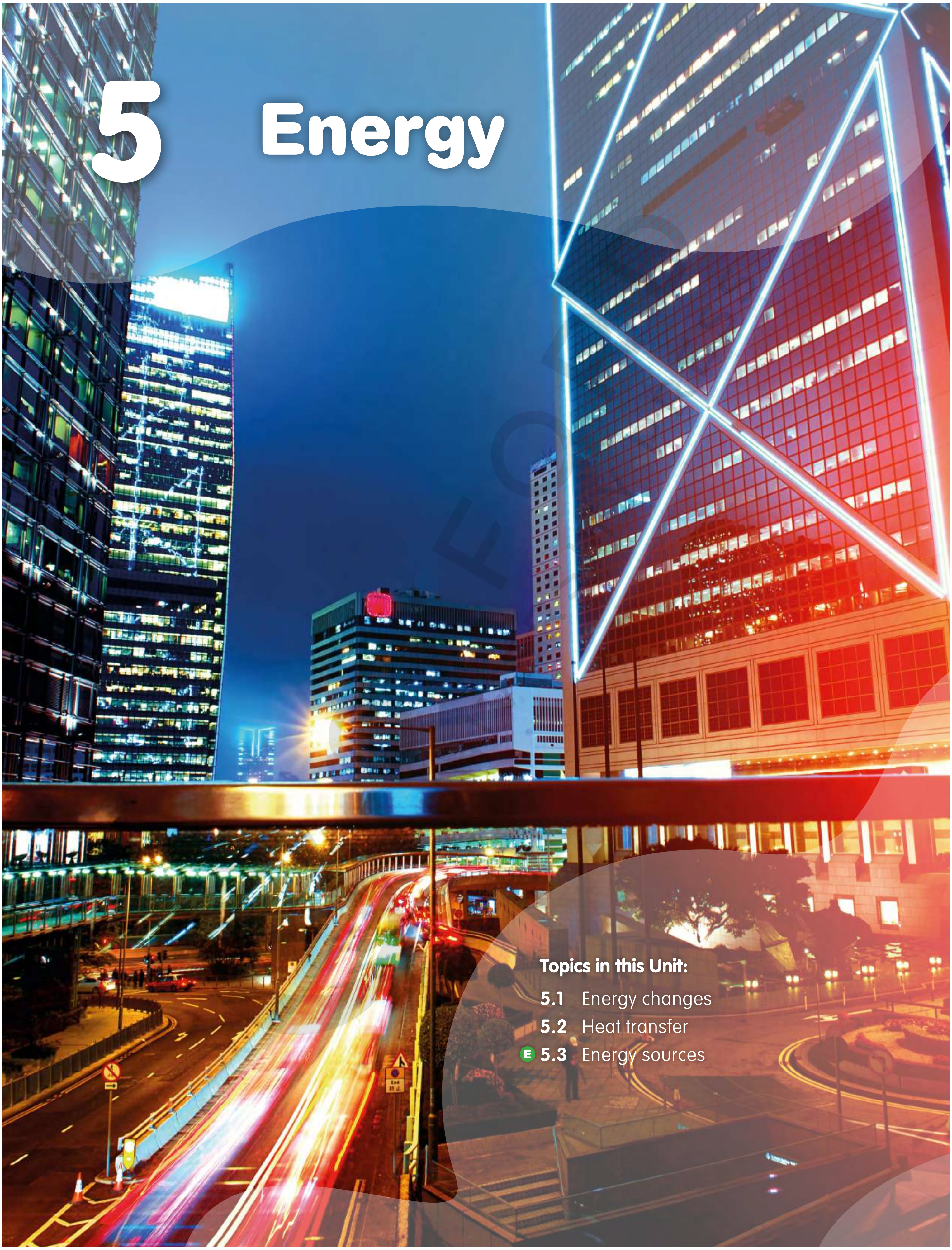
5 Energy



Topics in this Unit:

5.1 Energy changes

Let's begin

Flipped classroom

Watch a video and answer the questions.

On a busy road in Mong Kok, we can see people walking, buses moving, and street lamps and advertising signs shining. All these actions involve energy changes.

Fig 5.1 A busy road in Mong Kok

You have learnt the word '**energy***' in ***Unit 2 Water***. Do you know that there are different forms of energy, and energy can change from one form to another?

Everything happening around us are all related to one or more forms of energy. Energy can change from one form to another, leading to different outcomes. In this Section, we will learn about different forms of energy first. Then we will look at some examples of energy changes.

turning on a lamp

mobile phone ringing

All involve energy changes.

reading and writing

eating and talking

energy 能量

A Forms of energy

There are many different forms of energy. Below are some common forms.

1 Light energy

The Sun and street lamps give out **light energy***. Some living things, such as fireflies, also give out light energy.

Fig 5.2 (a) The Sun, (b) street lamps and (c) a firefly* give out light energy

2 Thermal energy

The Sun and an electric heater give out **thermal energy***. A gas flame and a hot spring* also give out thermal energy.

Fig 5.3 (a) An electric heater, (b) a gas flame and (c) a hot spring give out thermal energy

light energy 光能 firefly 螢火蟲 thermal energy 熱能 hot spring 温泉

3 Sound energy

When an alarm clock rings, it gives out **sound energy***. When we talk or sing, we give out sound energy too. Cicadas* can also give out sound energy. In summer, we often hear the loud 'beep beep' sound of cicadas.

