear | 81 |
| Offshore wind farm | 118–134 |
| Solar | 169 |
| Onshore wind farm | 93–104 |
| Biomass | 117–122 |

TABLE 1.3.4: Taken from Electricity Generation Costs, Dept of Energy & Climate Change, 2012, 'Table 1: Levelised cost estimates for projects starting in 2012, 10% discount.'

6. Renewable generating methods don't release harmful gases or make other waste materials. Why then do some people say they damage the environment?
7. Why not build the entire electricity-generating system using gas turbine stations?
8. Why might a gas turbine power station be built 'with $CO_2$ capture'?
9. Why do you think offshore wind power farms are more expensive to build and run than onshore ones?
10. Coal-fired power stations are around 45% efficient whereas wind turbines are around 38% and photovoltaic cells are about 21%. Explain whether this should persuade us to use more coal.

**Know this vocabulary**

**fossil fuel**
**non-renewable**
**renewable**

# Using electricity responsibly

We are learning how to:

- Apply the concept of energy transfer to a wind-up device.
- Critique claims made for the running costs of fluorescent light bulbs.
- Evaluate actions that could be taken in response to rising energy demand.

**It is easy to expect governments and energy suppliers to make good decisions about how we are supplied with energy. It is important that they do so, but as consumers we can also make decisions about how we use electricity. We have to get that right too.**

## Turning our work into light

The torch in Figure 1.3.5a has batteries in it but instead of buying them charged up or recharging them from the mains, you turn the crank. This drives a generator, which charges the batteries up. Then, when you want to use the torch, you switch it on like any other torch. When the bulb starts to go a bit dim you can recharge it with the handle.

FIGURE 1.3.5a: A wind-up torch.

Think about how the energy is transferred. It starts with you. You have energy stored in you and when you turn the handle the energy is transferred from you via the handle and the generator to the battery. Here it is stored.

Then when you switch the light on the energy is transferred from the battery, via the wires and the bulb to the environment. It's now spread out, or **dissipated**, widely. The energy is all still there but it's of little use.

1. What would happen if you turned the handle for longer?
2. What difference would it make if a torch had two bulbs that lit up instead of one?
3. Is it true to say that by using this device you are 'generating energy'?

## Investigating claims for low-energy light bulbs

Low-energy light bulbs have been around for a few years now but when they first came out manufacturers had to promote them. They were more expensive than the filament bulbs they replaced. Adverts like the one in Figure 1.3.5b are very appealing – they suggest that what you save in lower electricity bills more than pays for the cost of the more expensive bulb. Is it true though? In order to compare the bulbs, we need to allow for a number of factors, such as:

- how much the bulb costs;
- how much energy the bulb uses;
- how much it's going to be used;
- how long the bulb lasts for;
- how much electricity costs.





Assume we can buy a fluorescent bulb for £5 and a filament bulb for £1. The fluorescent bulb is rated at 20 W and the filament bulb at 100 W, but they both give out a similar amount of light. The fluorescent bulb will be good for 10 000 hours and the filament bulb for 1000 hours. Electricity costs 13p/unit and the bulb will be used for around 3 hours a day.

Let's see what they cost to run for a year, which will be the approximate life of the filament bulb. The filament bulb costs £1 and will use 0.3 units of electricity per day, which will cost 3.9p. Over the year this will total £14.24, plus the cost of the bulb, so £15.24.

The fluorescent bulb will use 0.06 units a day, which will cost 0.78p. Over one year this comes to £2.84. We need to add in the cost of the bulb, but remember that this kind of bulb will last for 10 000 hours. In the year we've only used it for about 1000 hours so we should only count one-tenth of its cost, which is 50p. The total is therefore £3.34.


FIGURE 1.3.5b: Adverts similar to this encouraged people to buy low-energy light bulbs.

4. What conclusion can you draw from the data?
5. Is the manufacturer's claim true?
6. Explain why the fluorescent bulb is cheaper to use, even though it's much more expensive to buy?
7. Instead of a fluorescent bulb you could use an LED bulb, which costs twice as much but lasts for twice as long and uses half the amount of electricity. Do the calculations for the use of the LED bulb over a year, to see how it compares.

