

## THEME

# 3

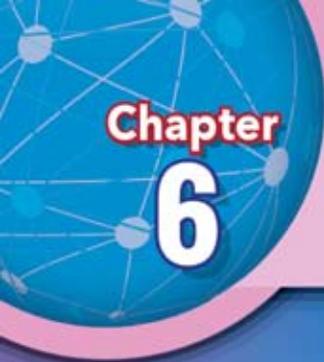
## Energy and Sustainability of Life

Solar cells are used to generate electricity. What is the importance of the generation of electricity using solar energy in Malaysia?



According to the law in Malaysia, the installation of smoke detectors in buildings such as hospitals, hotels, supermarkets and office buildings is compulsory. Smoke detectors normally contain a small amount of radioactive substance. Name this radioactive substance. What is the importance of handling radioactive substances effectively in daily life?





## Chapter 6

# Electricity and Magnetism

What are renewable and non-renewable energy sources?

What are the functions of step-up and step-down transformers?

How is the cost of electricity consumption calculated?



### Let's study

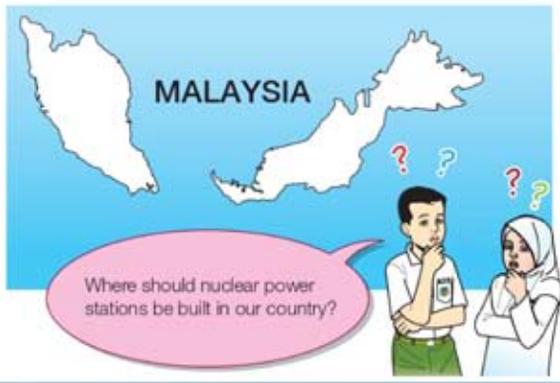
- ▶ Generation of electricity
- ▶ Transformer
- ▶ Transmission and distribution of electricity
- ▶ Calculating the cost of electricity consumption

## Science Gallery



According to a report from the Malaysian Nuclear Agency, Malaysia needs to have a nuclear power station in 2030. This power station should generate electricity that is sufficient to meet the electricity needs of our country. Do you agree or disagree with having of this power station in Malaysia? Why?

(Source: <http://www.utusan.com.my/sains-teknologi/inovasi/loji-nuklear-negara-beroperasi-2030-1.146680>)



### Keywords

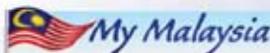
- ◆ Power station
- ◆ Induced current
- ◆ Direct current
- ◆ Alternating current
- ◆ Primary coil
- ◆ Secondary coil
- ◆ Input voltage
- ◆ Output voltage
- ◆ National Grid Network
- ◆ Earth wire
- ◆ Short circuit
- ◆ Electric shock
- ◆ Kilowatt-hour (kWh)
- ◆ Energy efficiency

## Various Energy Sources to Generate Electricity

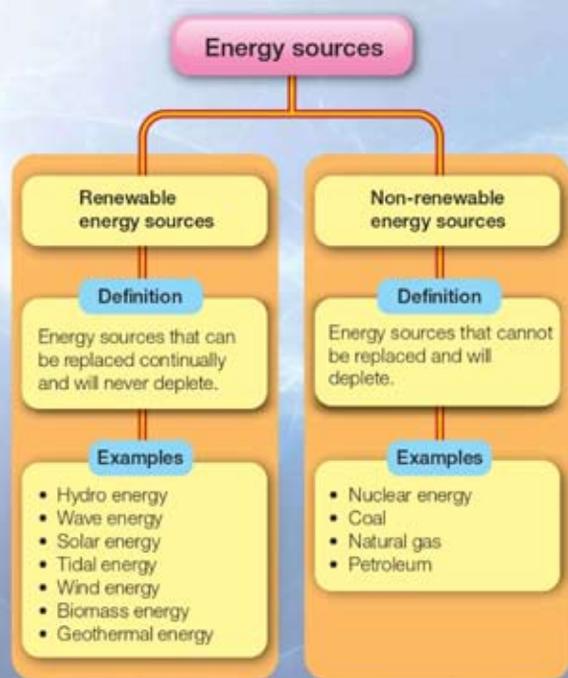
Did you know that our country, Malaysia is a country which is very successful in using various energy sources to generate electricity? What are the energy sources used in Malaysia to generate electricity?

Electricity is generated through various energy sources. These different energy sources can be classified into two main groups, namely **renewable energy sources** and **non-renewable energy sources** as shown in Figure 6.1.

Figure 6.2 shows renewable and non-renewable energy sources used in power stations in Malaysia.



Malaysia is currently the leading country in biomass industry in the Southeast Asian region. Sarawak and Sabah are two states in Malaysia that have a variety and a large amount of biomass. The variety of biomass includes the biomass of oil palm, forests, rubber trees, garbage, rice husks and maize. Besides the generation of electricity, biomass is also used to produce innovative products such as building materials.



Hybrid power station in Pulau Perhentian Kecil, Terengganu (Energy source: Wind, Solar, Diesel)

Figure 6.1 Renewable and non-renewable energy sources



Bakun hydroelectric power station in Sarawak (Energy source: Hydro energy)



Tuanku Jaafar power station in Negeri Sembilan (Energy source: Natural gas)



Sultan Azlan Shah power station in Manjung, Perak (Energy source: Coal)

Power stations  
in Malaysia



TSH Bio-Energy Sdn. Bhd. Biomass power station in Sabah (Energy source: Biomass)

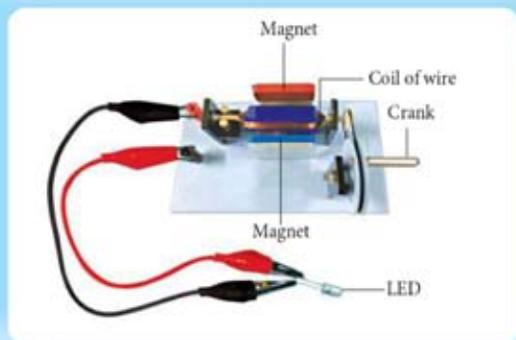


Gelugor power station in Pulau Pinang (Energy source: Diesel)

Figure 6.2 Power stations in Malaysia that use renewable and non-renewable energy sources

## Process of Generating Electricity

A **generator** is a device used to **generate electricity**. Look at Photograph 6.1 which shows an example of a generator model.



Photograph 6.1 Generator model

Name **two** main components that generate current in this generator model.



When the crank of the generator model is turned, a current known as **induced current** is produced. The flow of this induced current lights up the LED.

In 1831, a scientist named Michael Faraday conducted a series of investigations on the generation of electricity using a magnetic field. Electric current is produced by:

- **Movement of the wire** which causes the magnetic field lines to be cut. A connecting wire or solenoid is moved rapidly through the space between the magnetic poles as shown in Figures 6.3 and 6.4. An induced current is produced in the connecting wire or solenoid, and it flows through the galvanometer. The pointer in the galvanometer deflects.
- **Movement of the magnet** which causes the magnetic field lines to be cut. A magnet is moved as shown in Figures 6.5 and 6.6 so that the magnetic field lines are cut by the connecting wire or solenoid. An induced current is produced in the connecting wire or solenoid, and it flows through the galvanometer. The pointer in the galvanometer deflects.

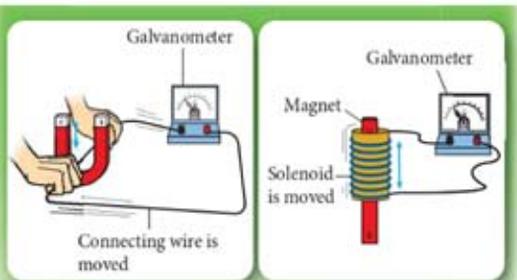


Figure 6.3

Figure 6.4

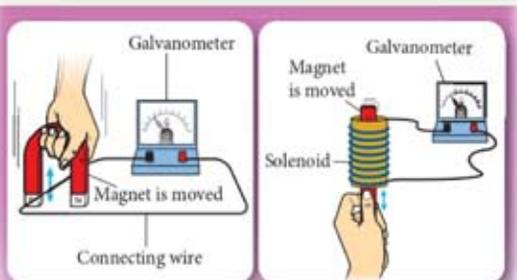


Figure 6.5

Figure 6.6

## Activity 6.1

### Inquiry-based activity

To study the production of electric current when magnetic field lines are cut by a copper wire

#### Materials

PVC insulated copper wire, connecting wire and cardboard tube with a coil of PVC insulated copper wire (coil of wire/solenoid)

#### Apparatus

Bar magnet, U-shaped magnet and centre-zero galvanometer

#### Instructions

1. Connect the PVC insulated copper wire to the centre-zero galvanometer.
2. Move the copper wire downwards between the north and south poles of a U-shaped magnet and then upwards as shown in Figure 6.3. Observe and record the deflection of the galvanometer pointer.
3. Move the U-shaped magnet upwards and then downwards as shown in Figure 6.5. Observe and record the deflection of the galvanometer pointer.
4. Connect the coil of PVC insulated copper wire to the centre-zero galvanometer.
5. Move the coil of wire as shown in Figure 6.4. Observe and record the deflection of the galvanometer pointer.
6. Move the bar magnet as shown in Figure 6.6. Observe and record the deflection of the galvanometer pointer.

#### Observations

Step	Deflection of galvanometer pointer
2	
3	
5	
6	

#### Questions

1. What is detected by the galvanometer when the galvanometer pointer deflects?
2. What happens when a magnet moves relative to a copper wire or coil of copper wire?
3. What is produced by the cutting of the magnetic field lines by a copper wire or coil of copper wire?

## Activity 6.2

To build a simple generator that can light up an LED using magnets and a coil of wire

### Materials

PVC insulated copper wire, cellophane tape, connecting wires with crocodile clips and LED

### Apparatus

Armature with axle, two magnadur magnets, wooden plank (base) and C-shaped magnet holder

### Instructions

1. Work in groups.
2. Construct a simple direct current (d.c.) generator as shown in Figure 6.7.
3. Make sure the axle is stationary. Observe and record if the LED lights up.
4. Rotate the axle. Then, observe and record if the LED lights up.
5. Present your findings.

### Observation

Condition of axle	Stationary	Rotating
LED		

### Questions

1. Mark '✓' for the true statement related to the cutting of magnetic field lines.

(a) When the coil of wire and magnet are stationary, the magnetic field lines are cut.	
(b) When the coil of wire moves inside the stationary magnet, the magnetic field lines are cut.	
(c) Current will only be induced when the magnetic field lines are cut.	

2. How is induced current detected in this activity?
3. How is induced current produced by the d.c. generator?
4. State **two** forms of energy other than electrical energy produced in this activity.
5. State **two** advantages of LED as a lighting device compared to a filament bulb.

