Rosary School – Marj Elhamam
Unit 2 - Electricity
Chapter 6 Mains Electricity

Name: ________________ Date: ____/____/ 2025

Grade: 9 (   ) **Physics Summary notes**

Objectives:

2.2 understand how the use of insulation, double insulation, earthing, fuses and circuit breakers protects the device or user in a range of domestic appliances

2.3 understand why a current in a resistor results in the electrical transfer of energy and an increase in temperature, and how this can be used in a variety of domestic contexts

2.4 know and use the relationship between power, current and voltage: power = current × voltage

(P = I × V) and apply the relationship to the selection of appropriate fuses

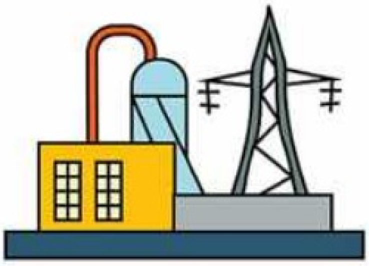
2.5 use the relationship between energy transferred, current, voltage and time:

energy transferred = current × voltage × time (E =I × V × t)

2.6 know the difference between mains electricity being alternating current (a.c.) and direct current (d.c.) being supplied by a cell or battery

Mains electricity:

- Mains electricity is the electricity we use in our homes for heating, lighting and air conditioning and it is supplied to us by power stations by the national grid.
- Electrical energy enters our homes through an underground **cable** that is connected to an **electricity meter**, which measures the electrical energy used. The cable is connected to a **consumer unit (fuse box)**, which contains fuses or circuit breakers for the various **ring circuits** in our homes. **Fuses** and **circuit breakers** are safety devices that open a circuit when the current in it becomes too large.
- Mains electricity is an **(a.c.)** supply.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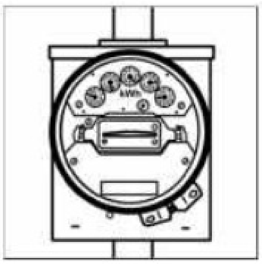
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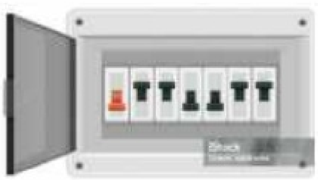
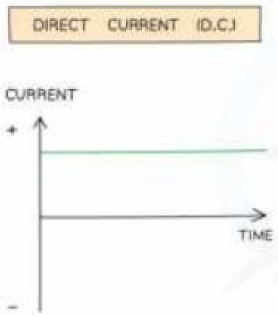
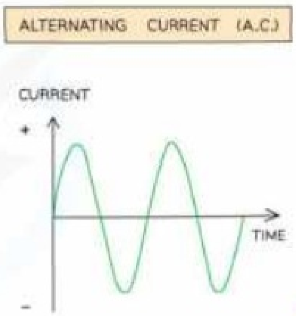


<u>Alternating current and direct current:</u>

- **(a.c.)** means **alternating current** or alternating voltage. In an alternating current the charges **continuously change direction** as the current / voltage varies from positive to negative. The current travels **forward and backward**.
- The frequency of an alternating current is the number of times the current changes direction back and forth each second.
- **(d.c.)** means **direct current**. A direct current is a **steady current** that constantly flows in the same **direction** in the circuit, from positive (+) to negative (-). The charges move in **<u>one</u>** direction. Cells, batteries, solar panels (photovoltaic cells) and power banks supply direct currents.
- In the United Kingdom the domestic electricity supply has a frequency of 50 Hertz (it changes direction 50 times every second) and is about **230 volts**.





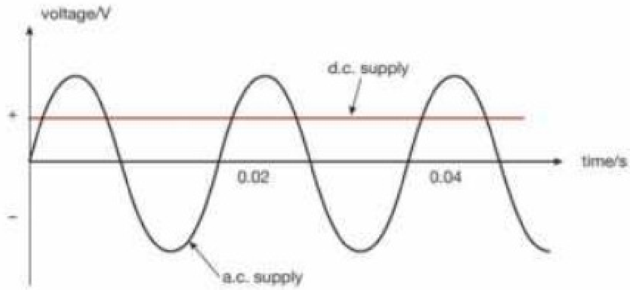


Figure 6.14 How the voltage of an a.c. supply compares with that of a d.c. supply