Fig 5.4 A ringing alarm clock gives out sound energy

Fig 5.5 We give out sound energy when we sing

Fig 5.6 A cicada can give out sound energy

4 Chemical energy

Fuels* such as wood and petrol store a large amount of **chemical energy***. When they burn, their chemical energy is released as light energy and thermal energy.

Food also stores chemical energy. The chemical energy in food provides us with energy for various activities and keeping us warm.

Refer to p. 96 for information on electrical energy.

▶ Dry cells* also store chemical energy. They provide electrical energy* for small electrical appliances.

Fig 5.7 (a) Wood, (b) food and (c) dry cells store chemical energy

sound energy 聲能 cicada 蟬 fuel 燃料 chemical energy 化學能 dry cell 乾電池 electrical energy 電能

5 Kinetic energy

Moving bodies, such as a running girl or a flying jet fighter, have **kinetic energy***. The more kinetic energy an object has, the faster it moves.

Fig 5.8 (a) A running girl, (b) a jet fighter and (c) swimming dolphins have kinetic energy

6 Potential energy

When an object moves to a higher position, it gains **potential energy***. A dumb-bell gains potential energy when it is raised. An object gains more potential energy when it moves to a higher position (Fig 5.9).

When we compress* or stretch* an elastic* object, such as a rubber band or a spring*, it also gains potential energy. An elastic object gains more potential energy as we compress or stretch it more (Fig 5.10).

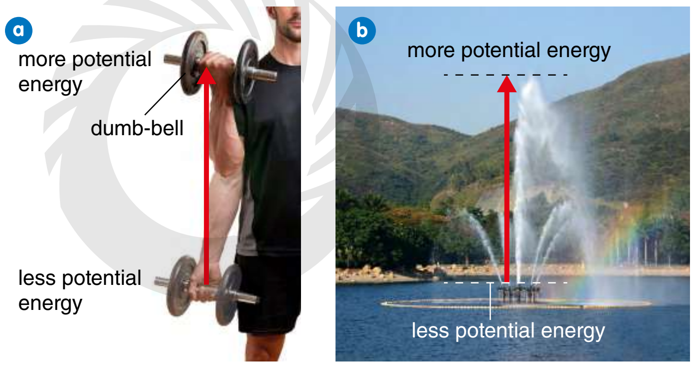


Fig 5.9 (a) The dumb-bell gains potential energy when it is raised; (b) The water gains potential energy when it goes up

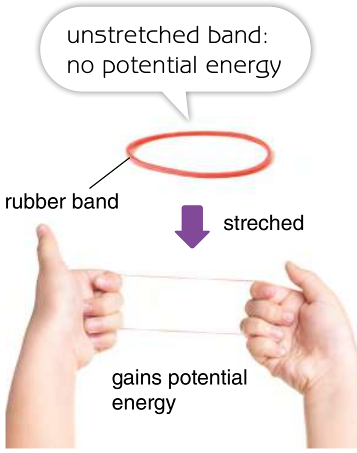


Fig 5.10 The rubber band gains potential energy when it is stretched

kinetic energy 動能 potential energy 勢能 compress 擠壓 stretch 拉長 elastic 有彈性的 spring 彈簧

7 Electrical energy

Link
You will learn more about electrical energy in ***Bk 2A, Unit 8***.

Many home appliances need **electrical energy** to work. Electrical energy can be supplied from mains sockets or dry cells. In the appliances, electrical energy is changed to other forms of energy. Electrical energy is a very important form of energy to the modern life.

We can also find electrical energy in Nature. For example, lightning carries a large amount of electrical energy.

Fig 5.11 An electric kettle changes electrical energy to thermal energy

Fig 5.12 A torch changes electrical energy to light energy

Fig 5.13 Lightning carries a large amount of electrical energy

Key point

Some common forms of energy include light energy, thermal energy, sound energy, chemical energy, kinetic energy, potential energy and electrical energy.

Quick check

Complete the following sentences.

1 The hot tea gives out ____________ energy.

2 The television set gives out ____________ energy and ____________ energy.

3 The running dog has ____________ energy.

4 The dry cells store ____________ energy.

5 The book gains ____________ energy when it is raised.

Check your answers (p. 162)

B Energy conversion

1 Converting energy from one form to another

Fig 5.14
Energy conversion occurs when a candle burns

Energy can be converted from one form to another. **Energy conversions*** happen all around us. For example, when a candle burns, the chemical energy stored in the candle is converted to light energy and thermal energy.

Chemical energy (stored in candle) → light energy + thermal energy (given out by the flame)

Let us observe more examples of energy conversion in ***Practical 5.1***.

Practical 5.1 Observing energy conversions

Aim

To observe some simple energy conversions

Video

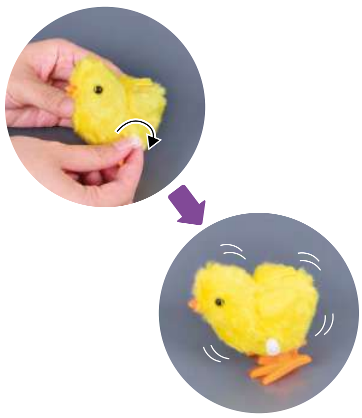
Apparatus and materials

per group		per class			
spring toy	1	circuit board	1	Bunsen burner	1
long inclined board*	1	dry cell	1	insulating mat	1
can	1	connecting wire	3	metal pipe with wire gauze	1
plastic bottle	1	switch	1	stand and clamp	1 set
sand		buzzer*	1		
alcohol thermometer or digital thermometer	1	gas lighter	1		

1 Wind up a spring toy and then release it.

Describe what you observe. (Does the toy move?)