### 21<sup>st</sup> Century Skills

- ICS, ISS, STEM
- Innovation-based activity

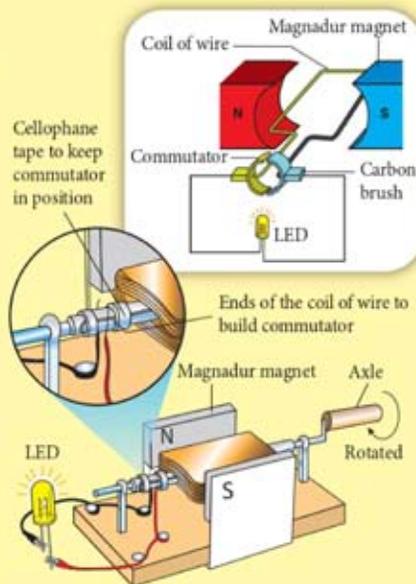


Figure 6.7 Simple d.c. generator

## Electricity Generated at Power Stations

Study Figures 6.8 to 6.13. Observe how electricity is generated at power stations using various sources of energy.

- 1** Power station using non-renewable energy sources such as **diesel, natural gas and coal**.

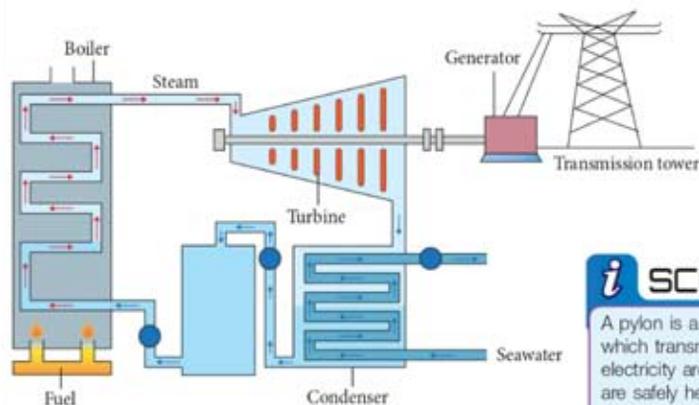


Figure 6.8 Thermal power station

### **i** SCIENCE INFO

A pylon is a tall metal structure to which transmission cables carrying electricity are fixed so that they are safely held high above the ground.

#### Mechanism

Burning of fuel → Boiling water produces steam → Steam rotates the turbine → Generator produces electricity

#### Energy Change

Chemical energy → Heat energy → Kinetic energy → Electrical energy

- 2** Power station using **solar energy**.

#### Mechanism

Sunrays → Solar panels convert light energy from the Sun into electricity

#### Energy Change

Solar energy → Electrical energy

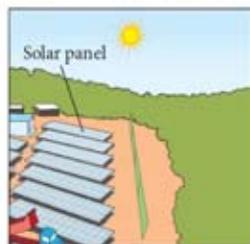


Figure 6.9 Power station using solar energy

### 3 Hydroelectric power station.

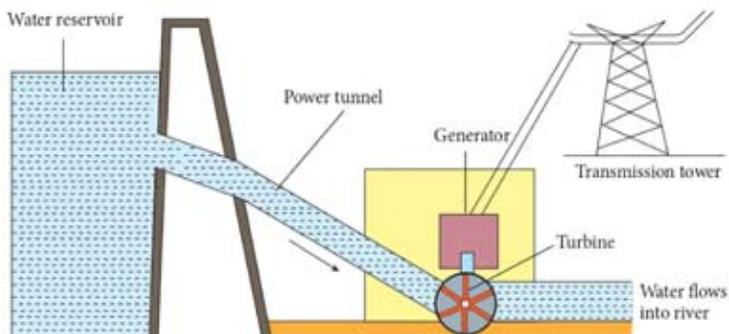


Figure 6.10 Hydroelectric power station

#### Mechanism

High dam stores water

Water flows from high level to low level

Flow of water rotates turbine

Generator produces electricity

#### Energy Change

Gravitational potential energy

Kinetic energy

Electrical energy

### 4 Power station using wind energy.

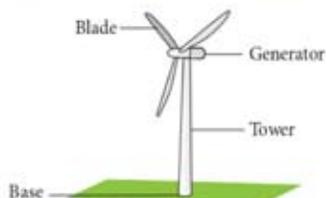


Figure 6.11 Power station using wind energy

#### Mechanism

Moving air or wind

Wind moves blades

Blades rotate turbine

Generator produces electricity

#### Energy Change

Kinetic energy

Electrical energy

**5** Power station using **nuclear fuel**.

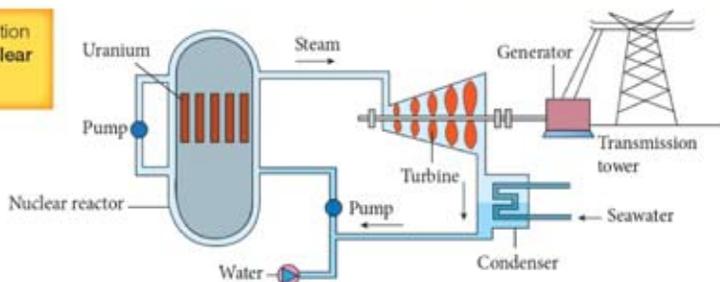


Figure 6.12 Nuclear power station

**Mechanism**

Nuclear reaction

Boiling water produces steam

Steam rotates the turbine

Generator produces electricity

**Energy Change**

Nuclear energy

Heat energy

Kinetic energy

Electrical energy

**6** Power station using **biomass**.

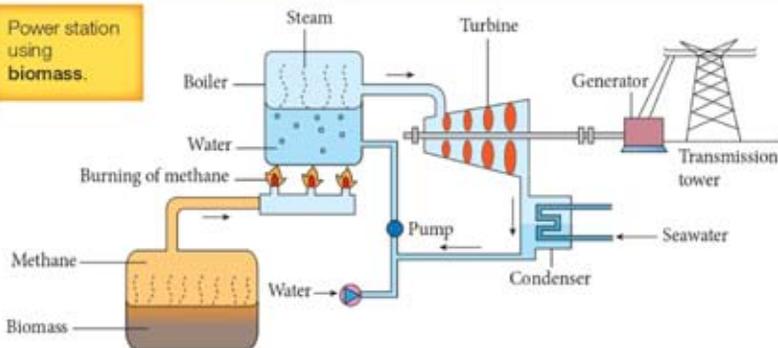


Figure 6.13 Biomass power station

**Mechanism**

Biomass produces methane

Boiling water produces steam

Steam rotates the turbine

Generator produces electricity

**Energy Change**

Chemical energy

Heat energy

Kinetic energy

Electrical energy

## Activity 6.3

To gather information and understand how electricity is generated at power stations

### Instructions

1. Work in groups.
2. Gather information on how electricity is generated at power stations using various sources of energy as shown in Figures 6.8 to 6.13:
  - (a) Process of generating electricity from various sources of energy
  - (b) Locations of power stations which use various sources of energy in Malaysia
3. Share the findings of your group discussion in class.

### 21<sup>st</sup> Century Skills

- ICS, ISS, STEM
- Discussion activity

## Direct Current and Alternating Current

Do you still remember the topic of electric current in Form 2?

Do electric charges flow through a conductor in one direction only or in constantly changing directions?



Electric current is divided into two types, **direct current (d.c.)** and **alternating current (a.c.)**.

### Direct Current (d.c.)

**Direct current** is an electric current that flows in one direction only. Examples of devices that use direct current are shown in Photograph 6.2.



(a) Torchlight



(b) Calculator



(c) Toy car

*Photograph 6.2 Examples of devices that use direct current*

Examples of generators or sources of electricity that produce direct current are shown in Photograph 6.3.



(a) Solar cells



(b) Accumulators



(c) Batteries

*Photograph 6.3 Examples of generators or sources of electricity that produce direct current*

### Alternating Current (a.c.)

**Alternating current** is an electric current that flows in constantly reversing directions. Look at Photograph 6.4 which shows examples of devices that use alternating current.



(a) Bread toaster



(b) Hair dryer



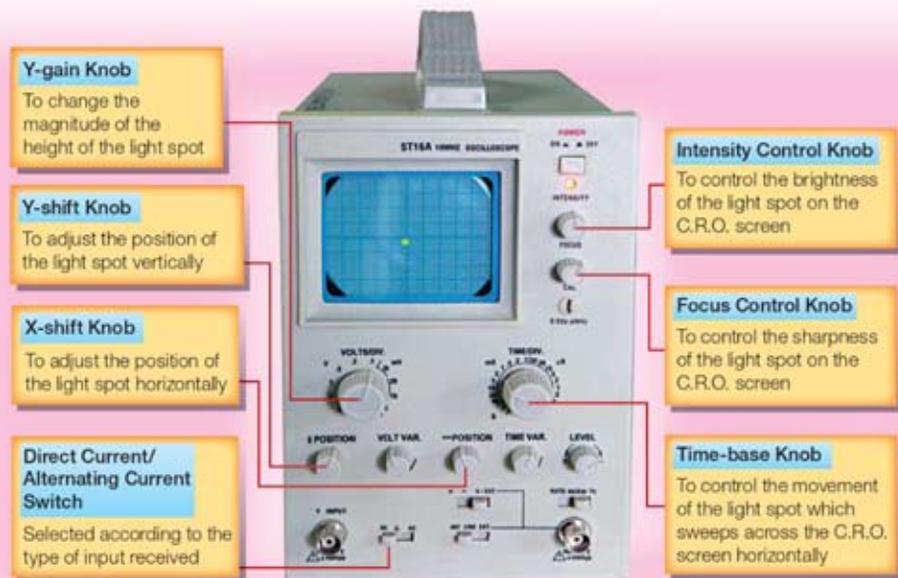
(c) Air conditioner

*Photograph 6.4 Examples of devices that use alternating current*

Do most of the electricity generators in power stations produce d.c. or a.c.?

### Cathode Ray Oscilloscope (C.R.O.)

**Cathode Ray Oscilloscope (C.R.O.)** is an electronic device that is used to show the differences in the shape of graph, direction of current and voltage change for direct current and alternating current. For this, you are encouraged to gather information on how to handle several control switches on the C.R.O. before carrying out Activity 6.4. For this purpose, observe Photograph 6.5.



*Photograph 6.5 Switches and control knobs on the C.R.O.*

Using a Cathode Ray Oscilloscope (C.R.O.) to show the differences in the shape of graph, direction of current and voltage change for direct current (d.c.) and alternating current (a.c.)

**Material**

Dry cell

**Apparatus**

Connecting wire, cell holder, C.R.O. and power source

**Instructions**

1. Switch on the C.R.O. and wait for a light spot to appear on the screen. Turn off the time-base knob. Turn the intensity control and focus control knobs to adjust the brightness and sharpness of the light spot shown in Figure 6.14.
2. Use the X-shift and Y-shift knobs to adjust the light spot so that it is at the zero position in the centre of the screen as shown in Figure 6.14.
3. Turn on the time-base knob and observe the trace displayed on the screen as shown in Figure 6.15.