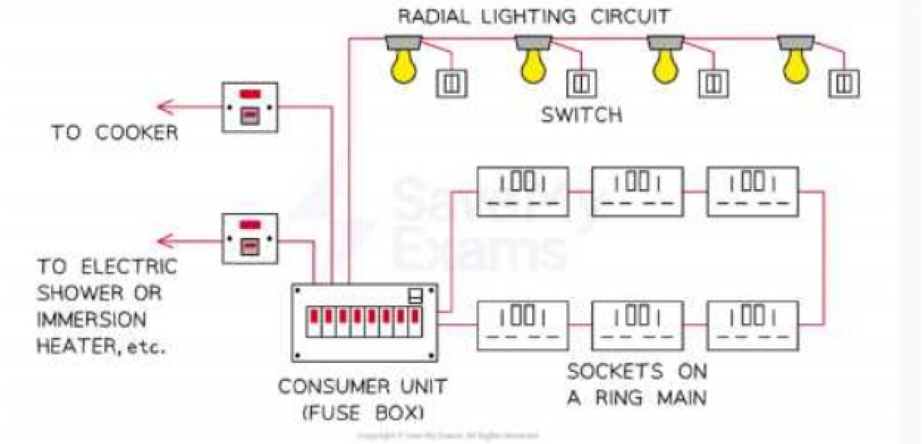
Direct current vs. alternating current table

Direct Current (d.c.)	Alternating Current (a.c.)
Continuous and in one direction	Constantly changing direction
Produced by cells and batteries	Produced by electrical generators i.e. mains electricity
Has a positive and negative terminal	Has two identical terminals

<u>Exam tip:</u>
If asked to explain the difference between alternating and direct current, <u>sketching</u> and <u>labelling</u> the graphs above can earn you full marks.

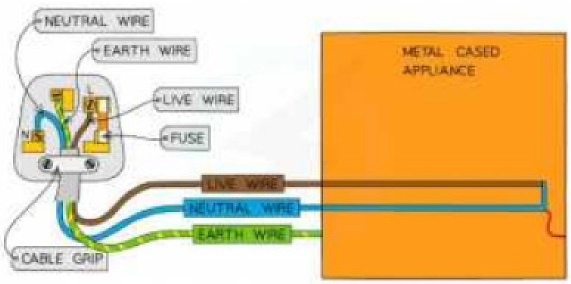
Cabling:

- Wires leave the consumer unit to **ring main circuits** found in each room. They provide a way of allowing several appliances in different parts in the same room to be connected to the mains supply with minimum wiring.



The consumer unit distributes current to all the circuits in the house

- **Ring main** circuits consist of three wires: **live** (brown), **neutral** (blue), **earth** (yellow and green stripes). Colour is specific for the type of wire to identify them.
- Plugs are connected to sockets in the ring main circuit.
- In a 3-core plug there are 3 wires as well: **live** (brown), **neutral** (blue), **earth** (yellow and green stripes).



1. **Live wire**
   - ➢ Brown, at 230V
   - ➢ Carries the alternating potential difference from the mains supply to the appliance.
   - ➢ This may be dangerous even if mains circuit is off, as current may still be flowing through it.
2. **Neutral wire**
   - ➢ Blue, at 0V
   - ➢ Completes the circuit by carrying the current away from the appliance.
3. **Earth wire**
   - ➢ Green and Yellow stripes, at 0V.
   - ➢ It only carries a current if there is a fault.
   - ➢ Safety wire to stop the ***appliance becoming live***.
   - ➢ It is connected to the earth and to the casing of the appliance.
   - ➢ If the live wire touches the metal casing of the appliance, earth wire will become live and carry the current to the ground (you'll get a serious electric shock if you touch the wire in this situation, as current flows through you to the ground). This stops the appliance from becoming live, if the live wire came loose and touched the casing.

- The outer part of a plug is called the casing. It is made of plastic which is a good **insulator.**
- Plugs are connected to the circuit via three brass pins. Brass as a metal is an excellent **conductor**.

Electrical safety:

- Mains electricity is potentially lethal. Potential differences as small as 50 V can pose a serious hazard to individuals. An important symbol for electrical safety is shown in the figure on the right.