____

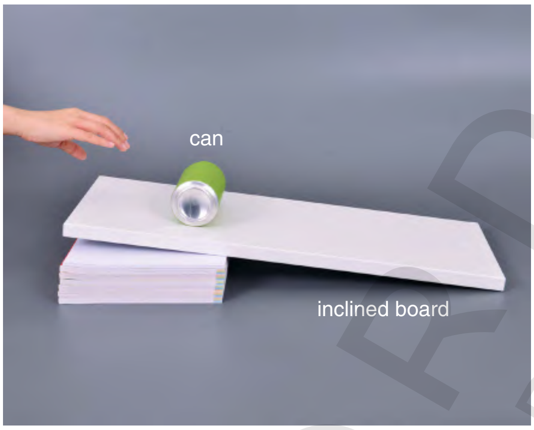


Energy conversion:

______ energy (stored in the spring)	→	______ energy (of the spring toy)

cont.

2 Release a can from the top of an inclined board.



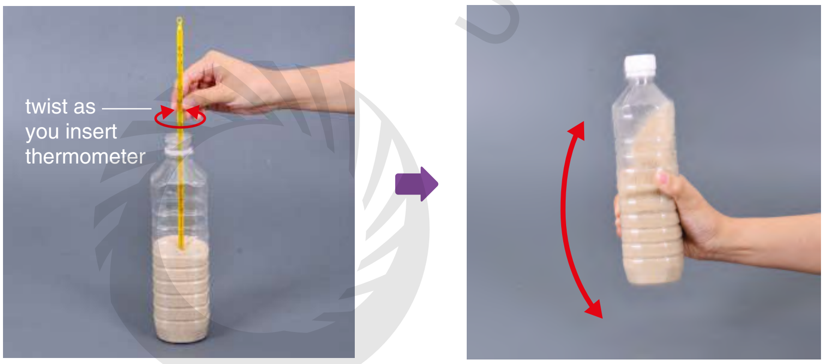
Describe what you observe. (How does the can move?)

____

Energy conversion:

____________ energy (stored in the can)	→	____________ energy (of the can)

3 Half fill a bottle with sand. Carefully insert a thermometer into the sand to measure its temperature. Remove the thermometer and put on the cap tightly. Take turns to shake the bottle hard for about three minutes. Measure the temperature of the sand again.



Wear safety spectacles!

Caution

- Do not insert the thermometer too deep into the sand. Be careful not to break the thermometer when inserting.
- Make sure the bottle is tightly closed before shaking it.
- Be careful not to let loose the bottle when you shake it.

Temperature at the beginning = ____________ °C

Temperature after shaking = ____________ °C

Refer to **Skill reminder** on p. 244 for how to measure temperature.

cont.

Describe what you observe. (Do you hear any sound when you shake? How does the temperature change?)

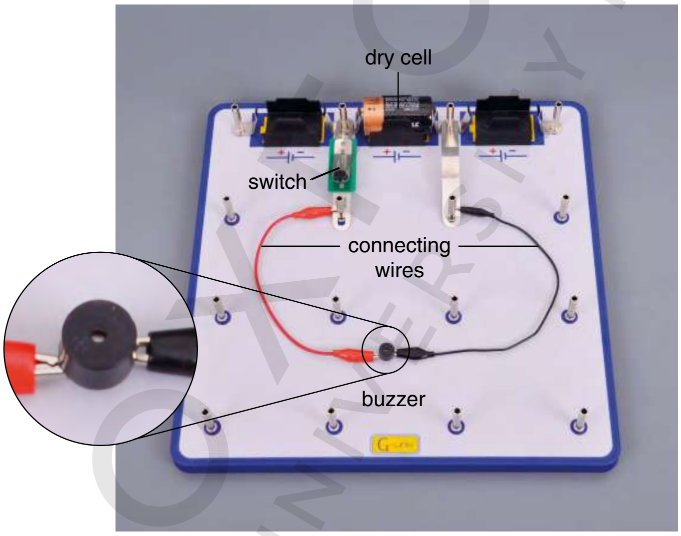
____

____

Energy conversion:

______________ energy (of the sand)	→	______________ energy and ______________ energy (given out by the sand)

4 Your teacher will connect a buzzer to a dry cell. Listen carefully.



Describe what you observe.

____

____

Energy conversion:

______________ (stored in the dry cell)	→	______________ (given out by the buzzer)

cont.

5 Your teacher will hold a metal pipe (with a wire gauze inside) on a stand with a clamp as shown. Heat the lower end of the metal pipe with a Bunsen flame for one minute. Then move away the Bunsen flame.

Wear safety spectacles!

Caution
Do NOT touch the hot metal pipe!

Describe what you observe.

____

____

Energy conversion:

____________________ (given out by the wire gauze)	→	____________________ (given out by the metal pipe)

Key point

Energy ______________ (can / cannot) be converted from one form to another.

2 More energy conversions

a Energy conversions of a ball or bean bag thrown upwards

You should have the experience of throwing a ball upwards. The ball shoots up into the sky, reaches the highest point and then returns to the ground. In the following practical, we will observe the motion of an object thrown upwards and study its energy conversions.