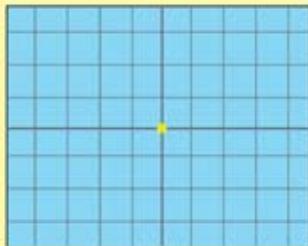


Figure 6.14

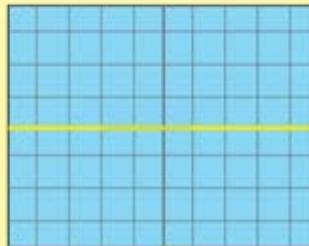
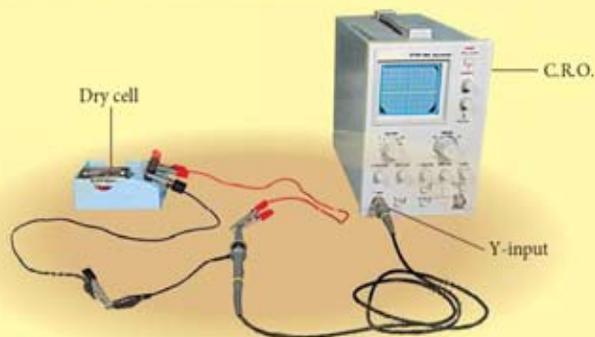


Figure 6.15

4. Select the input switch to d.c. and adjust the Y-gain knob to 1 V/division. Turn off the time-base knob.
5. Connect a dry cell to the Y-input (Photograph 6.6).



Photograph 6.6

- Observe and record the trace displayed on the screen shown in Figure 6.16. Determine the voltage across the dry cell by multiplying the displacement with the value of Y-gain.
- Turn on the time-base knob. Observe and record the trace displayed on the screen as shown in Figure 6.17.

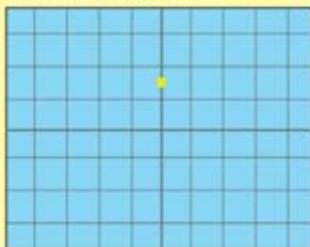


Figure 6.16

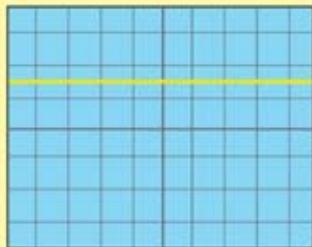


Figure 6.17

- Repeat steps 5 to 7 but reverse the connection of the dry cell terminals. Observe and record the trace displayed on the screen shown in Figure 6.18.
- Turn on the time-base knob. Observe and record the trace displayed on the screen as shown in Figure 6.19.

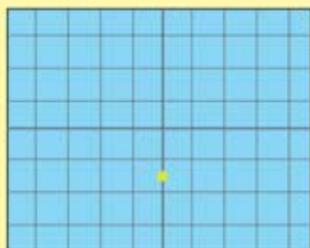
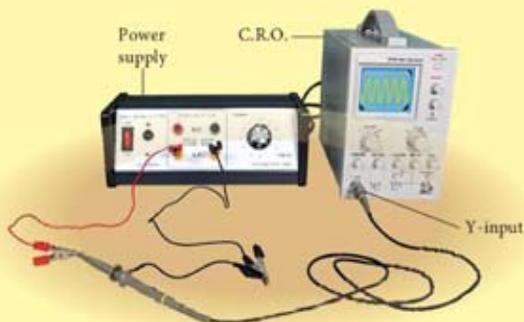


Figure 6.18



Figure 6.19

- Select the input switch to a.c. and adjust the Y-gain knob to 1 V/division. Turn off the time-base knob.
- Connect a 2 V a.c. terminal from the power supply to the Y-input as shown in Photograph 6.7.
- Observe and record the trace displayed on the screen as shown in Figure 6.20.



Photograph 6.7

13. Turn on the time-base knob. Observe and record the trace displayed on the screen as shown in Figure 6.21.

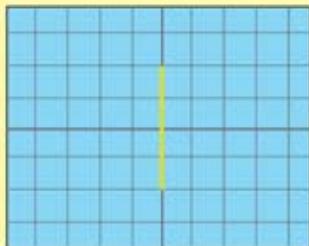


Figure 6.20

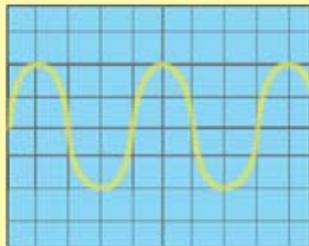


Figure 6.21

14. Repeat steps 10 to 13 but reverse the connection of the terminals of the power supply. Observe and record the trace displayed on the screen as shown in Figure 6.22.
15. Turn on the time-base knob. Observe and record the trace displayed on the screen as shown in Figure 6.23.

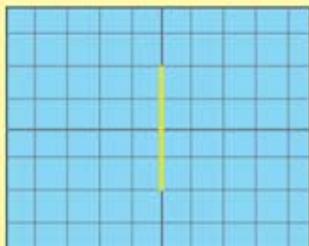


Figure 6.22

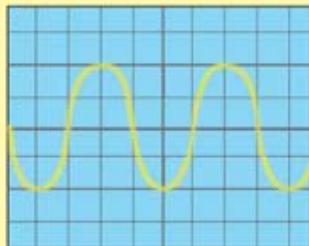


Figure 6.23

#### Observations

Step	Trace observed on the screen
6	
7	
8	
9	
12	
13	
14	
15	

### Questions

1. What is the function of the C.R.O. in this activity?
2. Compare and contrast the traces displayed on the screen as shown in steps 6 and 8.
3. What **two** inferences can be made based on your observations of the trace displayed on the screen in steps 7 and 9?
  - (a) First inference
  - (b) Second inference
4. Based on your observations of the trace displayed on the screen in steps 12 and 14, describe the change in voltage produced by the power supply. Explain your answer.
5. What are **two** inferences that can be made based on your observations of the trace displayed on the screen in steps 13 and 15?
  - (a) First inference
  - (b) Second inference
6. Name the type of electric current supplied by the following energy sources:
  - (a) Dry cell
  - (b) Power supply

## Solving Problems Related to Electricity Supply in Life

Have you ever experienced disruptions of electricity supply while at home or in school? If disruptions of electricity supply is a big problem in your life, can you imagine the lives of people living in rural areas without any electricity supply? Let us carry out Activity 6.5 to make a model of a generator that can produce electricity.



### Activity 6.5

To create or innovate a model for generating electricity using turbines and generators in rural areas without affecting the environment

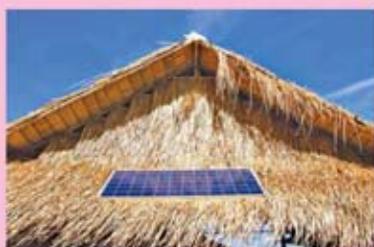
#### Instructions

1. Work in groups.
2. Create or innovate a model for generating electricity using turbines and generators in rural areas without affecting the environment.

#### 21<sup>st</sup> Century Skills

- ICS, CPS
- Project-based activity

### Examples of innovations to generate electricity.



Roof with solar cells

Absorbs and changes solar energy to electrical energy without affecting the environment



Wireless electrical transmission and distribution

Changes electrical energy to radio wave or microwave energy to be transmitted and distributed without wires to electrical devices. These electrical devices then change the radio wave or microwave energy back to electrical energy.

3. Present your model or innovation using turbines and generators to generate electricity.



### Formative Practice 6.1

1. What is meant by renewable energy sources and non-renewable energy sources?
2. Figure 1 shows three arrangements, P, Q and R with moving or stationary magnet and coil of wire.

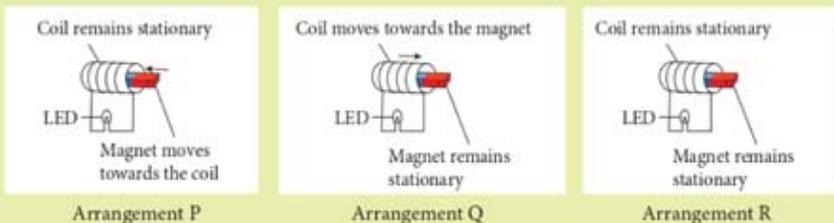
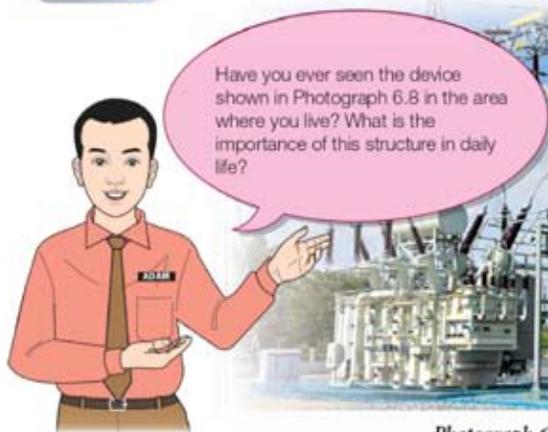


Figure 1

- (a) In which arrangement does the LED light up? Explain your answer.
  - (b) In which arrangement does the LED not light up? Explain your answer.
3. What is the function of a cathode ray oscilloscope or C.R.O.?

## 6.2 Transformer



Photograph 6.8 Transformer

### Step-up Transformer and Step-down Transformer

A **transformer** is a device for changing the voltage of an alternating current ( $V_{a.c.}$ ). A simple transformer is made up of **laminated soft iron core** which is wrapped by two insulated coils, the **primary coil** and the **secondary coil** as shown in Figure 6.24.

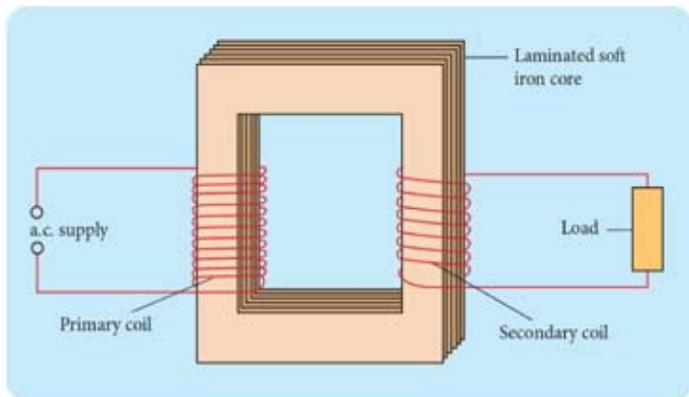
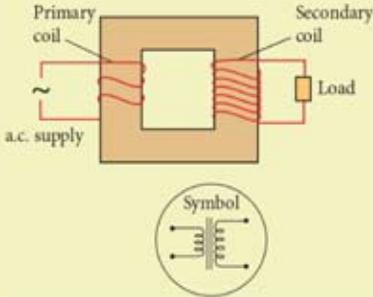
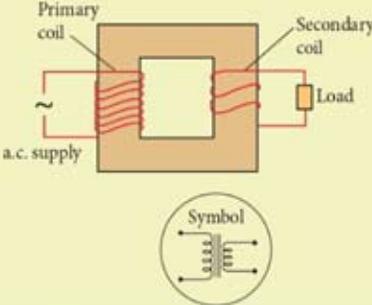


Figure 6.24 Structure of a simple transformer

There are two types of transformers, the **step-up transformer** and the **step-down transformer** as described in Table 6.1.

**Table 6.1** Step-up transformer and step-down transformer

Step-up transformer	Step-down transformer
	
<p>Primary voltage (input), <math>V_p</math>, across the primary coil is <b>lower</b> than the secondary voltage (output), <math>V_s</math>, across the secondary coil.</p>	<p>Primary voltage (input), <math>V_p</math>, across the primary coil is <b>higher</b> than the secondary voltage (output), <math>V_s</math>, across the secondary coil.</p>
<p>Number of turns of the primary coil is <b>less</b> than that in the secondary coil.</p>	<p>Number of turns of the primary coil is <b>more</b> than that in the secondary coil.</p>

Carry out Experiment 6.1 to construct and study the functions of simple step-up and step-down transformers.