- Common electrical safety hazards include:

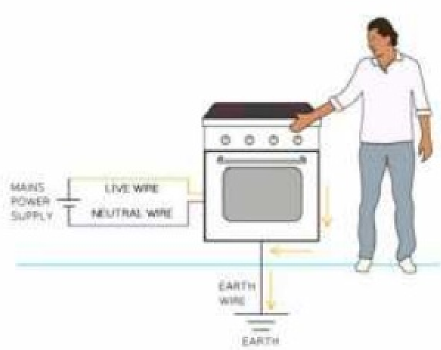
1. **Damaged Insulation** – if someone touches an exposed piece of wire, they could be subjected to a lethal shock.
2. **Overheating of cables** – passing too much current through too small a wire (or leaving a long length of wire tightly coiled) can lead to the wire overheating. This could cause a fire or melt the insulation, exposing live wires.
3. **Damp conditions** – if moisture comes into contact with live wires, it could conduct electricity either causing a short circuit within a device (which could cause a fire) or posing an electrocution risk.

Example 1:

An electrician is fixing an oven in the kitchen of a house.

Explain why he should also turn off the mains electricity supply in the kitchen, as well as the oven. (4)

because if the mains electricity
Still on so there is acurrent
in the live wire inside the oven
which make arisk on electrician
and causing electric shock
and injury



-To protect the user or the device, there are several safety features built into domestic appliances, including:

- **1)Insulation:**

  The conducting part of a wire is usually made of copper or some other metal. If this comes into contact with a person, this poses a risk of electrocution. To improve electrical safety wires are covered with an **insulating material**, such as **rubber**.

- **2)Double insulation:**

  Some appliances do not have metal cases, so there is no risk of them becoming electrified. Such appliances are said to be **double insulated**, as they have **two** layers of insulation:

1. Double insulation around the wires themselves.
2. A non-metallic case that acts as a second layer of insulation.

Double insulated appliances **do not** require an earth wire. They are usually fitted with a 2-core plug instead of a 3-core plug.

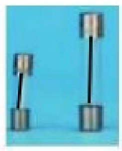
- **3)Earthing:**

  Many electrical appliances have metal cases. This poses a potential electrical safety hazard. If a live wire (inside the appliance) came into contact with the case, the case would become electrified and anyone who touched it would risk being electrocuted. The earth wire is an additional safety wire that can reduce this risk as it creates an alternate path for the current to pass through to earth.

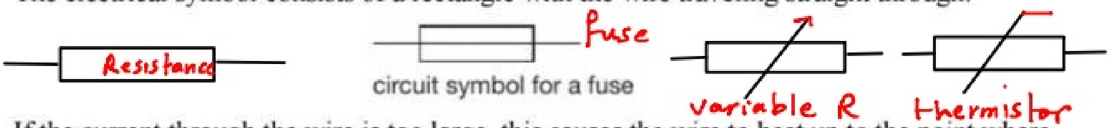
- **4)Fuses:**

▪ A fuse is a safety device designed **to cut off the flow of electricity**, to break (open) the circuit of an appliance, if the **current becomes too large** due to a fault or a surge.

▪ A fuse is a glass cylinder that contains a metal wire (alloy of tin and lead) found in an electric plug.



▪ The electrical symbol consists of a rectangle with the wire traveling straight through.



circuit symbol for a fuse

▪ If the current through the wire is too large, this causes the wire to heat up to the point where it melts. This means it breaks and consequently **breaks the circuit open** in the appliance, making it safe to touch and reducing the damage it sustains.

the LCD screen works correctly on 8 A and it is damaged if current inside it reaches 17 A.

What is the suitable fuse must be used?

5 A , 13 A , 20 A , 30 A .

most suitable

fuse must be bigger than correct current as close as possible.

Selecting fuses:

- Fuses have different values, indicating the maximum amount of current that can flow through them before they break.
- Fuses come in three sizes: 3 amps, 5 amps and 13 amps.
- To select the correct fuse for the appliance, use the **power equation** to calculate the amount of current it requires to operate.
- The fuse needed is **'the next size up'**. For example, an appliance with a current of 4.5 amps should use a 5 amp fuse, as a 13 amp fuse *will allow far too much current to pass through.*

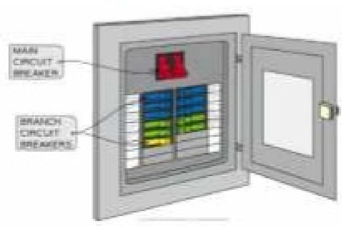
Example 2:

If an appliance uses a current of 3.1 A, what would be a suitable rating for a fuse?

5A.