Practical 5.2 Energy conversions of a bean bag thrown upwards

Aim

To study the changes in potential energy and kinetic energy of a bean bag thrown upwards

Video

Apparatus and materials per group	
bean bag	1
mobile phone / tablet computer	1

1 Carry out this practical on the playground. Form into groups of 4 or 5.

2 Set the video camera of a mobile phone / tablet computer at the slow-motion video mode.

3 One of the students hold a bean bag a few metres away from the mobile phone / tablet computer, so that the camera can capture the whole path of the movement of the bean bag when it is thrown upwards. Hold the bean bag near to the ground.

4 Start recording the video. The student throws the bean bag straight upwards by 1–2 m. Record the path of the movement of the bean bag until it reaches the ground again. Do not move the mobile phone / tablet computer during recording.

Caution
- Leave enough space between groups so that the falling bean bags do not hurt anyone.
- Do not throw the bean bag too hard.

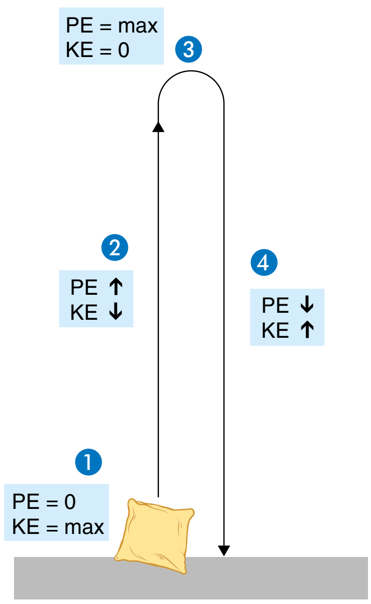
cont.

rotate 轉動 horizontal 水平

5 Observe the motion of the bean bag in the video. State whether the bean bag's potential energy (PE) and kinetic energy (KE) is increasing or decreasing. Complete the table.

Observation	PE	KE
a At the moment the bean bag leaves the hand, it moves the fastest.	Taken as zero	Maximum
b The bean bag moves slower and slower as it goes up.		
c The bean bag is momentarily at rest* at its highest position.	Maximum	Zero
d The bean bag moves faster and faster as it goes down.		

Let us study the energy conversion of a bean bag from it is thrown up until it reaches the ground:



1. The potential energy of the bean bag is taken as zero at the starting point.
2. When the bean bag is thrown upwards, its kinetic energy changes to potential energy. As the bean bag goes up, it gains more potential energy and loses kinetic energy, thus moving slower and slower.
3. At the highest position, the bean bag's potential energy reaches the highest. The bean bag is momentarily at rest so its kinetic energy is zero.
4. Then the bean bag goes down. It loses potential energy and gains kinetic energy, thus moving faster and faster as it goes down.

Link

You will learn more about the change between PE and KE in DSE Physics.

momentarily at rest 瞬時靜止

b Energy conversions in electricity generation

Electrical energy is a useful form of energy. It can be converted from other forms of energy. ***Practical 5.3*** shows how electricity is generated in a steam engine model*.

Practical 5.3 Generating electricity using steam engine model (Teacher demonstration)

Aim

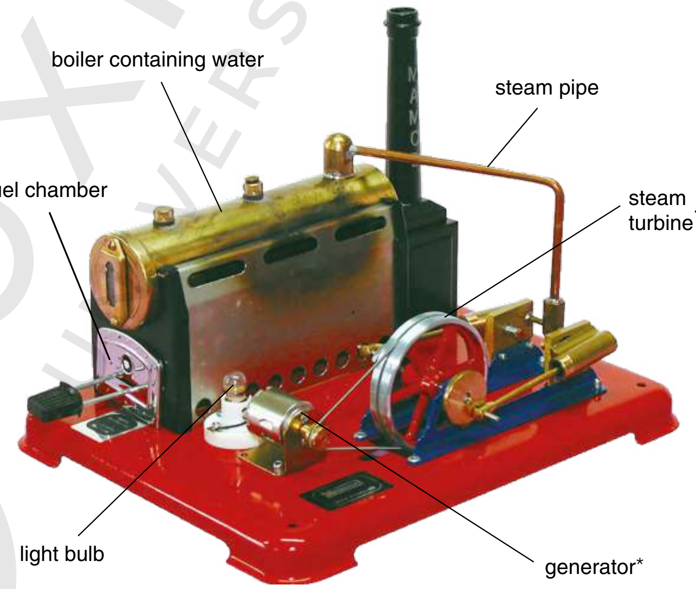
To use a steam engine model to generate electricity*

Video

Apparatus and materials per class	
steam engine model	1
alcohol	
water	

Caution
- The boiler and the steam are very hot. Do NOT touch them.
- Alcohol is flammable.
- When the fuel chamber is hot, do NOT add alcohol to the chamber.

1 Your teacher will show you a steam engine model. Identify different parts of the model.



2 Fill the boiler of the model with water to about one-third full.

3 Add alcohol to the fuel chamber. Light the alcohol to boil the water.

a What happens to the steam turbine?

____

____

cont.