## Experiment 6.1

### Aim

To construct and study the functions of simple step-up and step-down transformers using laminated soft iron core

### Problem statement

What are the functions of step-up and step-down transformers?

### Hypothesis

- In a step-up transformer, the secondary voltage (output) is higher than the primary voltage (input).
- In a step-down transformer, the secondary voltage (output) is lower than the primary voltage (input).

### Variables

- manipulated variable : Number of turns of the secondary coil,  $N_s$
- responding variable : Brightness of light bulb
- constant variable : Number of turns of the primary coil,  $N_p$

### Materials

Connecting wire, insulated copper wire and light bulbs

### Apparatus

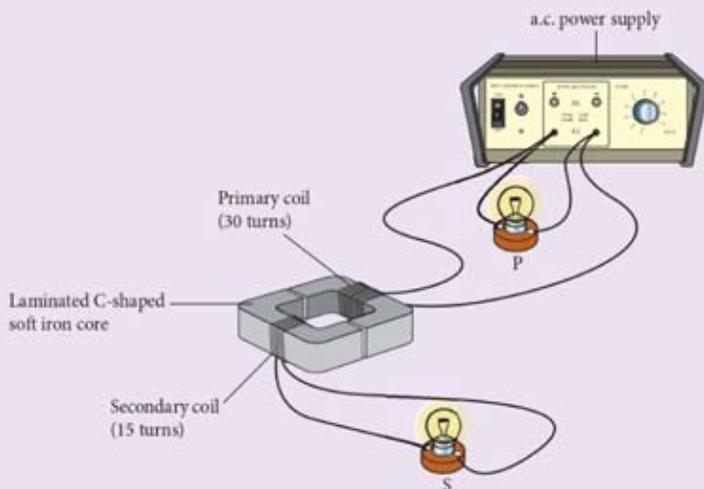
a.c. power supply and laminated C-shaped soft iron core

**Procedure**

1. Wind 30 turns of wire around one arm of the laminated soft iron core to form a primary coil as shown in Figure 6.25.
2. Wind 15 turns of wire around the other arm of the laminated soft iron core to form a secondary coil as shown in Figure 6.25.
3. Connect the primary coil to an a.c. power supply. Then, connect light bulb P to the primary coil and light bulb S to the secondary coil as shown in Figure 6.25.

**Safety Precaution**

Practise safety steps while handling power supply.



**Figure 6.25**

4. Switch on the a.c. power supply and adjust its voltage to 2 V.
5. Observe and compare the brightness of the two bulbs.
6. Repeat steps 3 to 5 but using a primary coil with 30 turns and a secondary coil with 60 turns.

**Observations**

Number of turns of primary coil, $N_p$	Number of turns of secondary coil, $N_s$	Brightness of bulb	
		P	S
30	15		
30	60		

**Conclusion**

Is the hypothesis of the experiment accepted? What is the conclusion of this experiment?

### Questions

- Based on the results of this experiment:
  - What is the effect on the brightness of the bulb if  $N_p > N_s$ ?
  - What is the relationship between  $V_p$  and  $V_s$  if  $N_p > N_s$ ?
  - What type of transformer is this?
- Based on the results of this experiment:
  - What is the effect on the brightness of the bulb if  $N_p < N_s$ ?
  - What is the relationship between  $V_p$  and  $V_s$  if  $N_p < N_s$ ?
  - What type of transformer is this?
- What happens to the change in voltage of the alternating current in a transformer if the difference between the number of turns in its primary coil and the number of turns in its secondary coil is increased?
- Why are the numbers of turns in the primary and secondary coils different in all transformers?

## Function of Transformer in Home Electrical Appliances

In Malaysia, the supply voltage of alternating current provided to our home is 240 V. Give **one** example of an electrical appliance at home that operates at 240 V alternating current without using a transformer.

Most electrical appliances at home use transformers such as those in mobile phone chargers (Photograph 6.9).

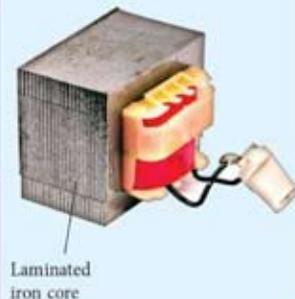


Photograph 6.9 A mobile phone charger

Is the transformer in a mobile phone charger a step-up or step-down transformer? Let us carry out Activity 6.6 to discuss the transformers and their functions in home electrical appliances.

## i SCIENCE INFO

An induced current formed in the iron core of a transformer is known as the **eddy current**. The formation of the eddy current in a transformer will reduce the efficiency of the transformer. Due to this, a laminated iron core is used to reduce eddy current and increase the efficiency of the transformer. A laminated iron core is made up of layers of soft iron and layers of insulators arranged alternately.



## Activity 6.6

To discuss the transformer and its functions in home electrical appliances

### Instructions

1. Work in groups.
2. Use various sources to gather information on transformers and their functions in home electrical appliances.

### 21<sup>st</sup> Century Skills

- ICS
- Technology-based activity

### Examples of the use of transformers in home electrical appliances



(a) Battery charger of a laptop



(b) Mobile phone charger



(c) Ceiling fan regulator

3. Discuss the gathered information.
4. Present the outcome of the discussion using multimedia presentation.

## Solving Problems Related to Transformers in Daily Life

Figure 6.26 shows an example of a home electrical appliance which is a ceiling fan regulator that uses a step-down transformer. What is the formula used to determine the number of turns in the secondary coil to lower the input voltage from 240 V to voltages ranging from 2 V to 10 V?

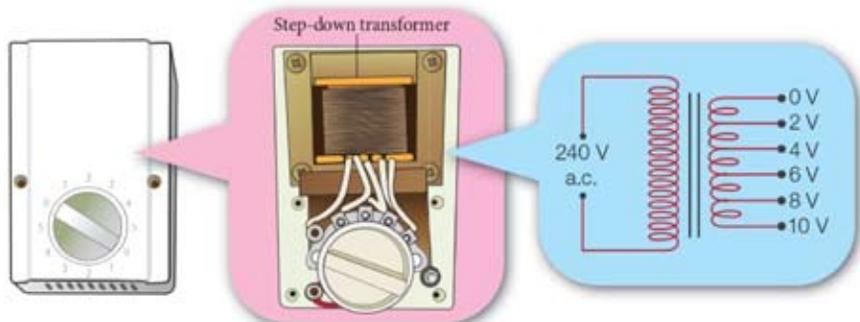


Figure 6.26 Ceiling fan regulator

### Transformer Equation

The ratio of the primary voltage to the secondary voltage is **equal** to the ratio of the number of turns of the primary coil to the number of turns of the secondary coil in a transformer. This relationship can be written in the following formula:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

where  $V_p$  = input voltage of the primary coil or primary voltage  
 $V_s$  = output voltage of the secondary coil or secondary voltage  
 $N_p$  = number of turns of primary coil  
 $N_s$  = number of turns of secondary coil

### Example

Figure 6.27 shows a 40 V bulb connected to a 240 V power supply through a transformer.

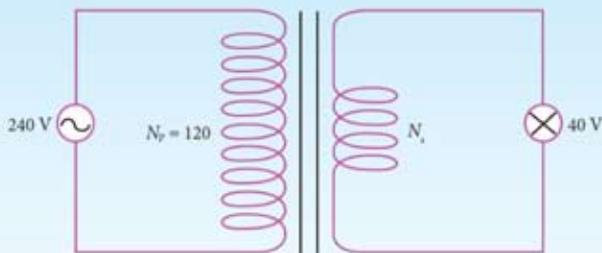


Figure 6.27

Find out the number of turns of the secondary coil,  $N_s$ , that is required for the bulb to light up at normal brightness?

### Solution

The bulb will light up at normal brightness if it is supplied with a voltage of 40 V.

- Output voltage,  $V_s = 40$  V
- Input voltage,  $V_p = 240$  V
- Number of turns in primary coil,  $N_p = 120$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$\frac{240}{40} = \frac{120}{N_s}$$

$$\begin{aligned} N_s &= 120 \times \frac{40}{240} \\ &= 20 \end{aligned}$$

Number of turns in secondary coil,  $N_s = 20$

## Formative Practice 6.2

- What is a transformer?
- Underline the correct answers.
  - Transformers only function using (direct/alternating) current.
  - In a step-down transformer, the number of turns in the primary coil is (more/less) than the number of turns in the secondary coil.
  - A (step-up/step-down) transformer is used to change 25 kV to 250 kV.
  - A (step-up/step-down) transformer is fixed in a radio.
- State **one** example of a home electrical appliance which uses the following types of transformers:
  - Step-up transformer
  - Step-down transformer
- Figure 1(a) shows a transformer in a 5 V mobile phone charger connected to the 240 V main power supply.



Figure 1(a)

Figure 1(b) shows a circuit diagram of the transformer in the mobile phone charger.

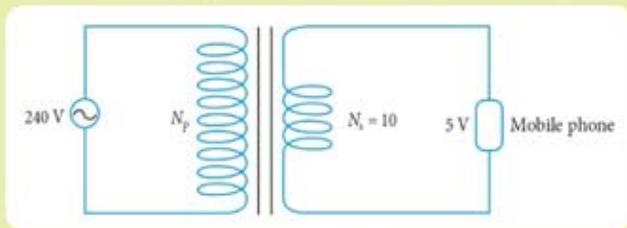


Figure 1(b)

- Calculate the number of turns in the primary coil. 🍷
- Is the transformer in the mobile phone charger a step-up or step-down transformer? Explain your answer. 🍷

## 6.3

# Transmission and Distribution of Electricity

## Functions of the Components in the Electricity Transmission and Distribution System

The electricity transmission and distribution system that connects a power station to your house is shown in Figure 6.28.

