12 Practical Electricity

Study Station ▸▸

A Electric Heating and Cost of Usage

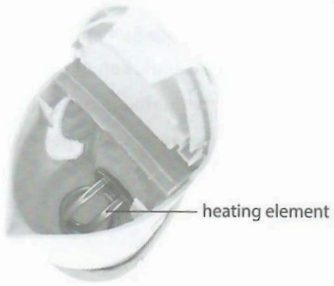
Learning Outcomes

- Describe the electrical heating effect in common home appliances such as electric kettles, ovens and heaters.
- Recall and apply $P = VI$ and $E = VIt$ to real-world situations and solve related problems.
- Calculate the cost of using electrical appliances and use kW h as a unit of energy.

1. We use electricity to run various appliances in our homes.

Examples of Home Appliance	Energy Transfer Process	What It Produces
bulb, television	propagation of electromagnetic waves	light
radio, television, speakers	propagation of mechanical waves	sound
fan, washing machine	mechanical	motion
electric kettle, oven, water heater, iron	thermal processes of conduction, convection and radiation	heating effect

2. To produce the heating effect, the appliances are equipped with a **heating element**.



kettle

- Heating elements are usually made of nichrome (alloy of nickel and chromium). Nichrome has *a high resistance and a high melting point, and it heats up very fast.*
- In contrast, **conducting wires** are usually made of copper. Copper has *a very low resistance and it heats up slowly.*

Worked Example 12.1

An electric kettle has a power rating of 2000 W. The electric kettle is connected to an electricity supply at 240 V.

The cost of 1 kW h of electricity is 10 cents. Calculate the cost of using the electric kettle for 30 days if it is used an average of 20 minutes every day.

Solution

$P = \frac{E}{t}$

$E = Pt$

$= 2000\ \text{W} \times \frac{20}{60}\text{h} \times 30\ \text{days}$

$= 20\ \text{kW h}$

$\text{Cost} = 20\ \text{kW h} \times \$0.10/\text{kW h}$

$= \$2.00$

Explanation

A power rating of 2000 W implies that the kettle operates normally at 2000 W.

Common Error

✗ kW h is a unit of power.

✓ kW h is not a unit of power.

Explanation

kW h is a unit of energy.

Link Discover Physics (5th Edition) Textbook — Section 15.1

Checkpoint 12.1

1. A small bakery uses a 5000 W oven on average 10 hours a day. The cost of 1 kW h of electricity is 25 cents. What is the cost of using the oven for a day?

Tip

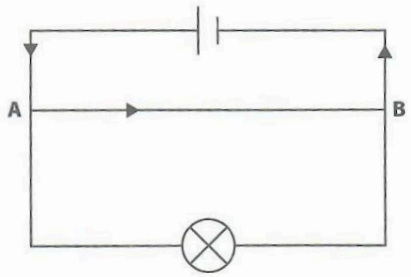
Questions testing calculations involving cost of using electricity has appeared in examinations, e.g., O GCE 'O' Level Science Physics Oct/Nov 2021, Paper 1, Q19.

B Using Electricity Safely

Learning Outcomes

- State the dangers of using electricity due to:
  (i) damaged insulation;
  (ii) overheating of cables;
  (iii) damp conditions.
- Describe a mains plug wiring.
- State what the terms live, neutral and earth mean.
- Explain safety features in electrical circuits including fuses with fuse ratings and circuit breakers.
- Explain the reason switches, fuses, and circuit breakers are fitted to the live wire.
- Explain safety features in appliances including earthing of metal casings and double insulation.

1. Using electricity carelessly may bring us harm. To reduce this risk, various safety features have been incorporated into our home electricity supply system and appliances.
2. A **short circuit** occurs when current is allowed *by accident* to flow through an *alternative path with much lower resistance*.