## Deciding on actions to take

Demand for electricity rises as population increases and people use more appliances. How is this dealt with? Sometimes actions are taken at national level and sometimes at local level. There are two areas to consider:

- How energy is supplied to a community. Is it being generated in a way that is not only cheap and reliable but doesn't damage the environment?
- How energy is used in the community. Are users being economical with their use of electricity, selecting efficient appliances and using them responsibly?

8. What kind of electricity generation system do you think we should be using? Justify your answer.
9. How can consumers be encouraged to use electricity more responsibly?
10. Efficient appliances, such as fridges with better insulation, sometimes cost more. How could you persuade people that they were a good idea?

Know this vocabulary

**dissipated**

# Energy stores and transfers

We are learning how to:

- Use a model of energy.
- Describe energy stores and transfers.
- Apply the energy model to different situations.

Energy is a really important concept in science and is used in many different areas. Explaining everything from food chains and chemical reactions through to roller coasters and electric circuits involves using ideas about energy. It's important to understand that although energy is used to explain many different effects, it's all just energy – there aren't different types of energy.

FIGURE 1.3.6a: This boy is using energy to lift these books – but what type of energy?

## A model of energy

A **model** is used in science to help us to understand a concept. A model for energy that is used is the 'stores and transfers' model. This helps us to make sense of what energy does. The model uses the idea that energy is in a 'store'. The energy may be transferred and then it will end up in another store. We can think of these stores being emptied as energy is transferred out of them, and filled as energy is transferred into them.

For example, if a teacher is lifting boxes of books onto a shelf, energy is being transferred. The teacher is a **chemical energy store** and as she does work the energy is transferred from that store, via the reactions that make muscles work, to the **gravitational potential energy store** in the boxes as they are raised up. If one of the boxes falls off the shelf, energy is transferred out of the gravitational potential energy store. The energy will then be **dissipated** to the surrounding environment – it will be spread out wastefully. The environment is a store too.

1. How would the amount of energy transferred differ if the boxes are put on a higher shelf?
2. How would the amount of energy transferred differ if more boxes are moved?

### Did you know…?

Every object that is raised up is a store of energy, because things can happen when it falls! This is because of gravity, and we call this store a gravitational potential energy store.

## Examples of stores and transfers

- Using a cooker to heat food. Energy is transferred from a chemical energy store (fuel and oxygen) to a **thermal energy store** in the food. The more energy that is transferred, the higher the temperature attained by the food.
- A child on a swing. Energy is transferred from the gravitational potential energy store (at the top of the swing) to a **kinetic energy store** of movement and then back to the gravitational potential energy store (at the other end). Swinging back and forth repeatedly involves many transfers and the stores filling up and emptying repeatedly.
- A person on a trampoline. Energy is transferred from the kinetic energy store as the person moves downward and is slowed down by landing and into an **elastic energy store** as the trampoline springs are stretched. Almost immediately the energy is transferred back again into a kinetic energy store.

3. A box falling off the shelf adds to the thermal energy store of the environment. Why is it difficult to measure this change?
4. Suggest another example of a device that stores energy in an elastic energy store.
5. Not all of the energy from the cooker will be transferred to the food; where will some of it be transferred to?
6. The kinetic energy store of the child on the swing keeps dropping to zero, at each end of the swing when they are momentarily stationary. But their gravitational potential energy store is never zero, even at the mid-point of the swing. Explain why.



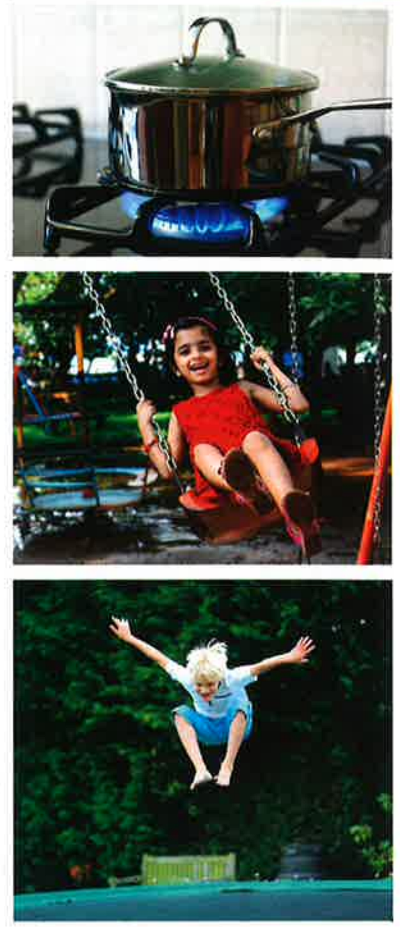


FIGURE 1.3.6b: Examples of stores and transfers.