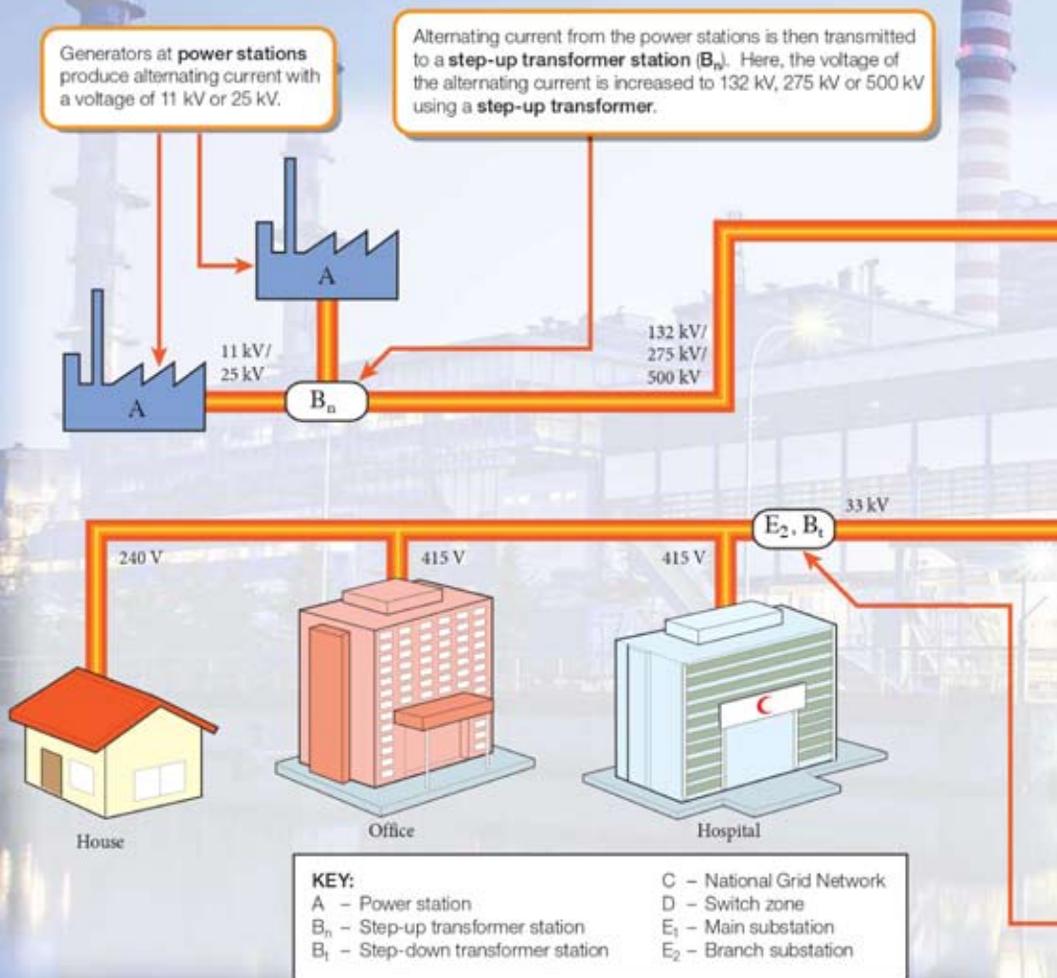


Figure 6.28 Electricity transmission and distribution system

The high voltage alternating current is then transmitted through a network of transmission cables called the **National Grid Network (C)** as shown in the photographs below.



500 kV alternating current transmission cables along the North-South Highway.



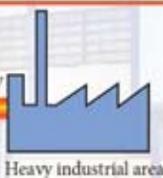
132 kV alternating current transmission cables at the Tanjung Kling Power Station, Malacca

Transmission through long distances



$E_1$   
 $D$   
 $B_1$

33 kV

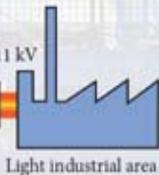


Heavy industrial area

33 kV

11 kV

$E_2, B_1$



Light industrial area

At the end of the grid, the alternating current flows to a **switch zone (D)** at the **main substation ( $E_1$ )**. This switch zone enables electricity to be sent to the **branch substation ( $E_2$ )** when needed. This switch zone is also used to enable specific power stations and grids to be closed for maintenance works without disrupting the electricity supply to consumers.



Main substation



Switch zone

At the **main substation ( $E_1$ )** and **branch substation ( $E_2$ )**, the alternating current is transmitted through a series of **step-down transformers ( $B_1$ )** at the step-down transformer station. The voltage of the alternating current is reduced gradually to different voltage values to be supplied to consumers according to their needs. For example:

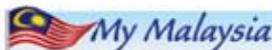
- heavy industrial area at 33 kV
- light industrial area at 11 kV
- office, business and residential areas at 240 V

## Impact on Residences Located Near the National Grid Network Pylons

High voltage alternating current is transmitted through transmission cables on the National Grid Network pylons as shown in Photograph 6.10. A strong **electromagnetic field** is produced by the high voltage alternating current and can be detected in the surrounding areas close to the pylons. Observe the effect of this electromagnetic field by using a compass. What happens to the position of the compass needle?



**Photograph 6.10** Transmission cables on the National Grid Network pylons



Go to the following websites:

<https://www.tnb.com.my/>

<https://www.sesb.com.my/>

<http://www.sarawakenergy.com.my/>

What are the facilities provided by Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd. (SESB) and Sarawak Energy Berhad (Sarawak Energy) to consumers in Malaysia?

Let us carry out Activity 6.7 to discuss the impact of the National Grid Network pylons on nearby residences.

### Activity 6.7

To discuss the impact of the National Grid Network pylons on nearby residences

#### Instructions

1. Work in groups.
2. Gather information related to the issues of the impact on residences located near the National Grid Network pylons as follows:
  - (a) Strength of electromagnetic field close to the National Grid Network pylons
  - (b) The impact of electromagnetic field on human health perceived by locals and confirmed by medical experts
  - (c) Ways to solve the issues regarding the electromagnetic field on residential areas close to the National Grid Network pylons
3. Share the outcome of your group discussion in class.

#### 21<sup>st</sup> Century Skills

- ICS, CPS
- Discussion activity



**Photograph 6.11** Residences located near a National Grid Network pylon

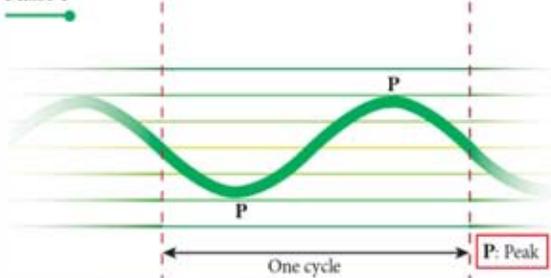
## Electrical Wiring System in Malaysia

The electrical wiring system in Malaysia consists of two different types, **one-phase wiring** (or single-phase) and **three-phase wiring** as shown in Figures 6.29 and 6.30.



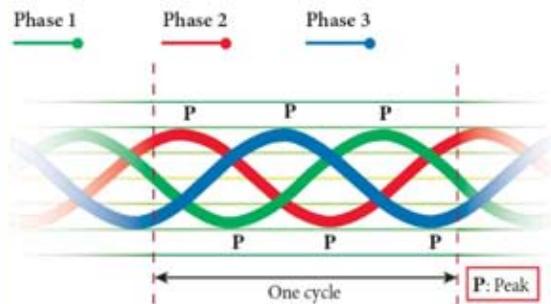
Tenaga Nasional Berhad (TNB) suggests that users of single-phase wiring who use more than 10 kW or 50 A to switch to three-phase wiring. Compare and contrast the importance of single-phase wiring and three-phase wiring in electricity usage. Does your family accept TNB's suggestion? Give your reasons.

Phase 1



The **single-phase wiring** is only suitable and stable enough for electricity usage not exceeding 10 kW or 50 A, such as in rural residential areas.

Figure 6.29 Single-phase wiring



In commercial and industrial areas where electricity usage is more than 10 kW or 50 A, the **three-phase wiring** which is more stable and reliable is used.

Figure 6.30 Three-phase wiring

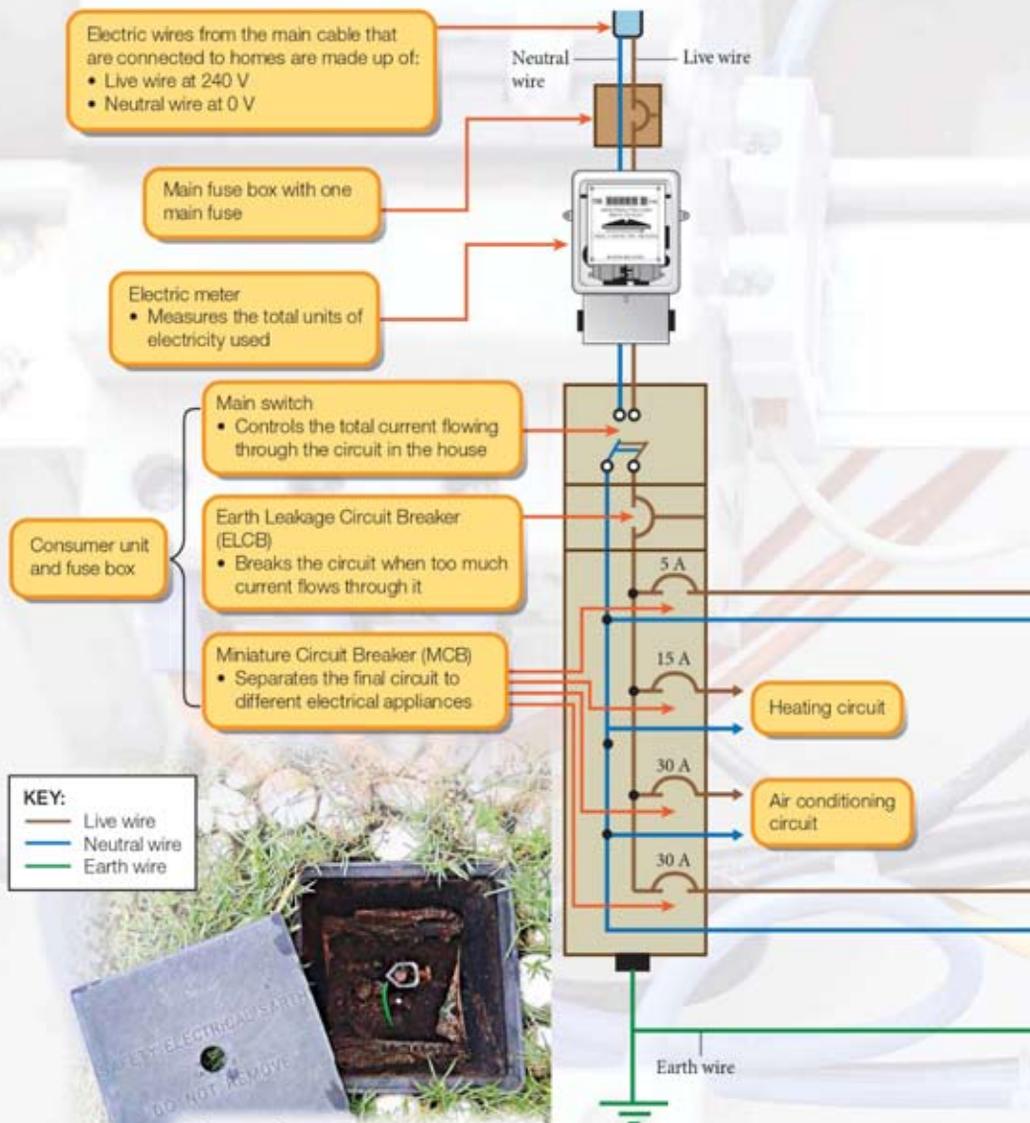
**Websites**

Ways to identify the types of electrical wiring

<http://bt.sasbadi.com/sc3187>

## Electricity Supply and Wiring System in Homes

Figure 6.31 shows an example of electricity supply and wiring system in homes.