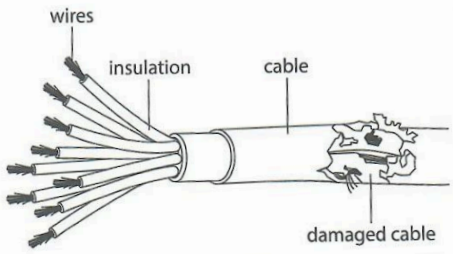
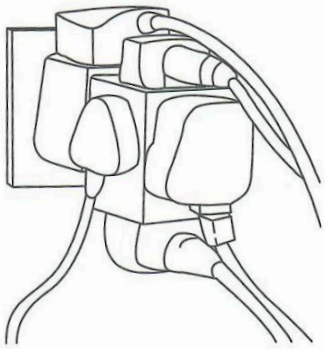
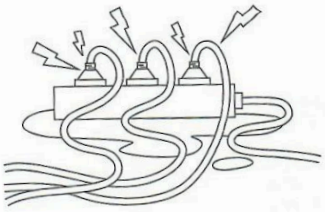
- As resistance R of path **AB** is very small and V (e.m.f. of battery) is constant, the *rate of electrical heating* $P = \frac{V^2}{R}$ will be *very large*. The *short circuit current* $I = \frac{V}{R}$ will also be *very large*.
- The high rate of electrical heating P causes *temperature to increase rapidly* and may cause flammable *substances to start burning*.

3. An **electric shock** is experienced when current is allowed *by accident* to flow through a *human body*.
   - If a large current flows through the human body, it can cause *electrical burns* (similar to damage from high temperature).
   - A large current can also shock the heart and even cause *heart failure* and death.

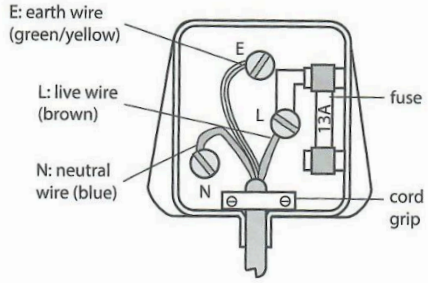
Tip

Lightning carries a current of about 30 000 A while the electric current normally used at home is about 30 A. That is why an electric shock from being struck by lightning is very dangerous.

4. We can prevent harm by not using electricity in **dangerous conditions**.

Dangerous Conditions	Risks	Actions
Damaged wire insulation  	• If the exposed wires are in contact with other materials, a short circuit may occur. • If a person accidentally touches the exposed wires, the person may get an electric shock.	• Do not touch the damaged wires directly. • Disconnect from the electricity supply and replace the damaged wire.
Overheating of cables  Too many plugs	• Overloading an electric socket with too many plugs leads to a current that is too large. The temperature increases rapidly and may melt the insulation (which is usually a plastic layer) to expose the wires underneath.	• Reduce the number of plugs connected to a single electric socket to reduce current.
Damp or wet environment 	• Water can provide a low-resistance path to cause a short circuit. • If a person accidentally touches the water, the person may get an electric shock.	• Avoid getting electrical connections wet. • Use waterproof appliances. • Avoid using non-waterproof appliances in damp environments. • Avoid touching electrical switches and sockets with wet hands.

5. Many appliances connect to the home electricity supply using the **three-pin plug**. It provides connections to the live, neutral and earth wires.



The wires follow the colour scheme set by the Energy Market Authority (EMA) of Singapore, which is valid since 1 March 2011.