➢ Circuit breakers

- A circuit breaker consists of an automatic electromagnet switch that breaks the circuit if the current exceeds a certain value.
- The **main circuit breaker** can quickly shut off electricity to the whole house.
- The **branch circuit breakers** can shut off electricity to specific areas of the house.
- A circuit breaker has a major advantage over a fuse as an electrical safety device because:

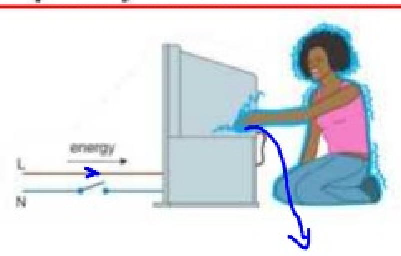


1. It **doesn't melt** and break, hence it can be **reset** and used again.
2. It works much **faster**.

- For these reasons, circuit breakers are used in mains electricity in homes as the most important electrical safety device.
- Sometimes they are misleadingly named "Fuse boxes".

➢ Switches:

- Switches in mains circuits should always be placed in the **live wire**.
- When the switch is open no electrical energy can reach the appliance.
- If it was placed in the neutral wire, electrical energy can still enter a faulty appliance, and could possibly cause an electrical shock.



Exam tip:

For your exam, you must explain how insulation, double insulation, earthing, fuses and circuit breakers protect the device or user in different domestic situations.

The heating effect of current: converting electrical to thermal.

- A current passing through a resistor (or wire) results in the electrical transfer of energy.
- Current is the **rate of flow of charge** (number of charge passing a point in wire each second). how many charges pass through sec.
- The temperature of a resistor increases due to **the collisions of the free electrons** within the wire. molecules so molecules vibrate faster so it heats up
- Some of the energy is dissipated into the surroundings by heating.
- This heating effect is utilised in many domestic contexts, including: electric heaters, electric ovens, electric hob, toasters, kettles, etc.

Electrical power:

Calculating power:

- Power is a measurement of **the rate of energy transfer**, or the **amount of energy transferred per second.**
- The power rating of an appliance defines how much energy is being transferred from the mains electricity to power the device each second.
- Power is measured in **joules per second (J/s)** or **watts (W)** $P = E/t$ $\frac{J}{s} \equiv$ watt
- A 50 W bulb has a lower power rating than a 70 W bulb. It is going to be dimmer because it transfers less *electrical energy* to *heat and light energy* every second.
- Devices that transfer lots of energy very quickly have very high power ratings expressed in kilowatts (kW)

→1kW = 1000 W

- The power (P) of an appliance is related to the **voltage** across it, and the **current** (I) flowing through it.

Power (watts) = current (amps) x voltage (volts)

$$P = I \times V$$

$$P = I^2 \times R \qquad P = \frac{V^2}{R} \qquad P = \frac{Energy}{t}$$

Example 3:

A 230 V television takes a current of 3 A. Calculate the power of the television.

$P = I \times V = 230 \times 3 = 690W$

Example 4:

Calculate the potential difference through a 48 W electric motor with a current of 4 A.

voltage

$P = I \times V \Rightarrow V = \frac{P}{I} = \frac{48}{4}$

$V = 12$ volt

Example 5:

A kettle has a power rating between 2000 W and 2500 W with an input voltage of 220 V to 240 V, as shown on the device label.

a. Calculate the maximum current that can safely pass into the device. (3)

$I = \frac{P}{V}$ for I to be max (P : max)(V : min)

b. Identify the correct fuse rating for the kettle. (1)

$I = \frac{2500}{220} = 11.36$ A $= 11.4$ A

13 A

Exam tips:

- Remember there are two steps involved in selecting a correctly sized fuse for an appliance:

1. Calculating the current required using the **electrical power equation.** If not mentioned in the question, always assume that the mains electricity voltage is 230 V.

2. Selecting the **next size up** fuse.

- Always practice rearranging and substitution.

Calculating energy transfers

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

$E = I V t$

- Work is done when charge flows through a circuit.
- Work done is equal to the energy transferred.
- The amount of energy transferred by electrical work in a component (or appliance) is calculated using the formula:

Energy = Power × time

E = P × t

Since **P= I × V**

So

E = I × V x t

- Energy, E in Joules (J)
- The current, I in amps (A)
- The potential difference, V in volts (V)
- The amount of time the component is used for, t in seconds (s)

- When charge flows through a resistor, for example, the energy transferred is what makes the resistor hot.
- The energy transferred can be calculated using the equation:
- When charge flows around a circuit for a given time, the energy supplied by the battery is equal to the energy transferred to all the components in the circuit.

we know that $P = I \times V$

and $P = \frac{E}{t}$ so $E = P \times t$

$E = I \times V \times t$

Example 6:

Calculate the energy transferred in 1 minute when a current of 0.7 A passes through a potential difference of 4V.

$$E = P \times t = IVt = 0.7 \times 4 \times (1 \times 60) = 168\ J$$

Exam tip:

'**Energy transferred'** and **'work done'** are often used interchangeably in equations; they mean the same thing. Always remember that the time (***t***) in the above equations must always be converted into **seconds.**

Homework: Chapter questions page 66

Past papers questions:

1) 4PH0 – S 2015 1P – Q4

4 A kitchen has a water supply, an electricity supply and electric lighting.

There are several electrical appliances in the kitchen including a toaster, a kettle, a clothes iron, a microwave oven and a dishwasher.

Discuss three hazards of using electricity in this kitchen.

(6)

1

2

3

MP1. Idea of **water** in contact with something electrical e.g. plugs/sockets/switches;	Idea that water conducts electricity; Idea that this can cause shock;
MP2. Idea that an electrical device with a heating element reaches a **high temperature**;	(risk of) burns; idea that insulation can melt and cause a fire;
MP3. Idea that **damaged equipment** poses a hazard; e.g. microwave oven	Live parts should not be exposed; Idea that this can cause shock; leaky microwave radiation can cause cancer;
MP4. Idea **overloaded** cables or sockets;	circuits should have correct fuses; can cause a fire; don't use multiway socket extensions; provide sufficient sockets;
MP5. Idea of **trip hazard** from trailing cables;	Do not use extension cables; Provide sufficient sockets; Use short mains leads; NOTE

(Total for Question 4 = 6 marks)

$P = IV$

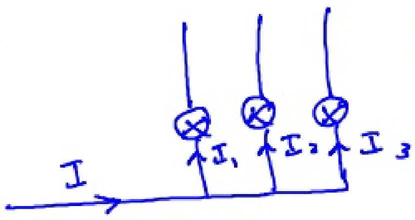
$P = I^2 \times R$

Energy = $P \times t$ ← sec.

IVt

I^2Rt

parallel connection

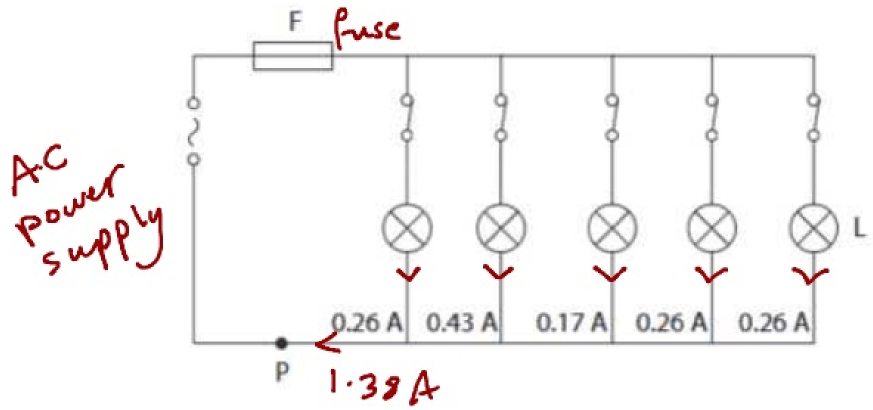


$I_1 + I_2 + I_3 = I$

2) 4PH0 – S 2015 1PR – Q2

2 The diagram shows part of a lighting circuit in a house.

The circuit is protected by fuse F.



(a) Give two reasons why the lamps are wired in parallel.

(2)

1 if one lamp burns the other still working

2 each lamp can be switched ON/off seperately

3- each lamp takes its max. voltage.

(b) What is the current at P?

(1)

- ☐ **A** 0.17 A
- ☐ **B** 0.26 A
- ☐ **C** 0.43 A
- ☒ **D** 1.38 A

addition of currents

(c) Explain how the fuse protects the circuit.

(3)

it is asafety device which melts if the current exceeds acertain value and cuts off current to prevent the circuit from over heating

(d) (i) State the equation linking power, current and voltage.

(1)

$P = I \times V$

$I = \frac{P}{V}$ ✓

(ii) Calculate the power of lamp L.
[assume the mains voltage is 230 V]

(2)

$I = 0.26\,A$
$V = 230\,V$

$P = 0.26 \times 230$

59.8

power = 60 W

(iii) Calculate the amount of energy transferred by lamp L in 3 minutes.