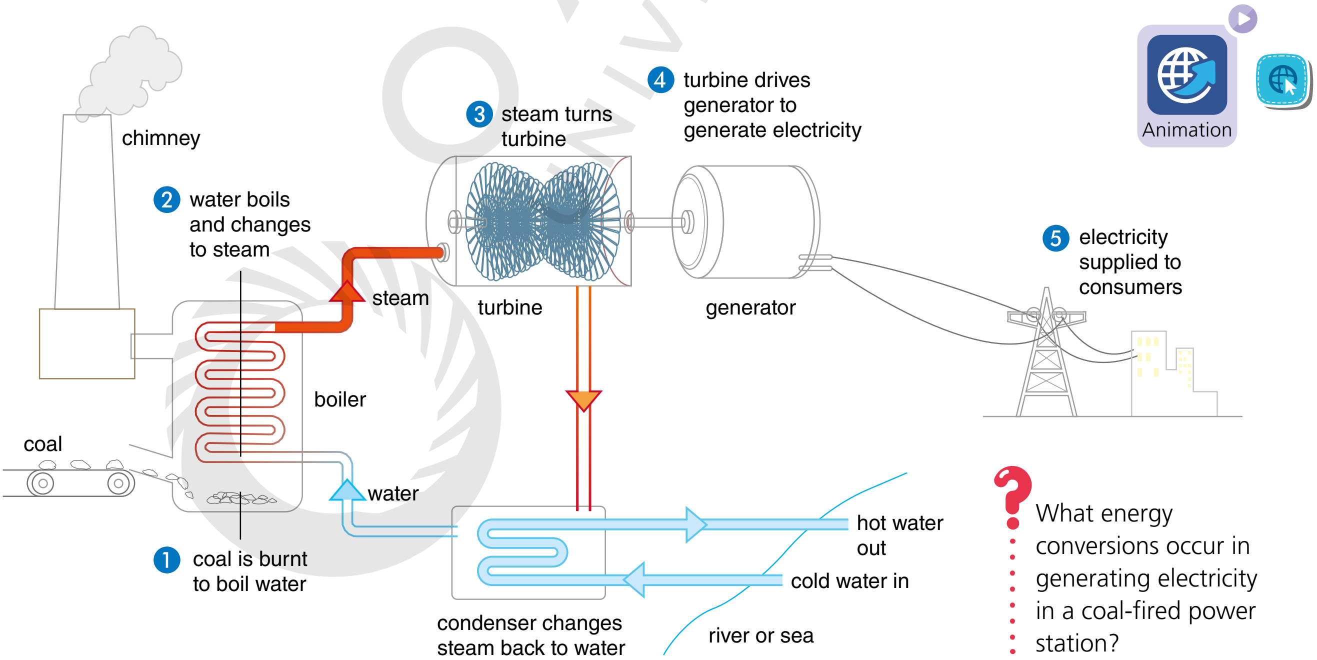
b What happens to the light bulb? What does this show?

The light bulb ________. This shows that ________ energy is supplied to the light bulb.

c Write down the energy conversions that occur in the steam engine model.

________ energy (stored in alcohol)	→	________ energy and ________ energy (of the flame)	→	________ energy and ________ energy (of the steam)	→	________ energy (of the steam turbine)	→	________ energy (generated by the generator)

A steam engine is a machine that uses the force produced by steam pressure to perform mechanical work. The force from the steam turns the steam turbine. The turbine turns the generator and electricity is generated. This mode of electricity generation is applied in most power stations that use fossil fuels (e.g. coal* and natural gas*) as the fuel (Fig 5.15).



What energy conversions occur in generating electricity in a coal-fired power station?

Fig 5.15 How electricity is generated in a coal-fired power station

coal 煤 natural gas 天然氣

Go further

Generator

A simple generator consists of some magnets and several coils of many turns of wires. When the coils are turned between the magnets, electricity is generated.

You can learn more about generators in DSE Physics.

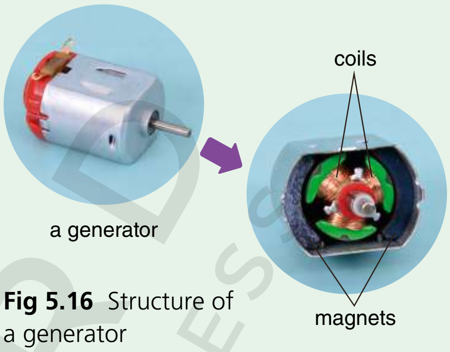


Fig 5.16 Structure of a generator

Fig 5.17 shows a hydroelectric power model*. The working principle of hydroelectric power is similar to the steam engine model except that the **force that drives the turbine comes from flowing water** instead of steam.

Link
You will learn more about hydroelectric power in ***Section 5.3***.

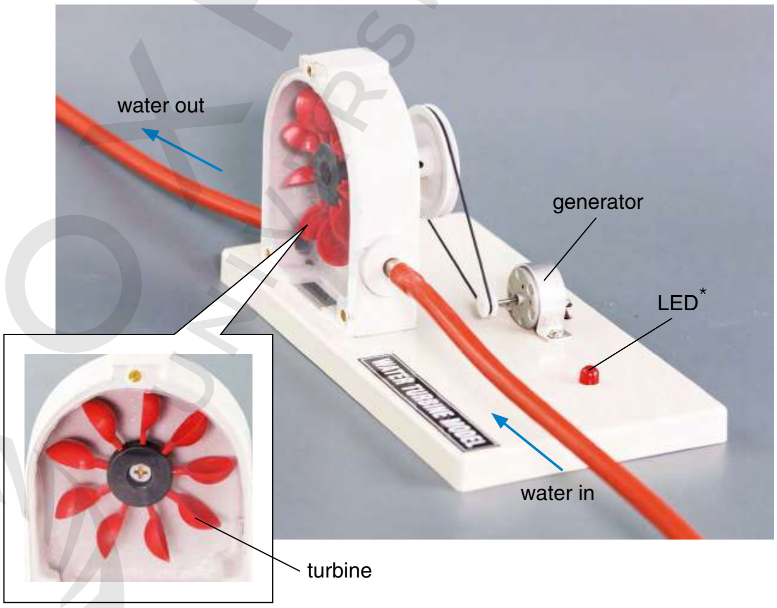


Fig 5.17 A hydroelectric power model

The energy conversions that occur in the hydroelectric power model is shown below.