Photograph 6.12 Earthing earth wire

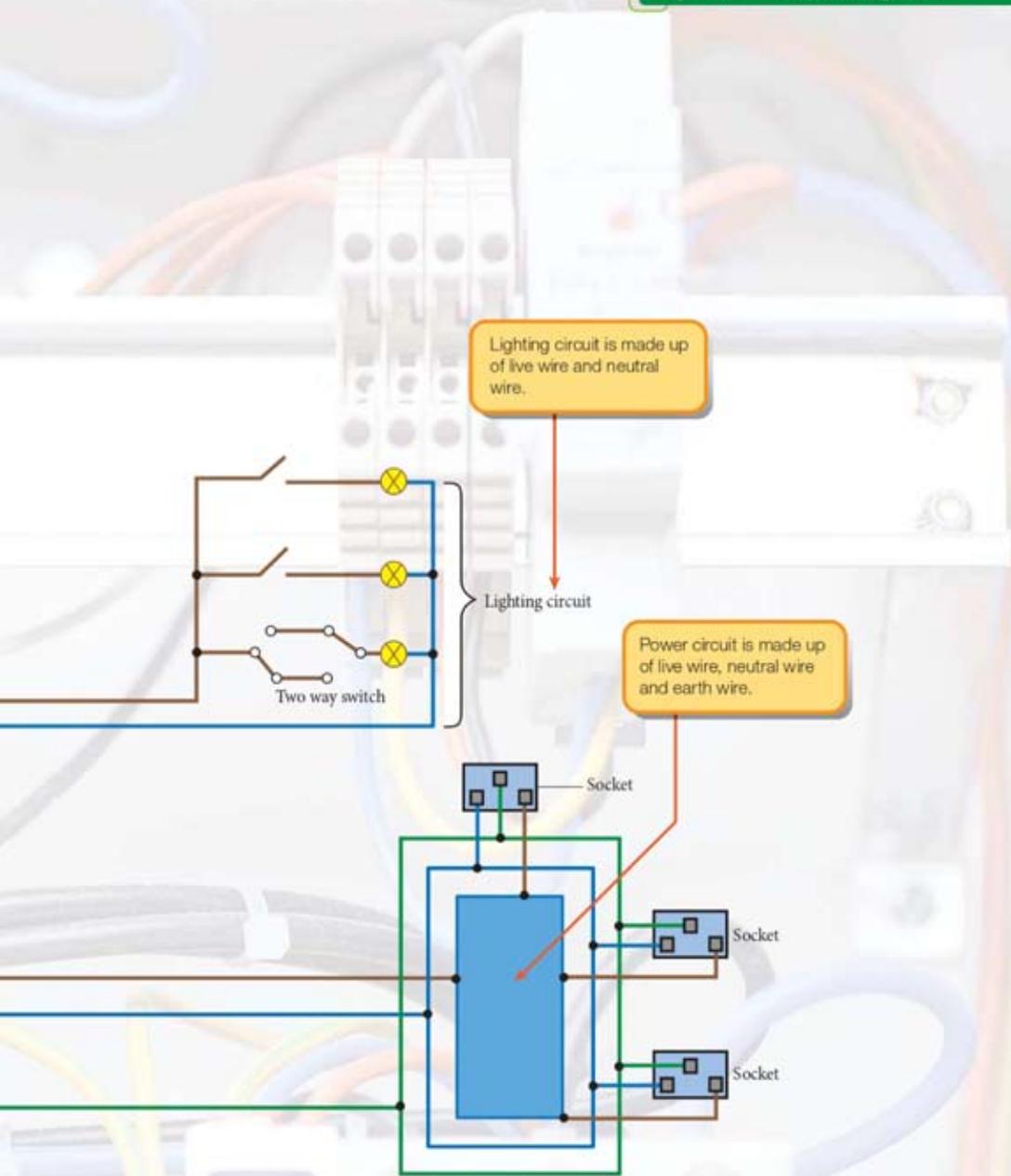


Figure 6.31 Example of electricity supply and wiring system in homes

### 3-pin Plugs and 2-pin Plugs

Compare and contrast the structures of the 3-pin plugs and 2-pin plugs shown in Photograph 6.13.



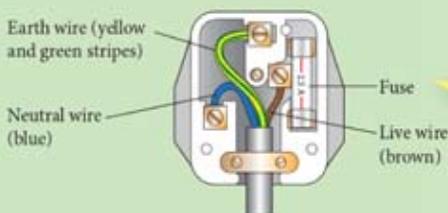
*Photograph 6.13 3-pin plugs and 2-pin plugs used in different countries*

The 3-pin plug and 2-pin plug used in our country are explained in Table 6.2.

*Table 6.2 3-pin plug and 2-pin plug in the wiring system in homes*

3-pin plug	2-pin plug
<p>Electrical appliances such as electric kettles and irons obtain electricity from the sockets on the walls through 3-pin plugs.</p> 	<p>Electrical appliances such as hair dryers and electric toothbrushes obtain electricity from the sockets on the walls through 2-pin plugs.</p> 

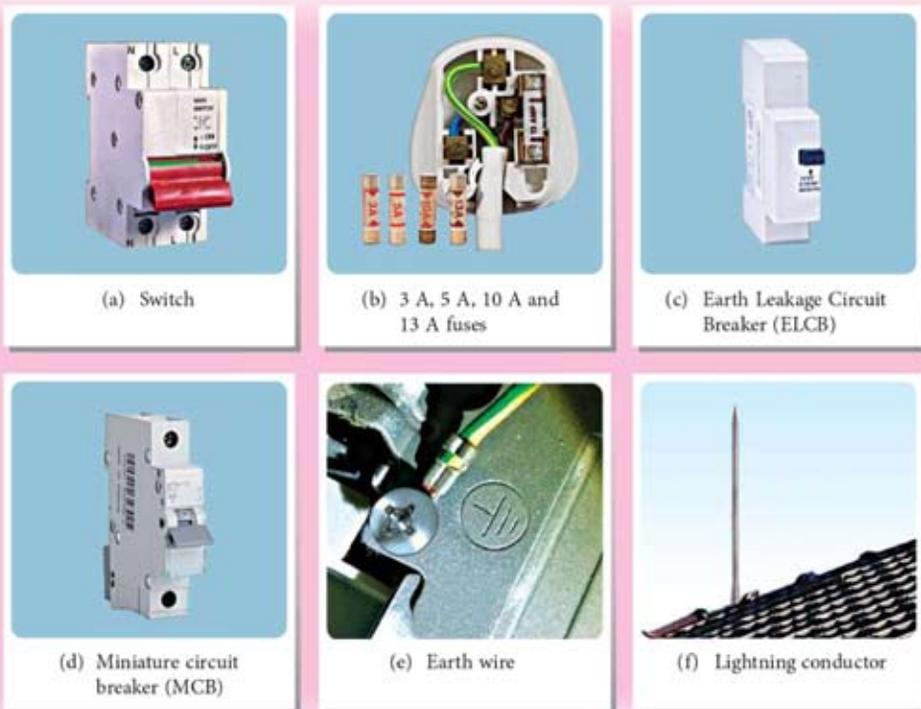
The live wire, neutral wire and earth wire connected to 3-pin plug are required to follow the international colour code for wiring shown in Figure 6.32 to ensure the safety of electricity use.



*Figure 6.32 International colour code for wiring*

## Safety Components in the Wiring System in Homes

In the wiring system in homes, some of the safety components are shown in Photograph 6.14.



Photograph 6.14 Safety components in the wiring system in homes

### Fuse

#### Structure of Fuse

A fuse, as shown in Figure 6.33, is a fine and short wire that heats up easily and melts when the current flowing through it exceeds the value of the fuse. If the wire of the fuse melts, the electricity supply will be cut off.

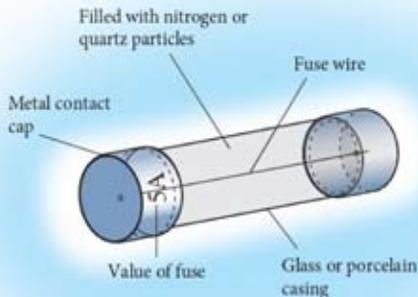


Figure 6.33 Structure of a fuse

## Cartridge Fuse and Replaceable Wire Fuse

The two types of fuses usually used are **cartridge fuse** and **replaceable wire fuse** (fuse installed with a fuse wire) as shown in Figure 6.34.



Figure 6.34 Two types of fuses

All fuses including cartridge fuses and replaceable wire fuses function as **electrical safety devices** in circuits or electrical appliances to protect the wires and appliances from any **excessive current flow**.

### Determining the Value of a Fuse

The **value of a fuse** is the **maximum value of current** that can flow through the fuse without causing its fuse wire to **melt**. For example, a 5 A fuse wire allows a maximum current of 5 A to flow through it. Some common fuse ratings are 1 A, 2 A, 3 A, 5 A, 10 A, 13 A, 15 A and 30 A.

**Choosing the value of a fuse** depends on the **value of the maximum current** that flows through a circuit or electrical appliance. The fuse to be used should have a value which is slightly higher than the maximum current that flows through a circuit or electrical appliance in normal operating conditions. For example, an electric kettle that uses a maximum electric current of 11.34 A should be installed with a 13 A fuse.

What is the maximum current that can flow through a 3-pin plug installed with a 13 A fuse?



### BRAIN TEASER

Why is an electric kettle fixed with a 3-pin plug that has a 13 A fuse?

## Activity 6.8

To discuss the safety components in the wiring system in homes

### Instructions

1. Work in groups.
2. Identify and discuss the following:
  - (a) Functions, types and values of fuses
  - (b) Function of an earth wire
  - (c) Function of circuit breakers, namely Miniature Circuit Breaker (MCB) and Earth Leakage Circuit Breaker (ELCB)
  - (d) Lightning conductor and switch
3. Use various sources to gather the required information.
4. Present the outcome of the discussion using multimedia presentation.

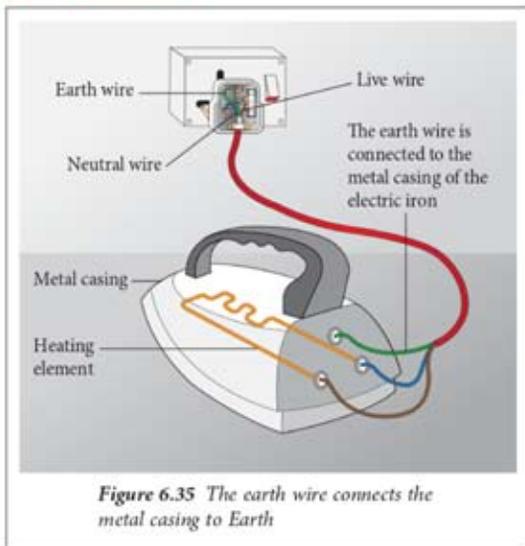
### 21<sup>st</sup> Century Skills

- ICS
- Discussion activity

## Safety in the Use of Electrical Appliances

When using electrical appliances, safety measures should be prioritised. This is because the ratio of deaths due to injury from electrical accidents is high compared to other categories of accidents. Failure to adhere to safety measures will result in serious accidents.

One of the safety measures in the use of electrical appliances is shown in Figure 6.35. When an individual touches the metal part that has been earthed, a large current flows to Earth through the earth wire and not through the individual. This large current also melts the fuse which then cuts off the electric circuit. Let us carry out Activity 6.9 to learn more about safety in the transmission and distribution system of electricity and the use of electrical appliances.



