Contents

Enquiry processes

3.1.3 Energy and power

Learning objectives

After this section you will be able to:

- describe what you pay for when you pay your electricity bill
- calculate the cost for home energy usage
- compare the energy usage and cost of running different home devices.

Fantastic Fact

When you make popcorn you are boiling water. The water inside the popcorn kernel turns to steam and it explodes.

▲ The power rating of this appliance is 2000 W.

▲ Some houses transfer more energy to the surroundings than others.

Some microwaves cook popcorn faster than others. Why is there a difference?

Microwave ovens have a power rating in **watts** (W). The power rating tells you how much energy is transferred *per second*–the *rate* of transfer of energy.

You can calculate **power** using this formula:

$$\text{power (W)} = \frac{\text{energy (J)}}{\text{time (s)}}$$

The power of a microwave oven is about 800 W. A traditional oven has a power of about 2500 W, or 2.5 **kilowatts**.

Most of the heating appliances in your house will have a rating in kilowatts. Light bulbs have a rating in watts.

Kilowatts and kilojoules

12 000 W is the same as 12 kilowatts, or 12 kW. There are 1000 W in 1 kW. You divide by 1000 to convert watts to kilowatts.

An oven with a rating of 2.5 kW transfers energy at a rate of 2500 J per second. This is the same as 12 kilojoules per second. There are 1000 J in 1 kJ.

A State the unit of power.

Keeping the temperature the same

All hot objects cool down. To keep a house at the *same* temperature you need to transfer energy to it at the *same* rate as energy is being transferred from it.

What are you paying for?

When you pay an electricity bill, you are usually paying for a fuel such as coal to be burnt in a power station. The power station generates the potential difference that we call 'mains electricity'. You are charged for the number of hours that you use each appliance and for the power of the appliance.

You can calculate energy use in **kilowatt hours** (kWh) or joules. This is the unit that electricity companies use to calculate your bill.

You can calculate the cost of using appliances at home using the formula:

$$\text{cost} = \text{power (kW)} \times \text{time (hours)} \times \text{price (per kWh)}$$

Suppose you use a 2.5 kW oven for 2 hours. Each kWh costs 10p.

$$\text{cost} = 2.5\,\text{kW} \times 2\,\text{hours} \times 10\,\text{p/kWh}$$
$$= 50\,\text{p}$$

B State the unit of energy that electricity companies use.

To reduce your energy bills you could use fewer appliances or appliances that require less power to produce the same output. You can also use appliances for fewer hours. Insulation reduces the rate at which energy is transferred to the surroundings, so it reduces the rate at which you need to supply energy to heat the house.

Governments can raise awareness about energy use to try to make fossil fuels last longer. This would also benefit the environment.

The electricity meter shows how much energy you have used in kWh.

The bulbs are the same brightness but the one on the right has a much lower power.

What's the cost?

A shower has a power of 10 kW. A family uses the shower for 1 hour per day.

a Calculate how much energy, in kilowatt hours, they would have to pay for each week for using the shower.

b An electricity company charges 10p for each kWh. Calculate the cost in pounds.

Key Words

watt, power, kilowatt, kilowatt hour

Summary Questions

1 Copy and complete the sentences below.

Energy is measured in ______ and power is measured in ______. Power is the energy transferred per ______. You pay for the number of ______ that are transferred to your house by electricity. You could save money by using appliances with a ______ power rating or by using them for ______ time.

(6 marks)

2 Compare the cost of using a kettle with a power rating of 2 kW and a kettle rated 1.2 kW.

(6 marks)

3

a Suggest a measure that a government can take to reduce a country's energy use. *(1 mark)*

b Suggest reasons why the campaign may be successful. *(1 mark)*

3.2.1 Energy adds up

Learning objectives

After this section you will be able to:

- use a model of energy transfer between stores to describe how jobs get done
- describe how the energy of an object depends on its speed, temperature, height, or whether it is stretched or compressed
- show how energy is transferred between energy stores in a range of real-life examples.

◀ Energy is a bit like money.

▲ Camping gas is a chemical store.

Do you have some money in your pocket? If you know how much you left home with and you didn't spend any on the way, then you know how much you have now.

Conservation of energy

Energy cannot just disappear, and you cannot end up with more than you had at the start. Energy cannot be created or destroyed, only transferred. This is the **law of conservation of energy**.

A State the law of conservation of energy.

Energy stores

There is energy associated with food and fuels (and oxygen). You can think of that energy as being in a **chemical energy store**. Energy is transferred from the store when you burn the fuel or respire. There are other types of energy store:

Energy to do with...	Type of energy store
food, fuels, batteries	chemical energy store
hot objects	**thermal energy store**
moving objects	**kinetic energy store**
position in a gravitational field	**gravitational potential energy store**
changing shape, stretching, or squashing	**elastic energy store**

Before and after

A camping stove burns gas, which is a fuel.