Kinetic energy (of water) → kinetic energy (of the turbine) → electrical energy (generated by the generator)

The Sun provides endless source of light energy. Scientists invented solar cells* to capture light energy from the Sun and convert it to electrical energy. Solar cells can also capture light energy from other light sources (Fig 5.18).

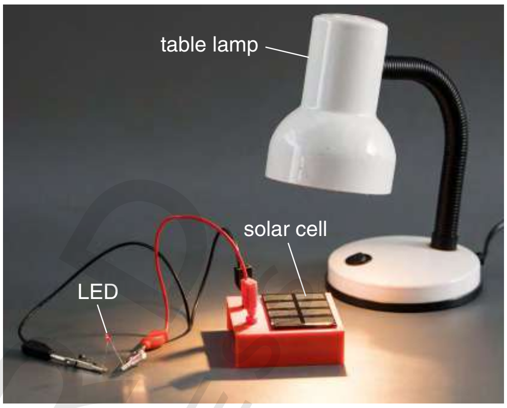


Fig 5.18 Solar cell captures light energy and convert it to electrical energy that lights up an LED

The energy conversion that occurs in the solar cell in Fig 5.18 is shown below.

Light energy (from the table lamp) → electrical energy (generated by the solar cell)

Link

You will learn more about generation of electricity in ***Section 5.3***.

Key point

There are different ways to generate electricity. They are examples of energy conversion.

Did you know?

Photosynthesis

Energy conversions also occur in Nature. Green plants take in carbon dioxide* and water, and build them into food using light energy. This process is called photosynthesis*. The energy conversion is:

Light energy (given out by the Sun) → chemical energy (stored in the food)

Link

You will learn more about photosynthesis in ***Bk 2A***, ***Unit 7***.

 solar cell 太陽能電池 carbon dioxide 二氧化碳 photosynthesis 光合作用

Quick check

Write down the energy conversion for each of the following processes.

1 Iron powder in hand warmer reacts with oxygen in air and the hand warmer becomes warm

_____________ energy (of the pack)
→ _____________ energy (of the pack)

2 Solar charger placed under light and generates electricity

_____________ energy (from the Sun)
→ _____________ energy (generated by the solar cell)

Check your answers (p. 162)

Conservation of energy

1 Units of energy

A common unit of energy is the **joule*** (J). Large amounts of energy can be measured in **kilojoules*** (**kJ**) or **megajoules*** (**MJ**):

1 kJ = 1000 J
1 MJ = 1 000 000 J

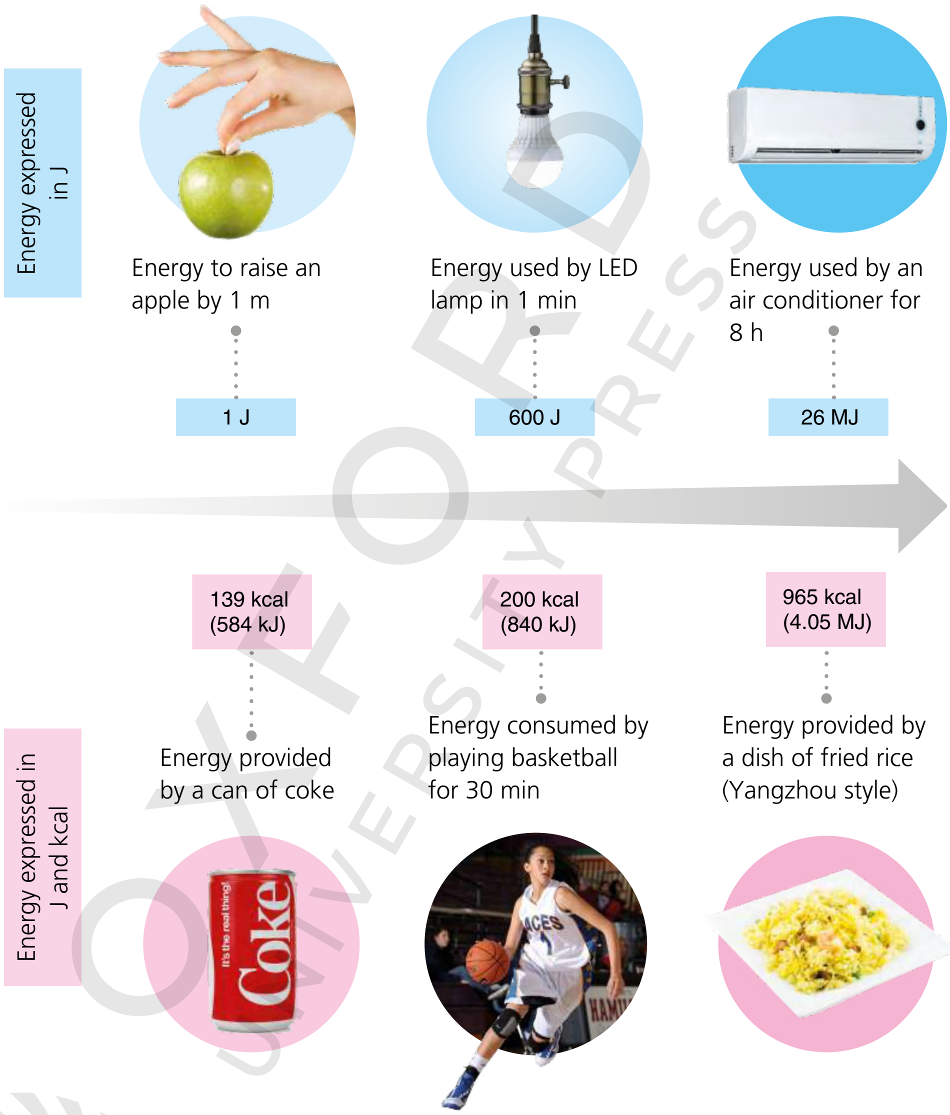
Another common unit of energy is the **kilocalorie*** (kcal). This unit is commonly used to measure the energy stored in food or the energy consumed in doing exercise. One kcal is about 4200 J.