Wire	Connection	Function
Live (brown)	Connected to 'live' voltage (usually 240 V, depending on the country)	Carries current into the appliance from electricity supply grid (or mains)
Neutral (blue)	Connected to neutral voltage (0 V)	Completes the circuit back to the source
Earth (green-and-yellow)	Connected to the ground (0 V)	Provides a path to the earth as protective measure

6. The **fuse** is a *safety device with a thin wire* that *disconnects a circuit when an excessive current flows.*

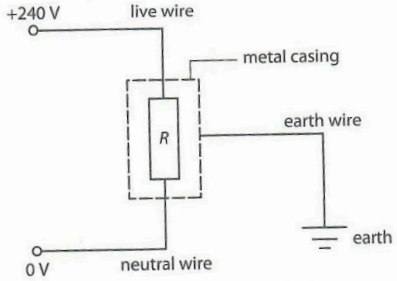
- When an excessive current flows through a fuse, the *metal wire in the fuse melts* to disconnect the circuit. The fuse is said to have "blown".
- The **current rating** of a fuse is the minimum current that can melt the wire and so should be slightly higher than the normal working current in the circuit (e.g. a 5 A fuse is used in a circuit that uses 4 A current). Common current ratings are 1 A, 2 A, 5 A, 10 A and 13 A.

7. The **circuit breaker** is an *automatic switch* that *disconnects a circuit when an excessive current flows.* When it is activated, it is said to have "tripped".

Type of Circuit Breaker	Situation When Circuit Breaker Is Activated
Miniature Circuit Breaker (MCB)	Detection of an excessive current in the electricity supply to the home
Earth Leakage Circuit Breaker (ELCB)	Detection of a current flowing in the earth circuit (indicating a current leak from the live wires)
Residual Current Circuit Breaker (RCCB)	Detection of a difference in the current between the live and neutral wires (also indicating a current leak)

8. *Switches and safety features* including fuses and circuit breakers are *always connected to the live wire to stop current flowing in case of electrical faults.*

9. The **earthing of metal casings** of appliances is a product design to provide a *low-resistance path for current to flow to the ground safely* if current from the live wires leaks into the metal casings.



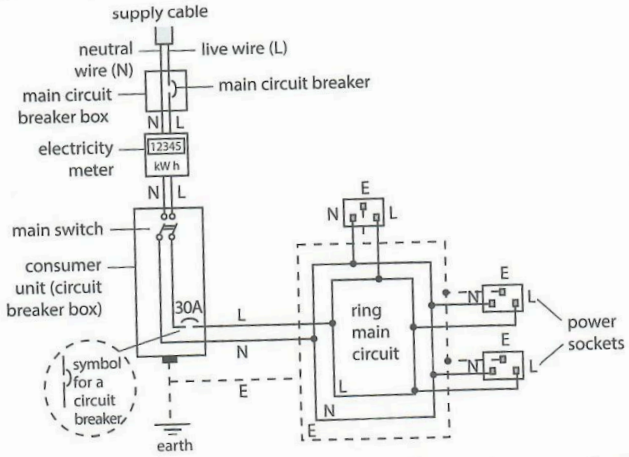
- The metal casings are connected to the ground through the earth wire in the 3-pin plug.
- When a person touches the metal casing of a faulty appliance, the person avoids electric shock. Very little current flows from the metal casing to the person; most current flows in the earth wire.

10. **Double insulation** is a product design of having *two layers of insulation around the live wires* in an appliance.

Symbol of double insulation feature on appliances

- The *first layer of insulation* prevents the current in the live wire from *leaking to the internal components* of the appliance.
- In case the first layer fails, the *second layer of insulation* prevents the leaked current in the internal components from leaking further to the external casing.

11. The electricity supply system in our homes incorporates various safety features to minimise the risk of danger of using electricity.



A typical home circuitry incorporates safety features such as circuit breakers and earthing.

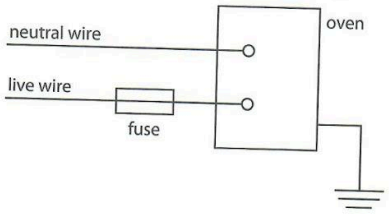
Tip

Summary notes for this chapter:

- Electricity can be used for heating.
- Heating power $P = VI = I^2R = \frac{V^2}{R}$
- Unit of energy consumption, 1 kW h = 1 kW × 1 hour
- Risks of using electricity include (i) short circuit and (ii) electric shock.
- Dangerous conditions to use electricity include (i) damaged insulation, (ii) overloading and overheating of cables and (iii) wet and damp environments.
- A mains plug has live, neutral and earth connections.
- Safety features in circuits include (i) fuses and (ii) circuit breakers.
- Fuses, circuit breakers and switches are connected to live wires.
- Safety features in products include (i) earthing of metal casings and (ii) double insulation.