## Applying the model

The 'stores and transfers' model can be used to describe what is happening in a variety of situations. See if you can apply it to these:

7. A pendulum swings back and forth.
8. A ball is dropped and bounces back up again.
9. The pendulum eventually stops swinging.
10. The bouncing ball eventually comes to rest on the ground.
11. Alex says 'There's water in this jug and I can pour it into a cup. All the water is still there but it's been transferred to a different store.' How good is this way of explaining what happens to energy when it is transferred between stores?

### Know this vocabulary

**model**
**chemical energy store**
**gravitational potential energy store**
**dissipated**
**thermal energy store**
**kinetic energy store**
**elastic energy store**

# Exploring energy transfers

We are learning how to:

- Recognise what energy is and its unit.
- Describe a range of energy transfers using simple diagrams.
- Use a Sankey diagram as a model to represent simple energy changes.

The Sun is our main source of energy. Plants convert this energy by chemical processes to make food. Solar panels transfer the Sun's energy by electric current to provide electricity for our use. By transferring energy from the Sun, useful energy can be provided for our planet.

## Thinking about transfers

When **energy** is transferred, useful things can happen. When a log is burned, energy is transferred by chemical reactions to the surroundings by light and heat. Switching on a light bulb transfers energy by electric current to the bulb. Energy is then transferred from the bulb to the surroundings increasing the temperature.

Energy is never lost or made; it is just transferred to the surroundings, increasing the temperature.

FIGURE 1.3.7a: Where has the energy to light this bulb come from?

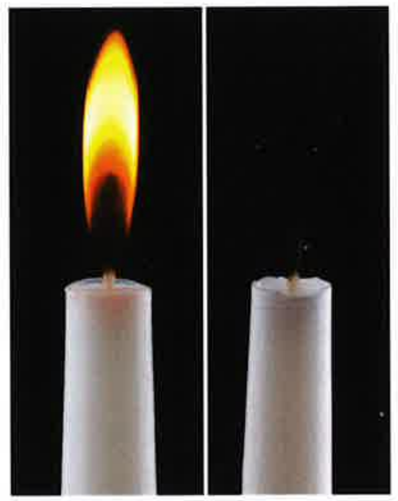


FIGURE 1.3.7b: Describe the differences, in terms of energy transfer.

1. Look at the photos on this page. In which of them is energy being transferred?
2. a) What is happening as a result of the energy transfer you can see in Figure 1.3.7b?
   b) What is happening in the other photo in Figure 1.3.7b? Why is it not possible for energy to be transferred here?

## Energy transfers

It is useful to track the processes by which the energy is transferred. This can be done using a simple **energy transfer diagram** (see Figure 1.3.7c). When you switch on a light bulb, you want to transfer energy by light. However, the light bulb also gets hot. Transferring energy by heating is not useful in this instance. Energy-**efficient** light bulbs have been designed to transfer more energy by light and less by heating.

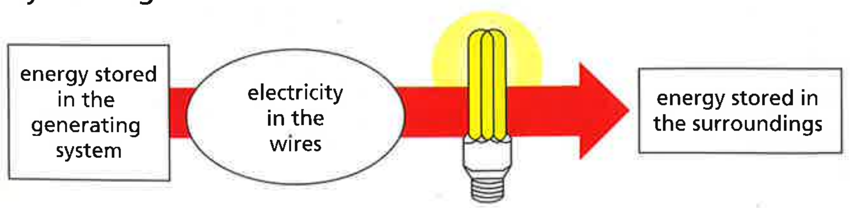



FIGURE 1.3.7c: Simple energy transfer diagram for a light bulb.