1 kcal = 4200 J

Fig 5.19
Food label showing energy in kJ and kcal

joule 焦耳 kilojoule 千焦耳 megajoule 兆焦耳 kilocalorie 千卡

Below are examples of different amounts of energy.



Key point

The joule and the kilocalorie are common units of energy.

2 Law of conservation of energy

Energy is one of the most important ideas in science. We have learnt that:

- anything that happens is related to one or more forms of energy;
- energy can be converted from one form to another.

Scientists also found this: in each energy conversion, **the total amount of energy before the conversion is always the same as that after the conversion**. That is, energy is **conserved*** in the process.

These are summarized in the **law of conservation of energy***: **energy can be converted from one form to another, but it cannot be created or destroyed**. This is one of the most important laws in science.

For example, when an electric fan is turned on, it converts 500 J of electrical energy to 300 J of kinetic energy, 100 J of sound energy and 100 J of thermal energy. The energy input to the fan is equal to the total energy output; no more, no less.

Language tips

'*Conserve*' is a **verb**, '*conserved*' is an **adjective**, and '*conservation*' is a **noun**.

Example:

- We need to **conserve** (i.e. save) energy.
- The law of **conservation** of energy states that the total energy is **conserved** (i.e. keeps unchanged).

500 J of electrical energy (from mains electricity*) → 300 J of kinetic energy (of moving air) + 100 J of sound energy + 100 J of thermal energy (100 J of sound energy and 100 J of thermal energy: given out by the fan)

Total: 500 J

Big science ideas

Change and constancy in energy conversion

In an energy conversion, the amounts of individual forms of energy may **change**, but the total amount of energy stays **constant**.

Key point

- Energy is conserved. The **law of conservation of energy** states that
  ① energy can be converted from one form to another, but
  ② energy cannot be created or destroyed.
- Total amount of energy before conversion = total amount of energy after conversion

3 Sankey diagram

We can draw a **Sankey diagram*** to show that energy is conserved in an energy conversion process. Below is the Sankey diagram for the electric fan on p. 109.

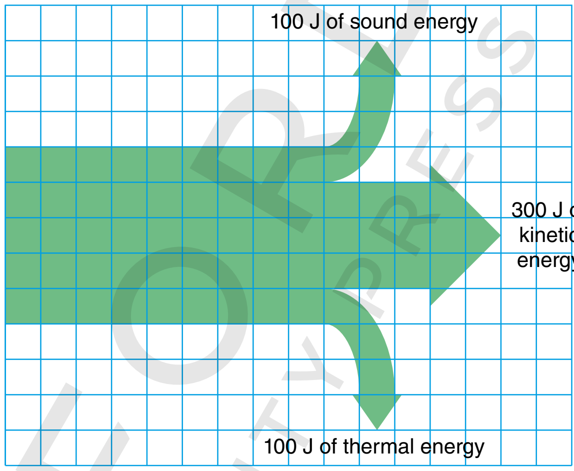


Fig 5.20 A Sankey diagram showing the energy conversion in an electric fan

In a Sankey diagram,

- the **left**-hand side shows the energy **input** (electrical energy in the above example).
- the arrow pointing towards the **right** represents the **useful** energy output (kinetic energy), while arrows pointing **upwards** or **downwards** represent energy output that is **not useful** to us (sound and thermal energy).

Flowing air makes us cool, so kinetic energy is useful to us; noise and heat is unwanted, so their related forms of energy are not useful.

- the widths of the arrows are directly proportional to the amounts of energy represented.
- the width of the energy input is equal to the sum of the widths of the three energy output arrows. This shows that energy is conserved in the conversion process.

Skill builder 5.1

Drawing Sankey diagrams (p. 111)

Key point

- We can use a Sankey diagram to represent an energy conversion.
- The widths of the arrows are proportional to the amounts of energy represented.

Skill builder 5.1

Drawing Sankey diagrams

Video

Note the skills below in drawing a Sankey diagram. Take the Sankey diagram on p. 110 as an example.