	Before:	After:
What we have	unburnt fuel, more oxygen cold soup	less fuel, more carbon dioxide and water hot soup (and slightly hotter air)
Thinking about energy	more energy in the chemical energy store less energy in the thermal energy store	less energy in the chemical energy store more energy in the thermal energy store

If you could measure the energy in the chemical and thermal energy stores you would see that:

total energy before = total energy after

B Name five types of energy store.

Transferring energy

Electric current, radiation (like light), waves (like sound), and heating are ways of transferring energy between stores. After you use your phone, there is less energy in the chemical energy store and more energy in the thermal energy store of the surroundings.

C State three ways that energy is transferred between stores.

Driving at a steady speed

When you are driving along the motorway at 70 m.p.h. you might think that there is energy going into a kinetic energy store. If your speed is not changing, then the energy in the kinetic store is not changing either. Here is an analysis:

	Before	After
What we have	colder car and surroundings, more petrol and oxygen, less carbon dioxide and water	warmer car and surroundings, less petrol and oxygen, more carbon dioxide and water
Thinking about energy	more energy in the chemical energy store of the petrol and oxygen less energy in the thermal energy stores of the car and surroundings	less energy in the chemical energy store of the petrol and oxygen more energy in the thermal energy stores of the car and surroundings

Bouncing a ball

When you bounce a ball it doesn't bounce as high. What is happening in terms of energy?

	Before	After
What we have	ball lifted up, cooler ball and surroundings	ball at the top of the first bounce, warmer ball and surroundings
Thinking about energy	more energy in the gravitational potential energy store of the ball less energy in the thermal energy stores of the ball and surroundings	less energy in the gravitational potential energy store of the ball more energy in the thermal energy stores of the ball and surroundings

▲ Cars on a motorway are heating the surroundings.

▲ When a ball bounces, it heats the air and the ground.

Remember those stores!

Use the first letter of each of the stores in the table above to write a mnemonic to help you to remember them.

Fantastic Fact

If all the energy in the food that you eat was converted to energy in a thermal energy store, you would glow like a light bulb.

Key Words

law of conservation of energy, chemical energy store, thermal energy store, kinetic energy store, gravitational potential energy store, elastic energy store

Summary Questions

1 Copy and complete the sentences below, choosing the correct bold words.

The law of conservation of energy says that energy cannot be **created/transferred** or **destroyed/transferred**. When you burn coal, you transfer energy from a **chemical/thermal** energy store to a **chemical/thermal** energy store. You **can/cannot** explain why things happen using energy. *(5 marks)*

2 Describe in terms of energy stores and transfers what happens when you:

a use a torch

b generate electricity using coal to run a cooker

c generate electricity using wind to run a motor. *(6 marks)*

3 Describe how the energy store of an object is linked to its speed, temperature, height, and compression. *(1 mark)*

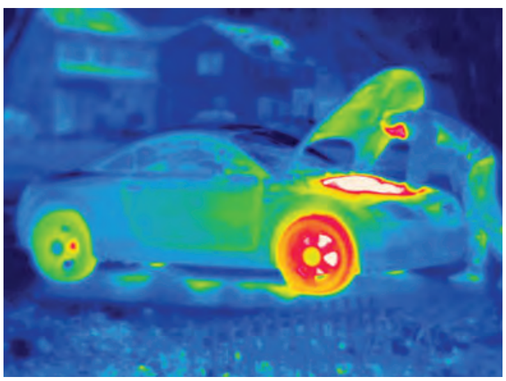
4 Use the ideas on these two pages to explain in detail what energy transfers happen when you cook sausages on a camp fire burning wood. *(6 marks)*

3.2.2 Energy dissipation

Learning objectives

After this section you will be able to:

- describe what dissipation means
- calculate the useful energy and the amount dissipated, given values of input and output energy
- explain how energy is dissipated in a range of situations.



▲ A car engine gets very hot.

Link

You will learn more about energy transfers in Book 2, 3.4.2 Energy transfer: particles and Book 2, 3.4.3 Energy transfer: radiation and insulation.

Key Word

dissipation

Fantastic Fact

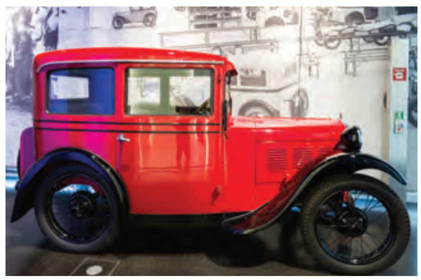
When it comes back to Earth, air resistance from the atmosphere heats up the outside of a space vehicle to several thousand degrees Celsius.