3. Write a sentence to describe the energy transfers shown in Figure 1.3.7c.
4. Draw a diagram to show how energy is transferred by:
   a) a boiling kettle;
   b) a toaster;
   c) a log fire.
5. In your answers to question 4, underline the useful energy transfers and circle the unwanted energy transfers.

### Did you know...?

The amount of energy transferred to the Earth from the Sun in one minute is enough to meet the world's energy demands for one year.

## Sankey diagrams

If you move a weight of 1 N through a distance of 1 m, you transfer 1 joule (1 J) of energy. One joule of energy is also needed to heat 1 cm$^3$ of water by 1 °C.

A **Sankey diagram** is a type of energy transfer diagram that shows the relative amounts of energy transferred by a device. The width of each arrow shows how much energy is transferred. The non-useful energy transferred is always shown pointing downwards. The greater the proportion of energy transferred that is useful, the more efficient we say the device is.

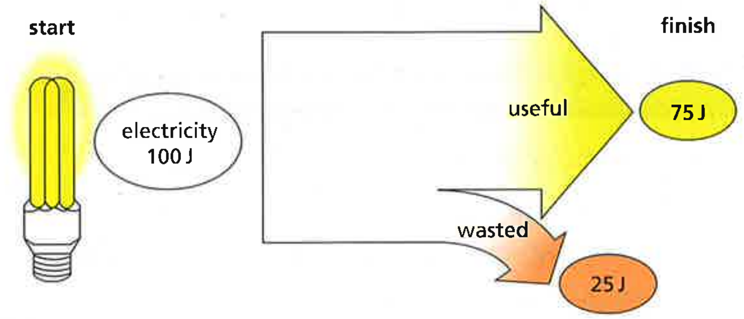



FIGURE 1.3.7d: Sankey diagram for an energy-efficient light bulb. How would the Sankey diagram for an old-style, less efficient light bulb compare with this one?

For example, in Figure 1.3.7d, 100 J of energy is transferred to the light bulb by electric current. It transfers 75 J by light (useful) and 25 J by heating the surroundings (wasted). If you draw these on graph paper, you can accurately represent the proportions of energy involved.

6. What is the percentage of energy wasted in the light bulb in Fig 1.3.7d?
7. On graph paper, draw a Sankey diagram for an electric drill that transfers 500 J of energy. 300 J of energy is transferred as movement and 200 J are transferred to the environment. You will need to decide which of the outputs are useful and which are useless.
8. What would make the drill in question 7 more efficient?

### Know this vocabulary

**energy transfer diagram**
**efficient**
**Sankey diagram**

# Understanding potential energy and kinetic energy

We are learning how to:

- Recognise energy transfers due to falling objects.
- Describe factors affecting energy transfers related to falling objects.
- Explain how energy is conserved when an object falls.

Many theme parks make use of energy transfer in their rides. An object high up has the potential to transfer energy. There is a new vertical-drop ride, the 'Drop of Doom', which, at 126 metres tall, is the tallest ever. People will fall from a stationary position at the top and reach speeds of up to 150 km per hour.

FIGURE 1.3.8a: *The Zumanjaro: Drop of Doom*, theme park ride. How is energy being transferred as people drop from the top to the bottom of this ride?

## What is gravitational potential energy?

Objects at a height possess energy, because of the Earth's gravitational field – think of parachute jumpers or sky divers. Their **gravitational potential energy store** is pretty full. This energy is transferred when the object loses height.

1. What is the unit for gravitational potential energy?
2. What is the name of the force acting on objects that causes them to have gravitational potential energy?

## Factors affecting gravitational potential energy

The higher an object is, the more gravitational potential energy it has. More energy can be transferred to make it move. When the objects falls, energy is transferred from the gravitational potential energy store to the **kinetic energy store**. As it does so, the object moves faster and faster.

It is useful to think about objects acting as energy stores, which can be filled up in different ways. For example, the kinetic energy store is filled as an object speeds up and the gravitational potential energy is filled when an object is raised.

The greater the force acting on the object, the more energy that can be transferred. The force of gravity is greater on Jupiter than on Earth, so an object falling the same distance on Jupiter will transfer more gravitational potential energy than it would on Earth.

FIGURE 1.3.8b: How does gravitational potential energy affect these people?