Worked Example

The diagram below shows the wire connection to the metal casing of an oven.



(a) An electrical fault in the oven caused a current to flow through the metal casing. Explain why the fuse blew.

(b) Describe how the location of the fuse prevents a user from getting an electric shock.

Solution

(a) Due to the electrical fault, the current flowed through the earth wire to the ground. As resistance of the earth wire is very small, the current became very large and exceeded the fuse rating which caused the fuse to blow.

(b) When the fuse blows, the electricity supply is cut off and current no longer flows from the live wire to the oven. Therefore, when the user touches the oven, current does not flow through the user.

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Checkpoint 12.2

1. What is the function of a fuse and where is it fitted?

	Function	Location
A	prevent overheating of wire	fitted in live wire
B	prevent overheating of wire	fitted in earth wire
C	prevent electric shock of user	fitted in live wire
D	prevent electric shock of user	earth

Tip

Questions regarding fuse has often appeared in examinations, e.g., O GCE 'O' Level Science Physics Oct/Nov 2019, Paper 1, Q17.

Test Station ▸▸

1. Regina uses a 6 kW hair dryer for 5 minutes and a 1.5 kW air conditioner for 8 hours in a day. Given that 1 kW h costs 14 cents, calculate how much using these appliances costs her in a day.

   A $1.20 **B** $1.75

   C $12.50 **D** $42.14

2. Which of the following is **not** a safety feature of a three-pin plug?

   A Built-in fuse

   B Built-in circuit breaker

   C Connection to the earth

   D Insulated cover

3. Figure 15.1 below shows a circuit diagram with a 400 Ω resistor connected to a 10 V battery. **A** and **B** are points on the circuit.

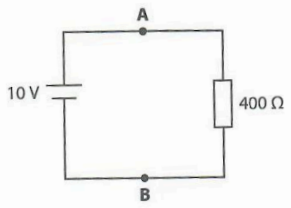

Figure 15.1

   (a) Calculate the heating rate in the resistor. [2]

   (b) A piece of 2.0 Ω wire is connected between **A** and **B**. Calculate the current flowing in the 2.0 Ω wire. [2]

   (c) Calculate the heating rate in the 2.0 Ω wire. [2]

   (d) Suggest how connecting the 2.0 Ω wire affects the battery. [2]

   (e) Explain why connecting the 2.0 Ω wire is hazardous. [2]

4. A rice cooker is connected to a 240 V power supply. The power rating of the rice cooker is 900 W.

(a) What is the current flowing through the rice cooker when it is being used? [2]

(b) Fuses of ratings 3 A, 5 A and 7 A are available to be used in the rice cooker plug. State the most suitable fuse. [2]

(c) Suggest why a fuse of rating 10 A is **not** suitable to be used in the rice cooker plug. [2]

5. Figure 15.2 is a circuit diagram which shows an electrical appliance with resistance *R* connected to the mains supply of 240 V.

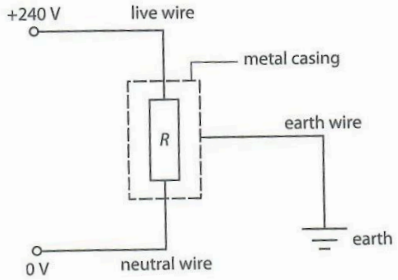

Figure 15.2

(a) Explain whether the electrical appliance uses a two-pin plug or a three-pin plug. [2]

(b) Both the earth and neutral wires are at 0 V. Explain why the metal casing is connected to the earth wire instead of the neutral wire. [3]