What does it mean to 'save energy'? If energy is conserved, how can it be saved?

Wasting energy

When you travel in a car you want the fuel that you burn to produce an increase in energy in the store that you want (your accelerating car), not in the energy store that you don't (a hot engine).

The useful energy is in a kinetic energy store, and the wasted energy is in a thermal energy store.



▲ Engineers have improved car design to reduce energy transferred to the surroundings.

Here are two situations where energy transfers to both useful and wasted energy stores.

Situation	Energy in this store decreases	Useful energy in this store increases	Wasted energy in this store increases
car accelerating	chemical energy store of the fuel (petrol) and oxygen	kinetic energy store of the accelerating car	thermal energy store of the surroundings
using a toaster	chemical energy store of the fuel (coal at power station) and oxygen	thermal energy store of the toast	thermal energy store of the surroundings

When you are driving a car, energy is transferred to the thermal store of the surroundings. The air or ground heats up a bit. That is not useful. You cannot transfer that energy to another store that you want it to go to, so it is effectively 'wasted'. In that case, scientists say that energy is **dissipated**.

A What does 'dissipation' mean?

Why is energy dissipated, and how can you reduce dissipation?

In a car, you want all the energy in the chemical energy store of the fuel and oxygen to end up in the kinetic energy store. This does not happen because of the contact forces acting on the car. Air resistance acts on the car as it moves through the air. Friction acts between engine parts and between the car and the road. These processes transfer energy to the thermal energy store of the surroundings.

B Name two ways to reduce dissipation in a car.

▲ We say things ‘burn up’ in the atmosphere. We mean that the force of air resistance has a large heating effect. When bits of rock hit the atmosphere we see a meteor shower.

Energy is not just dissipated by contact forces.

- Friction between surfaces can make them vibrate, producing sound.
- When a current flows in a wire, the wire gets hot. This transfers energy to the thermal energy store of the surroundings. You can reduce the energy dissipated by reducing the resistance of the wires.
- When objects get hot, they transfer energy to anything around them that is at a lower temperature. You can reduce dissipation by using insulation.

What is efficiency?

You can show how much energy is transferred usefully, and how much is wasted, using the idea of efficiency.

$$\text{efficiency (\%)} = \frac{\text{useful energy output} \times 100}{\text{energy input}}$$

For example, if the energy transferred from the chemical energy store of the fuel and oxygen in a car is 100 J and only 40 J is transferred to the kinetic energy store of the car, then the engine is 40% efficient.

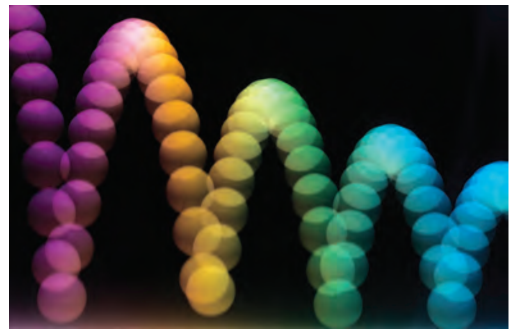
The wasted energy, or energy dissipated

$$= \text{energy input} - \text{useful energy output}$$
$$= 100\text{ J} - 40\text{ J}$$
$$= 60\text{ J}$$

Wasting energy

You may have heard people say that it is important to save energy. But if energy is conserved, how can you save it? You aren’t really saving energy. You are saving fuel. There is less wasted energy, so you need to use less fuel to do the job that you want.

▲ When you buy an appliance a label should tell you how efficient the appliance is.



▲ A ball loses energy each time it bounces.

Summary Questions

1 Copy and complete the sentences below by choosing the correct words:

Energy can be transferred to the surroundings or to other places that we do not want by ________ ________, such as air resistance or ________. When this happens we say that energy is wasted, or ________.

(3 marks)

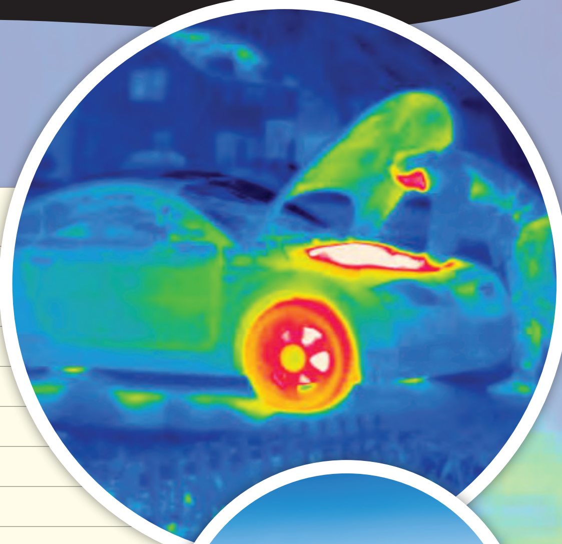
2

a A kettle transfers 200 J of energy to the thermal energy store of the water in it for every 500 J of input energy. Calculate the wasted energy. *(2 marks)*