3. A tennis ball falls from the following heights:
   i) 10 mm ii) 10 cm iii) 10 m
   a) Represent this by an energy transfer diagram showing stores and transfers.
   b) Which fall will transfer the most energy?
4. Look at Table 1.3.8. If a tennis ball is dropped from the same height on each planet, on which planet will it reach the highest speed?

TABLE 1.3.8: Gravitational field strengths on different planets.

| Planet | Gravitational field strength (N/kg) |
|---|---|
| Earth | 10 |
| Mars | 3.7 |
| Saturn | 11 |

## Conservation of energy in falling objects

Gravitational potential energy is transferred by movement and heating the surroundings. As a falling object drops lower, its gravitational potential energy decreases and the amount of energy transferred to kinetic energy increases. Some energy will also be transferred by heating the surroundings, due to friction with the air particles during the fall. The faster the object falls, the greater the energy transferred by heating. When the object hits the ground, some of the kinetic energy may stay in it if it bounces back up but the rest is transferred by heating and sound to the surroundings.

5. Look at Figure 1.3.8c of a ball falling from a height. In which position (A, B or C) does the ball have:
   a) The greatest amount of energy in the gravitational potential energy store?
   b) The least amount of energy in the gravitational potential energy store?
   c) The least amount of energy in the kinetic energy store?
   d) The greatest amount of energy in the kinetic energy store?
6. Sketch two graphs to show how the energy levels in the gravitational potential energy store and the kinetic energy store of the ball in Fig 1.3.8c change during the fall.

### Did you know…?

The Stealth roller coaster at Thorpe Park has the greatest acceleration of any such ride in the UK. Riders accelerate from rest to 130 km/h in under 2 seconds, propelling them to a height of 62.5 m. Occasionally energy losses mean the train fails to reach the peak and (safely) rolls back.

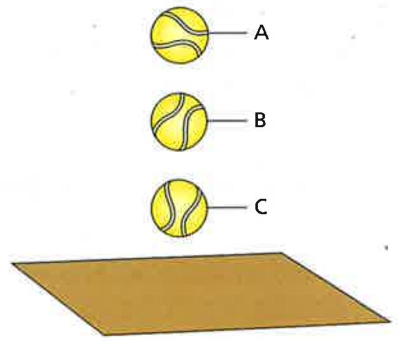



FIGURE 1.3.8c: A ball transferring gravitational potential energy.

### Know this vocabulary

**gravitational potential energy store**
**kinetic energy store**

# Understanding elastic energy

We are learning how to:

- Describe different situations that use the energy stored in stretching and compressing elastic materials.
- Describe how elastic energy in different materials can be compared.
- Explain how elastic energy is transferred.

Elastic materials have the ability to store energy ready for use. The muscle tissue in animals consists of fibres of protein that can expand and contract, providing a potential store of elastic energy. This ability allows us to jump and move – and allows fleas to jump more than a hundred times their own height!

FIGURE 1.3.9a: A flea's jump is an example of elastic energy being transferred.

## What is elastic energy?

Energy is stored when an elastic material is stretched or compressed (squashed) by a force. You do work when you pull an elastic band or squash a spring. This transfers energy, which is stored in an **elastic energy store**.

The stored energy is transferred when the elastic material returns to its original shape.

The further a material is stretched or compressed, and still be able to return to its original position, the more energy can be transferred.

1. In which of the situations in Figure 1.3.9b is more elastic energy transferred?
2. What causes the jack-in-the-box to bounce up when the lid is opened?

## Applications of elastic energy

Catapults and archery bows use elastic materials. Elastic energy is stored when the elastic is stretched or the bow is bent. More elastic energy is stored if the elastic is harder to stretch because more work is done in pulling it back.

Some shock absorbers in cars have strong springs. When driving over a bump, energy is transferred by movement into the elastic energy store in the springs. This energy is released slowly when the car gets beyond the bump.

FIGURE 1.3.9b: What do these have in common?





3. Some students are testing two different elastic materials for use in a catapult. They want to find out which would transfer more energy.
   a) How should they make the investigation a fair test?
   b) What should they measure to collect evidence?
4. Describe the energy transfers in a wind-up clock and represent this on an energy transfer diagram showing stores and transfers.