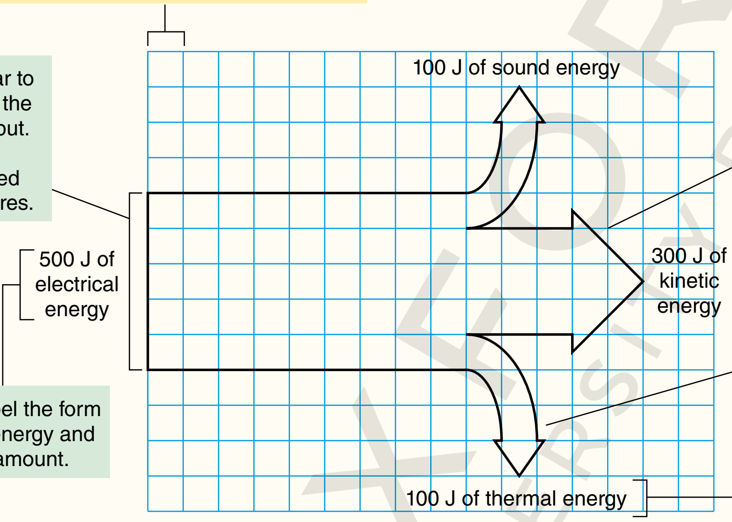
Steps

1 Choose a suitable scale, e.g. each square represents 100 J.

Use a sharp HB pencil to draw the diagram.

2a Draw a bar to represent the energy input. 500 J is represented by 5 squares.

2b Label the form of energy and its amount.



3a Draw arrows to represent the energy outputs. Draw an arrow pointing towards the right to represent the useful kinetic energy (3 squares to represent 300 J).

3b Draw two other arrows pointing upwards and downwards to represent sound energy and thermal energy (1 square to represent 100 J).

3c Label the arrows.

Draw a Sankey diagram for the following energy conversion: an electric toy boat converts 6 J of electrical energy to 3 J of kinetic energy, 2 J of sound energy and 1 J of thermal energy.

Check your answers (p. 162)

Extension

D Energy conversion efficiency

In Fig 5.19 on p. 109, the electric fan converts electrical energy to kinetic energy, sound energy and thermal energy. However, only the kinetic energy is useful to us. The sound and thermal energy is wasted. By the law of conservation of energy,

$$\text{total energy input} = \text{useful energy output} + \text{energy wasted}$$

To find out what percentage* of the input energy is converted to useful energy in an energy conversion, we can calculate the **efficiency***.

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

Example 5.1

Efficiency of electric toy boat

Calculate the efficiency of the electric toy boat on p. 111.

Video

Solution

The useful energy output is the 3 J of kinetic energy and the total energy input is the 6 J of electrical energy.

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\% = \frac{3}{6} \times 100\% = 50\%$$

Calculate the efficiency of the fan on p. 109.

Check your answers (p. 162)

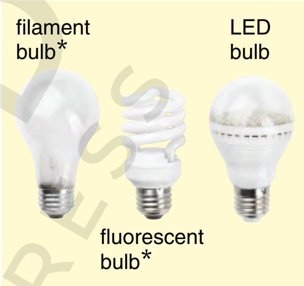
percentage 百分比 efficiency 效率

Extension

Activity 5.1 Comparing efficiency of light bulbs

A light bulb converts electrical energy to light energy and thermal energy. Three different bulbs are used for 1 minute. Complete the table below.

	Filament bulb	Fluorescent bulb	LED bulb
Energy input (J)	2400	600	400
Light energy output (J)	120	120	
Thermal energy output (J)	2280		300
Efficiency			



Which bulb works best to convert electrical energy to light energy?

____

The LED bulb is the most efficient. A high-efficiency appliance uses less input energy than a low-efficiency appliance to do the same job.

Section summary 5.1

Common forms of energy	• Light energy • Chemical energy • Electrical energy • Thermal energy • Kinetic energy • Sound energy • Potential energy
Common units of energy	• The joule (J) and the kilocalorie (kcal) • 1 kJ = 1000 J, 1 MJ = 1 000 000 J
Law of conservation of energy	• ① Energy can be converted from one form to another, but ② energy cannot be created or destroyed. • Total energy before conversion = total energy after conversion
Sankey diagram	• It represents an energy conversion; the widths of the arrows are proportional to the amounts of energy represented.
E Energy conversion efficiency	• Total energy input = useful energy output + energy wasted • Efficiency = $\frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$

filament bulb 鎢絲燈泡 fluorescent bulb 熒光燈泡

Section exercise 5.1

Level 1

1 Which of the following statements about energy is INCORRECT?

A Energy is conserved in an energy conversion.

B Energy can be converted from one form to another.

C Light is a form of energy.

D Electrical energy is created in power stations.

p. 109

E 2 A loudspeaker gives out 8 J of sound energy when 500 J of electrical energy is input to it. What is the efficiency of the energy conversion?

A 0.016%

B 1.6%

C 16%

D 40%

p. 112

Level 2

3 A burning wood gives out light energy and thermal energy. Given that 2000 J of chemical energy of the wood gives 1400 J of thermal energy.

a Express 1400 J in kJ. (1 mark)

p. 108

b Write down the energy conversion of the burning of wood. (2 marks)

p. 97

c Calculate the light energy given out. (2 marks)

p. 109

E **d** The wood is burnt to give warmth. Calculate the efficiency of the energy conversion. (2 marks)

p. 112