**Figure 6.35** The earth wire connects the metal casing to Earth

### Activity 6.9

To create brochures or posters on safety and electrical accidents

#### Instructions

1. Work in groups.
2. Gather information from various sources regarding the following:
  - (a) Causes of short circuits
  - (b) Causes of electrical accidents
  - (c) Safety measures when using electrical appliances
  - (d) Steps to be taken when an electric shock occurs
3. Discuss the information gathered.
4. Create brochures or posters on the above matters.
5. Display the brochures or posters created on the science bulletin board in your class or science laboratory.

#### 21<sup>st</sup> Century Skills

- ICS
- Project-based activity



## Formative Practice 6.3

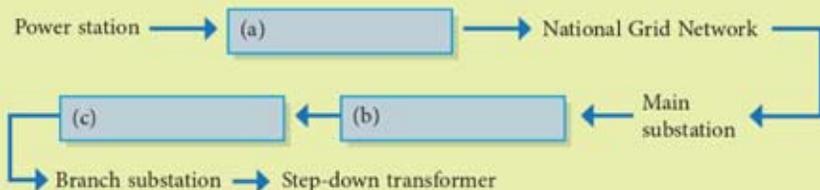
1. In a science class, Wazir learnt about the components in an electricity transmission and distribution system.

Step-up transformer station

Step-down transformer station

Switch zone

Using the words given above, complete the following flowchart. This flowchart shows the sequence of the components in the electricity transmission and distribution system.



2. Underline the correct answers.
- The voltage of the alternating current is (increased/decreased) before it is transmitted through the National Grid Network.
  - The voltage of the alternating current is highest at the (power station/National Grid Network/branch substation).
  - The (Switch zone/National Grid Network) enables electricity to be transmitted to the branch substation when needed.
3. (a) State **three** safety components in the wiring system in homes.  
(b) What is the function of a fuse?
4. (a) State **one** example of the cause of a short circuit. Explain your answer.   
(b) Figure 1 shows several electrical appliances with their respective 2-pin plugs connected to a socket.  
(i) State the electrical condition as shown in Figure 1.  
(ii) Give **one** example of an electrical accident that might occur. Explain your answer. 



Figure 1

## 6.4

## Calculate the Cost of Electricity Consumption



Photograph 6.15 Electric bulbs that light up with different brightness

Photograph 6.15 shows electric bulbs connected to a 240 V electrical supply which light up with different brightness. The power of each bulb is as labelled.

Which bulb has the highest efficiency?  
Explain your answer.



## Energy Efficiency

Energy efficiency is the percentage of energy input converted to useful form of energy output. Energy efficiency can be defined as follows:

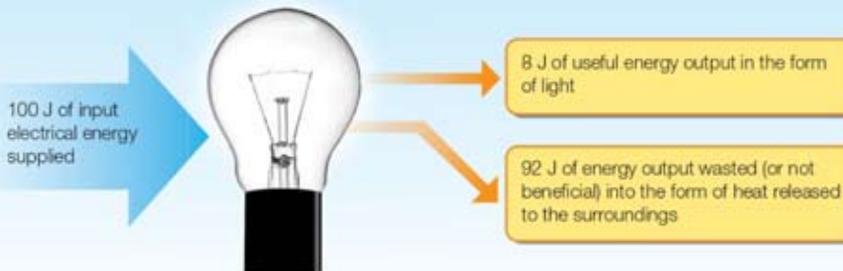
$$\text{Energy efficiency} = \frac{\text{Useful energy output}}{\text{Energy input supplied}} \times 100\%$$



Do you agree that the use of filament bulbs should be banned in Malaysia? Explain your reasons.

## Example

Photograph 6.16 shows a lighted filament bulb. What is the energy efficiency of the bulb?



Photograph 6.16

## Solution

$$\begin{aligned} \text{Energy efficiency of filament bulb} &= \frac{\text{Useful energy output}}{\text{Energy input supplied}} \times 100\% \\ &= \frac{8 \text{ J}}{100 \text{ J}} \times 100\% \\ &= 8\% \end{aligned}$$

## Technology which Applies the Concept of Energy Efficiency

The technology of electrical lighting devices which applies the concept of energy efficiency is shown in Table 6.3.

**Table 6.3** Technology of electrical lighting devices which applies the concept of energy efficiency

Lighting device	Filament lamp	Energy saving lamp (compact fluorescent lamp, CFL)	LED lamp
Structure			
Energy efficiency	Maximum electrical energy converted to light energy $\approx$ 10%	Maximum electrical energy converted to light energy $\approx$ 50%	Maximum electrical energy converted to light energy $\approx$ 90%



### Case Study

Gather information on technology applying the concept of energy efficiency from various sources including the following website:

<http://bt.sasbadi.com/sc.3196>



### MARVELS OF SCIENCE

The filament bulb lasts approximately 1 000 hours. CFL lasts 8 000 hours and LED lasts between 20 000 to 60 000 hours!

Discuss the information gathered. List examples of technology that apply the concept of energy efficiency in order of their importance in daily life.

Do you know how we can identify an energy efficient electrical appliance? Have you ever seen the energy efficient label introduced by the Energy Commission (EC) shown in Figure 6.36?



The Energy Commission (EC) has launched an energy efficiency labelling program for various types of electrical appliances for public interest.

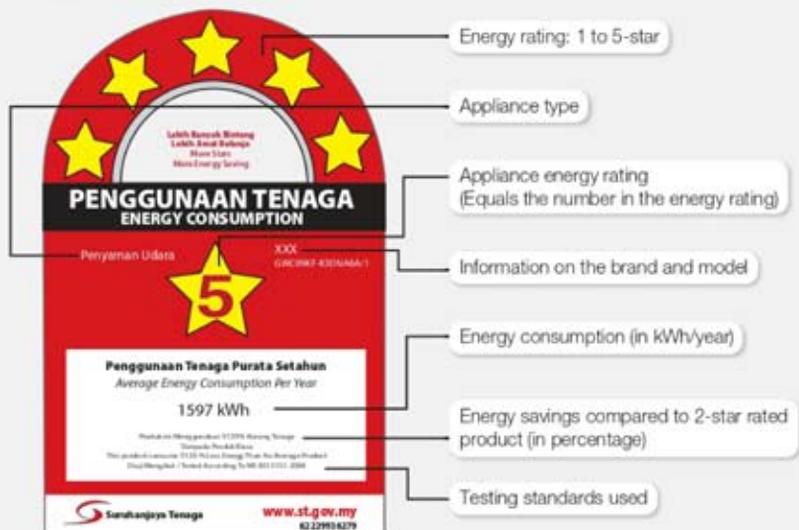


Figure 6.36 Energy efficiency label introduced by the Energy Commission (EC)

## Use of Electricity in Electrical Appliances

Photograph 6.17 shows an electric meter for a three-phase wiring system. The function of an electric meter is to measure the **quantity of electricity** used. The reading on the electric meter is taken at the end of every month for the purpose of determining the **cost of electricity consumed**.



Do you know how to read the electric meter in your house?

What is the electric meter reading in Photograph 6.17?



Photograph 6.17 Electric meter

### Electric Power, $P$

**Electric power,  $P$** , is the rate of **electrical energy,  $E$** , used by an electrical device. The S.I. unit for power is **watt (W)**. The power of 1 **watt (W)** means 1 **joule (J)** of electrical energy used in 1 **second (s)**. Electric power can be defined as follows:

$$\text{Electric power, } P \text{ (W)} = \frac{\text{Electrical energy used, } E \text{ (J)}}{\text{Time taken, } t \text{ (s)}}$$

### Electric Current, $I$

**Electric current,  $I$** , is defined as the rate of flow of **electric charge,  $Q$** , through a conductor. The S.I. unit for electric current is **ampere (A)** and electric charge is **coulomb (C)**. Electric current is defined as follows:

$$\text{Electric current, } I \text{ (A)} = \frac{\text{Electric charge, } Q \text{ (C)}}{\text{Time taken, } t \text{ (s)}}$$

### Voltage, $V$

**Voltage,  $V$** , is defined as the **electrical energy,  $E$** , used to move a unit of **electric charge,  $Q$** , through a conductor. The S.I. unit for voltage is **volt (V)**. Voltage can be defined as follows:

$$\text{Voltage, } V \text{ (V)} = \frac{\text{Electrical energy used, } E \text{ (J)}}{\text{Electric charge, } Q \text{ (C)}}$$

## SCIENCE INFO



*Photograph 6.18 Two light bulbs with different electrical power*

Photograph 6.18 shows two light bulbs which are used in homes. The 40 W light bulb uses electrical energy at the rate of  $40 \text{ J s}^{-1}$  while the 60 W light bulb uses electrical energy at the rate of  $60 \text{ J s}^{-1}$ . Therefore, the 40 W light bulb with a lower watt rating uses less energy.

### Calculating Flow of Current through Electrical Appliances

By relating power, voltage and electric current, the total electric current that flows through an electrical appliance can be determined. Observe the following example. Then, carry out Activity 6.10 to learn more about power, voltage and current that flows through electrical home appliance.

#### Example



Model : SJK-17M	MS 472 : 1979
Voltage : 240VAC/50Hz	Capacity : 1.7L
Watt : 2.2kW	
Product of Malaysia	

Electric jug with  
Power rating = 2 200 W  
Voltage rating = 240 V

Photograph 6.19

The electric jug shown in Photograph 6.19 is rated 2.2 kW, 240 V. Calculate the current that flows through it.

#### Solution

Using the equation  $P = VI$

$$\begin{aligned} I &= \frac{P}{V} \\ &= \frac{2.2 \text{ kW}}{240 \text{ V}} \\ &= \frac{2\,200 \text{ W}}{240 \text{ V}} \\ &= 9.17 \text{ A} \end{aligned}$$



Can the electric jug manufactured in Malaysia shown in Photograph 6.19 be used in Thailand?

In Thailand, the voltage for alternating current supplied to homes is 120 V. What will happen if the electric jug is used in Thailand?

### Activity 6.10

To study the power, voltage and current flowing through electrical home appliances

#### Instructions

1. Work individually.
2. List examples of electrical appliances in your home. Gather information on the power and voltage of these electrical appliances.
3. Calculate the total current that flows through these electrical appliances using the following equation:

$$\text{Power (W)} = \text{Voltage (V)} \times \text{Electric current (A)}$$

4. Present the information you have gathered.

#### 21<sup>st</sup> Century Skills

- ICS
- Inquiry-based activity

## Calculating the Cost of Electrical Energy Used

The common unit used for electrical energy is **kilowatt-hour (kWh)** as shown on the electric meter in Photograph 6.17. 1 kilowatt-hour is the amount of electrical energy used at the rate of 1 kilowatt or 1 000 watts in 1 hour. 1 kWh is usually referred to as **1 unit**. Electrical energy can be calculated using the following equation:

$$\text{Electrical energy used (kWh)} = \text{Power (kW)} \times \text{Time (h)}$$

### Example

A 2 kW electric kettle takes 10 minutes to boil water. Calculate the cost of electrical energy used to boil the water if the rate per unit is 21 sen.