### Did you know...?

Many elastic materials can stretch up to five times their original length. The first type of elastic material was natural rubber, made from the sap of rubber trees. Scientists have recently invented a gel material that can stretch up to 20 times its original length and still recover. It has a possible application as artificial cartilage, because it is also extremely strong.

## Explaining elastic energy

Elastic materials, such as rubber, are made up of **molecules** that are bound together. When the material is stretched, the bonds between the molecules store energy.

In its relaxed state, rubber consists of long strands of molecules which are all coiled up. When the rubber is stretched, the coils become elongated and straightened, enabling the rubber to extend in length. When the stretching force is removed, the molecules return to their coiled-up state and the material returns to its original length.

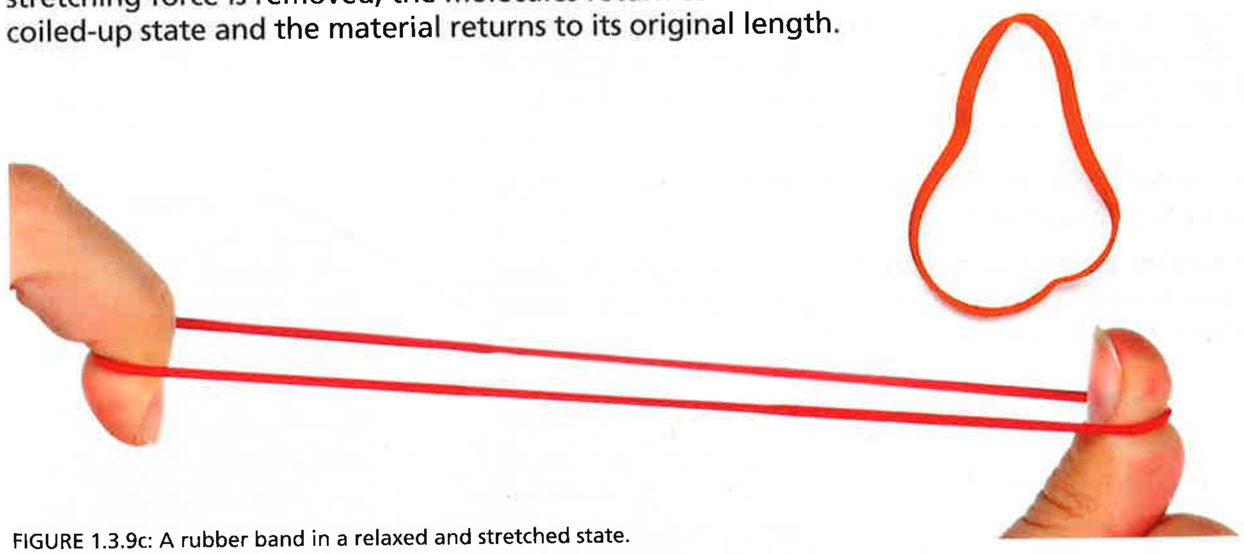


FIGURE 1.3.9c: A rubber band in a relaxed and stretched state.

The elastic energy stored in a rubber band or a spring is equal to the energy transferred in stretching it. This energy can be transferred as kinetic energy when the stretching force is removed.

5. Can all materials store elastic energy? Explain your answer.
6. How would you test which had more elastic energy – a coiled metal spring or an elastic band?

### Know this vocabulary

**elastic energy store**
**molecules**

# Checking your progress

*To make good progress in understanding science you need to focus on these ideas and skills.*

| | | |
|---|---|---|
| Describe how jobs get done, using an energy model where energy is transferred from one store to another. | Explain that energy is transferred from one type of energy store to another when change happens. | Explain that all changes, physical or chemical, result in a transfer of energy. |
| Recall that energy is measured in joules. | Explain that it is sometimes better to measure energy in kilojoules or kilowatt hours. | Carry out calculations of quantities of stored and transferred energy. |
| Describe what is meant by rate of energy transfer. | Identify the rate at which electrical appliances transfer energy (their power rating), using the correct units (watts or kilowatts). | Compare rates of energy transferred when electrical appliances are used. |
| Use the power rating of an appliance to calculate the amount of energy transferred. | Compare the energy usage of different appliances. | Calculate the cost of energy usage: cost = power (kW) × time (hours) × cost (pence per kWh). |
| Recognise that energy is transferred by a range of different processes. | Interpret and draw energy transfer diagrams for a range of different energy transfers. | Use Sankey diagrams to explain a range of energy changes and demonstrate that all energy is always accounted for. |