b Calculate the efficiency of the kettle. *(2 marks)*

3 Compare the conservation of energy and the dissipation of energy, and explain the link between the two. *(6 marks)*

3 Energy: Summary



Key Points

Energy costs

- There is energy associated with food and fuels. Energy is measured in joules, J.
- Fossil fuels are non-renewable energy resources used for heating, transportation, and generating electricity.
- Renewable energy resources can also be used to generate electricity.
- Power tells you how quickly energy is transferred by a device. You can calculate power using the formula: power (W) = $\frac{\text{energy (J)}}{\text{time (s)}}$.
- You can work out the cost of the energy transferred by appliances in your home using the formula: cost = power (kW) x time (hours) x price (kWh). Energy companies use the unit of kilowatt hours.

Energy transfer

- Energy cannot be created or destroyed, it can only be transferred between stores. This is the law of conservation of energy. An energy store is a way of keeping track of energy.
- Radiation (like light), heating, forces, and electricity are ways of transferring energy between stores.
- Energy is dissipated in any energy transfer process because of friction, air resistance, electrical resistance, and heating of the surroundings by hot objects.
- You can calculate the useful energy or the wasted energy from the energy input and energy output.

Key Words

energy, joules, kilojoules, energy resources, fossil fuels, non-renewable, renewable, watts, power, kilowatts, kilowatt hours, law of conservation of energy, chemical energy store, dissipated

BIG Write

Energy campaign

You are a local councillor who wants to raise awareness of energy issues in schools.

There are two parts to the campaign:

- raising awareness of the energy content of food and how that links to the energy needed for activities that people do
- saving fossil fuels for the future.

Task

a Design an energy diary that students could use to take a snapshot of their own energy use over a day or a week.

b Write an article for the school newspaper that explains the link between closing doors or insulating buildings, cost, and fossil fuel use.

End-of-Big Idea questions

1 Here are some energy resources. List the renewable energy resources.

wind solar oil coal geothermal gas

(**1 mark**)

2

a Write the letter of the correct definition of power below. *(1 mark)*

A the energy transferred per kilogram

B the energy transferred

C the energy transferred per second

D the force over a distance

b Select all the units of power from this list:

kW J watts kilojoules kilowatts W joules kJ

(1 mark)

(**2 marks**)

3

a Explain, in terms of energy, why a pendulum swings lower and lower when you let it go. *(2 marks)*

b Describe an everyday situation where energy is dissipated by friction. *(1 mark)*

(**3 marks**)

4

a Name a fossil fuel that can be burned in a power station. *(1 mark)*

b Explain why it is called a 'fossil' fuel. *(1 mark)*

c Use your answer to part **b** to explain why fossil fuels are non-renewable. *(2 marks)*

(**4 marks**)

5 A tablet charger has a power of 100 W.

a Convert 100 W to kW. There are 1000 W in 1 kW. *(1 mark)*

b Calculate the cost of using the charger for 3 hours if the cost of 1 kWh is 10 p.

(2 marks)

c State and explain one way of reducing the costs on your home energy bill. *(2 marks)*

(**5 marks**)

6 You want to reduce your energy bills.

a Calculate the power of a lightbulb that transfers 6000 J every minute. *(2 marks)*

b Two bulbs are equally bright. State and explain which lightbulb you should use.

(2 marks)

c State and explain one way of reducing the costs on your home energy bill.

(2 marks)

(**6 marks**)

7 A tennis ball has 0.5 J of energy when it is 1 m above the floor.

a Name the store associated with this energy. *(1 mark)*

b A student states that there will be 0.5 J of energy in the kinetic store just before it hits the ground.

i Explain why the student has made that statement. *(1 mark)*

ii Explain why the student might not be correct. *(1 mark)*

c Explain why the ball moves. *(2 marks)*

(**5 marks**)

8 Here are some data about two types of kettle.

Kettle	Energy input (kJ)	Useful energy output (kJ)	Wasted energy (kJ)
BoilFast	600	540	
KettlePro	800		80

a Copy and complete the table. *(2 marks)*

b Calculate the efficiency of each kettle.

(4 marks)

c A student says that the BoilFast kettle must be more efficient because it wastes less energy. Explain why this is not correct. *(2 marks)*

(**8 marks**)