### Solution

$$\begin{aligned}\text{Electrical energy used (kWh)} &= \text{Power (kW)} \times \text{Time (h)} \\ &= 2 \text{ kW} \times \frac{10}{60} \text{ h} \\ &= \frac{1}{3} \text{ kWh} \\ &= \frac{1}{3} \text{ unit}\end{aligned}$$

$$\begin{aligned}\text{Cost of electrical energy used for the electric kettle} &= \frac{1}{3} \text{ unit} \times 21 \text{ sen/unit} \\ &= 7 \text{ sen}\end{aligned}$$

Let us carry out Activity 6.11 to audit the cost of electrical energy used at home as a way of saving electrical energy.

### Activity 6.11

To audit the cost of electrical energy used at home as a way of saving electrical energy

#### Instructions

1. Work individually.
2. Gather your home electricity bills for the past three months.
3. Study and draw a conclusion on the pattern of the cost of electrical energy used in your home which is observed based on the records of the electricity bills.
4. Download the PDF page from the URL on the right.
5. Suggest other practices that save electrical energy besides those listed in the electrical energy saving guide.
6. Take measures to save electrical energy for a period of three months. Compare and contrast the pattern of the cost of electrical energy used in your home before and after the measures are taken.
7. Share your findings in class.

<http://bt.sasbadi.com/sc3200>



#### 21<sup>st</sup> Century Skills

- CPS
- Project-based activity

## Ways to Save Electrical Energy Consumption

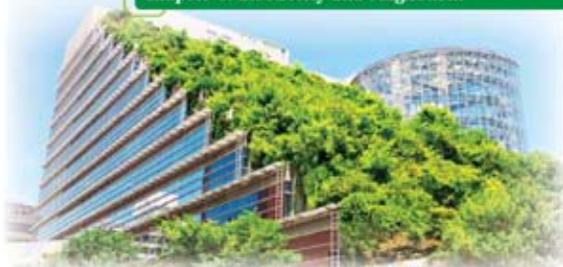
Other than encouraging the saving of electrical energy consumption in homes, the Energy Commission also provides services such as ECOS for the use of industries and businesses that apply the concept of energy conservation.

The **green building** shown in Photograph 6.20 which applies the concept of energy conservation has succeeded in reducing the cost of electrical energy consumption.

The construction of green buildings is gradually expanding in Malaysia. Among the features of a green building are as follows:

- Efficient ventilation system to reduce the use of air conditioning and fans
- Maximising the use of natural lighting to reduce the cost of electrical energy consumption
- Installation of solar panels as a renewable energy source to replace conventional energy sources

Let us carry out Activity 6.12 to further understand the green building concept in local and global contexts.



Photograph 6.20 A green building

 **My Malaysia**

ECOS – Online system provided by Energy Commission related to energy efficiency.  
<http://bt.sasbadi.com/sc3201-1>




Does a green building mean a building that only has green plants?

### Activity 6.12

To understand the green building concept in the local and global contexts

#### Instructions

1. Work in groups.
2. Gather and share information on the following:
  - (a) Green building concept in the local context
  - (b) Green building concept in the global context

Latest information on greenhouse and reducing the release of carbon dioxide.  
<http://bt.sasbadi.com/sc3201-2>



#### 21<sup>st</sup> Century Skills

- ICS, ISS
- Technology based activity



1. Obey the ethics of social media use.
2. Respect intellectual property rights.

3. Discuss the information shared.
4. Present the findings of your group discussion using multimedia presentation such as MS PowerPoint or social media.

## Designing a Model of a Green Building

Did you build a model of a greenhouse when you were in Form 2? Let us carry out Activity 6.13 to innovate or invent another model of a greenhouse which uses the concept of energy savings.

### Activity 6.13

Innovate or design a model of a green building using the concept of energy savings

#### 21<sup>st</sup> Century Skills

- ICS, ISS, CPS
- Project-based

#### Instructions

1. Work in groups.
2. Innovate or create a green building model using the concept of energy conservation in a local or global context. Among the points to be emphasized are:
  - (a) energy efficiency
  - (b) power sales
  - (c) appliances with Energy Efficiency Rating and Labelling
3. You can refer to the following websites:

TNB - Energy efficiency, power sales, appliances with Energy Efficiency Rating and Labelling  
<http://bt.sasbadi.com/sc3202-1>



ECOS - Energy Commission (EC) services related to energy efficiency  
<http://bt.sasbadi.com/sc3202-2>



4. Present your group's innovation or creation of the green building model in class.

## Formative Practice 6.4

1. Give the definition of energy efficiency.
2. The electrical energy used by an air conditioner for 2 minutes is 180 kJ. Calculate the power of this air conditioner in the following units:
  - (a) W
  - (b) kW
3. A microwave oven rated 1.2 kW, 240 V is connected to a 240 V electricity supply. Calculate the current that flows through the oven.
4. An electric rice cooker rated 800 W, 230 V is switched on for 30 minutes.
  - (a) How much electrical energy is used by the rice cooker?
  - (b) Calculate the cost of energy that is used by the rice cooker if the cost per kWh is 30 sen.
5.
  - (a) What is the importance of star rating labelling of an electrical appliance?
  - (b) How many stars in the star rating label of an electrical appliance should be used? Explain your answer.

## Electricity and magnetism

is applied in

## Generation of electricity

from

Renewable energy sources

such as

Hydro, wave, solar, tidal, wind, biomass, geothermal energies

Non-renewable energy sources

such as

Nuclear energy, coal, natural gas, petroleum

producing

Induced current

when

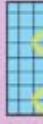
magnetic field lines are cut by coil of wire

## Electricity generator

produces

Alternating current

With variable voltage



C.R.O. screen

With a.c. voltage

increased by

Step-up transformer

decreased by

Step-down transformer

According to the formula:

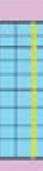
$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

## Solar cells and dry cells

produce

Direct current

With fixed voltage



C.R.O. screen

With fixed d.c. voltage

## Transmission and distribution system

made up of

Power station, step-up transformer station, National Grid Network, step-down transformer station, main substation, switch zone, branch substation

with

One-phase and three-phase wiring systems

and

Safety components

## Electric efficiency

depends on

Power, voltage, current, energy consumption, cost of energy consumption

and

Method of saving electrical energy used

## Summary





## Self-reflection

After studying this chapter, you are able to:

### 6.1 Generation of Electricity

- Describe energy sources in terms of renewable energy and non-renewable energy.
- Explain with examples the process of generating electricity from various sources of energy.
- Differentiate between direct current and alternating current.
- Solve problems related to electricity supply in life.

### 6.2 Transformer

- Carry out an experiment to build step-up and step-down transformer.
- Communicate transformers and the use of transformers in electrical home appliances.
- Solve numerical problems using formula involving transformers.

### 6.3 Transmission and Distribution of Electricity

- Explain the functions of the components in the transmission and distribution of electricity by drawing.
- Explain with examples electricity supply and wiring systems in homes.
- Distinguish between safety components in a home electrical wiring system.
- Communicate safety in transmission and distribution of electricity and the use of electrical appliances.

### 6.4 Calculate the Cost of Electricity Consumption

- Define energy efficiency.
- List examples of technology that applies the concept of energy efficiency.
- Determine the amount of electricity used in electrical appliances.
- Relate electrical energy consumption, power and time by calculating the cost of electrical energy used by electrical appliances.
- Conduct a home energy audit of electrical appliances used as a measure of saving electricity use at home.
- Communicate ways of saving electrical energy use at home.



## Summative Practice 6

Answer the following questions:

1. Determine whether the given statements about electricity or magnetism are **True** or **False**. Write your answer in the space provided.

(a) Power stations that use wind energy do not contaminate the air.	
(b) Solar cells can produce alternating current.	
(c) 2-pin plugs are not connected to the earth wire.	

2. Match each of the following energy sources with the correct type of energy.

## Energy source

(a) Coal

(b) Biomass

(c) Geothermal

(d) Wave

## Type of energy source

Renewable energy source

Non-renewable energy source

3. A coil of wire is moved in the direction of the arrow through the space between two magnets as shown in Figure 1.
- What is the effect on the magnetic field when the coil is moved?
  - What is produced in the coil of wire?
  - What happens to the LED? Explain your answer.
  - Name a device in power stations that applies a similar concept.

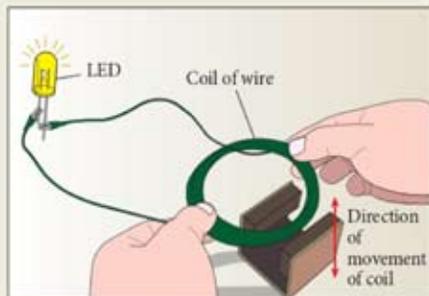


Figure 1

4. Figure 2(a) shows a device used to investigate electric current.



Figure 2(a)

- Name the device shown in Figure 2(a).
- What are the properties of electric current studied using this device?
- Figures 2(b) and 2(c) show two traces displayed on the screen of this device.

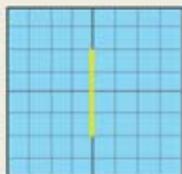


Figure 2(b)

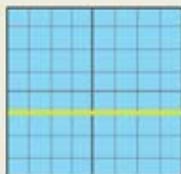


Figure 2(c)

Name the type of electric current represented by the trace on the screen in the following figures:

- Figure 2(b)
- Figure 2(c)

5. Figure 3 shows a type of transformer.

- Name the type of transformer.
- Explain your answer in question 5(a).
- Why is a laminated iron core used in a transformer?
- If the number of turns in the primary coil is 100 and the number of turns in the secondary coil is 20, calculate the secondary voltage if the primary voltage is 10 V.

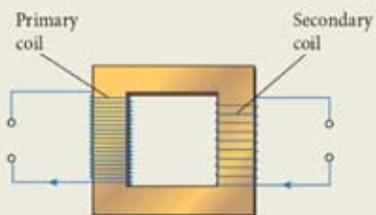


Figure 3

- Name the safety component in the electrical wiring system in homes supplied by TNB, SEB or SESB.
  - State **one** similarity and **one** difference between a fuse and Miniature Circuit Breaker (MCB).
  - What is the suitable fuse rating of a hair dryer rated 700 W, 240 V? Explain your answer.

## Focus on HOTS

- An electric heater is rated 230 V, 10 A.

  - Calculate the power of the electric heater in kW.
  - Which fuse is most suitable for the electric heater? Explain your answer.
  - Explain why other fuses are not suitable to be used based on the answer for question 7(b).

8. Figure 4 shows a model of Miniature Circuit Breaker (MCB).

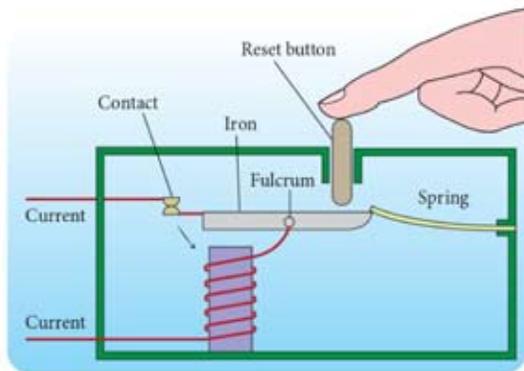


Figure 4

- (a) What is an MCB?  
 (b) State the function of an MCB and the way it works.  
 (c) You are required to build an MCB model using the materials provided below. Explain the function of each part. 