| | | |
|---|---|---|
| Identify simple energy transfers that involve gravitational potential, elastic, kinetic, thermal and chemical energy. | Explain how energy is transferred using elastic, chemical and gravitational potential energy. | Analyse changes in gravitational potential energy in different situations. |
| Recognise that electricity is generated in a variety of ways. | Describe advantages and disadvantages of various ways of generating electricity. | Use data to evaluate social, economic and environmental consequences of a particular way of generating electricity. |
| Give examples of renewable and non-renewable energy resources. | Explain the advantages and disadvantages of renewable and non-renewable energy resources. | Explain the challenges involved in moving towards a more renewable energy supply system. |
| Identify how appliances that transfer energy result in some energy being dissipated, reducing the useful energy. | Suggest ways in which energy dissipation in a process could be reduced. | Suggest ways in which a home energy bill could be reduced. |
| Understand that food is a fuel. | Explain that food labels provide information about the different amounts of energy in various foods. | Explain that energy is transferred from the chemical energy store when we perform physical activities. |

# Questions

## KNOW. Questions 1–4

See how well you have understood the ideas in this chapter.

**1.** Which of the following is a unit of energy? [1]

**a)** kilogram **b)** kilojoule **c)** kilometre **d)** kilohertz

**2.** Which of the following is *not* a fuel? [1]

**a)** petrol **b)** sugar **c)** coal **d)** air

**3.** State two ways that energy can be stored. [2]

**4.** Describe the energy transfer when a ball falls from a height. [2]

## APPLY. Questions 5–7

See how well you can apply the ideas in this chapter to new situations.

**5.** Describe the energy transfers that happen when an archer pulls back and then releases a bow to shoot an arrow. [2]

**6.** Describe the energy transfers that occur as a burning gas drives an electricity generator. [2]

**7.** Nutritional information about food products is shown on their labels, including the energy stored. Table 1.3.11 shows some information about different types of milk. What does this tell you about the differences between whole, semi-skimmed and skimmed milk? [2]

TABLE 1.3.11

| | | Amounts in 100 cm³ of milk | | |
|---|---|---|---|---|
| | **Unit** | **Whole (full cream)** | **Semi-skimmed** | **Skimmed** |
| **Energy stored** | kilojoule (kJ) | 282 | 201 | 148 |
| **Protein** | gram (g) | 3.4 | 3.6 | 3.6 |
| **Carbohydrate** | gram (g) | 4.7 | 4.8 | 4.9 |
| **Fat** | gram (g) | 4.0 | 1.8 | 0.3 |





## EXTEND. Questions 8–10

See how well you can understand and explain new ideas and evidence.

**8.** Julia's science teacher tells her that 'energy-efficient' light bulbs are better to use because they waste less energy through heating the surroundings. But Julia knows that her mother, who is a farmer, uses old-fashioned filament light bulbs to keep newly hatched chicks warm in winter. Which of these statements is correct? [1]

**a)** Julia's teacher is right – bulbs that transfer most of the energy by heating the surroundings are always wasteful.

**b)** The chicks don't need heating – they just need to see where they are going.

**c)** Heating the surroundings is only wasteful if you don't make use of it.

**d)** Julia's mother should switch to energy-efficient light bulbs.

**9.** Explain why an electric kettle has a power rating of 2000 W, but a small TV has a power rating of 65 W. [1]

**10.** You are looking for the best possible fuel source for the future. Use the data in the table to make your choice. Give reasons for your answer. [2]

| Fuel | Energy per gram (J/g) | State | Harmful products of combustion | Availability |
|---|---|---|---|---|
| coal | 24 | solid | carbon dioxide, soot, acid rain | running out |
| hydrogen | 123 | gas | none | plenty |
| petrol | 46 | liquid | carbon dioxide | running out |
| biofuel | 33 | liquid | carbon dioxide | renewable |