Give the unit.

(3)

$E = P \times t = 60 \times 3 \times 60 = 10800$

$= 10800$

$= IVt = 0.26 \times 230 \times 3 \times 60$

$= 10764$

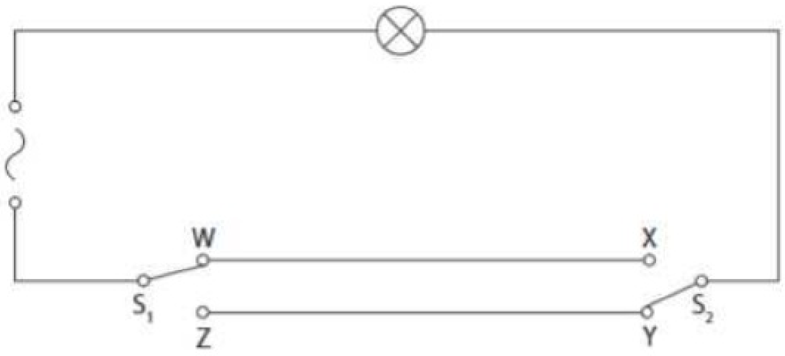
10800

energy transferred = 11000 unit J

10800

11 kJ

(e) This diagram shows another lighting circuit.



(i) Complete the table by putting a tick (✓) in the box if the lamp is lit and a cross (✗) in the box if the lamp is not lit.

(2)

S_1 position	S_2 position	lamp lit (✓ or ✗)
W	X	✓
W	Y	✗
Z	X	✗
Z	Y	✓

(ii) Suggest where this circuit would be useful in a house.

(1)

bed room
on stairs
corridor
kitchen

(Total for Question 2 = 15 marks)

3) 4PH0 – W 2015 1P – Q1

1 Mains electricity is used in circuits at home.

(a) Double insulation is needed for safety when there is

(1)

☐ **A** no circuit breaker

☒ **B** no earth connection

☐ **C** no fuse

☐ **D** no switch

(b) A fuse is used so that

(1)

☐ **A** an earth connection is not needed

☐ **B** the appliances are more efficient

☒ **C** the circuit cannot overheat if there is a fault

☐ **D** the user cannot touch a live wire

(c) Most lamps at home have their own switch.

This is because the lamps are connected

(1)

☒ **A** in parallel

☐ **B** in series

☐ **C** to a fuse

☐ **D** to an earth wire

(Total for Question 1 = 3 marks)

4) 4PH0 – S 2017 1P – Q4

4 (a) These terms are used on the safety labels found on electrical appliances.

Explain the meaning of each term.

(i) insulated wire

(1)

a wire is covered by insulating that doesn't conduct electricity to stop it getting electruted when it is touched.

(ii) 5 A fuse

(2)

a wire in acylinderical tube burns and melts and cuts off the circuit when the current exceeds a (5A)

(iii) earthed

(2)

connecting the metalic outer case of appliance to earth to prevent the case to be live when a fault or when the live wire be in contact with it.

(iv) double insulated

(2)

↳ when the outer case of appliance is made of plastic or insulator to prevent electrication when touching the case if there is acontact with live wire

5) 4PH0 – S 2018 1P – Q3

3 The photograph shows an electrical appliance called a toaster.

(a) The toaster has a power of 1800 W when operating at a voltage of 230 V.

(i) State the equation linking power, current and voltage.

(1)

$P = I \times V$ or $I = \frac{P}{V}$ ✓

(ii) Show that the current in the toaster is about 8 A.

(2)

$I = \frac{P}{V} = \frac{1800}{230}$

$I = 7.823 \simeq$ 7.82 A
7.8 A
8 A

(iii) Which fuse rating would be suitable for the toaster?

(1)

☐ **A** 1 A

☐ **B** 3 A

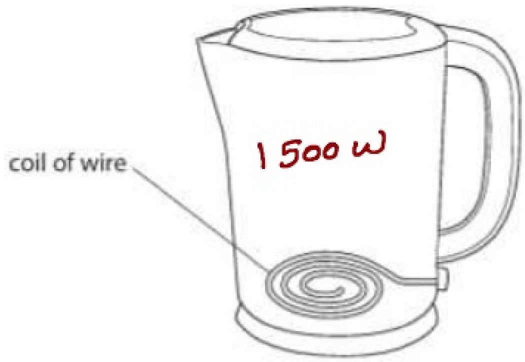
☐ **C** 7 A

☒ **D** 13 A

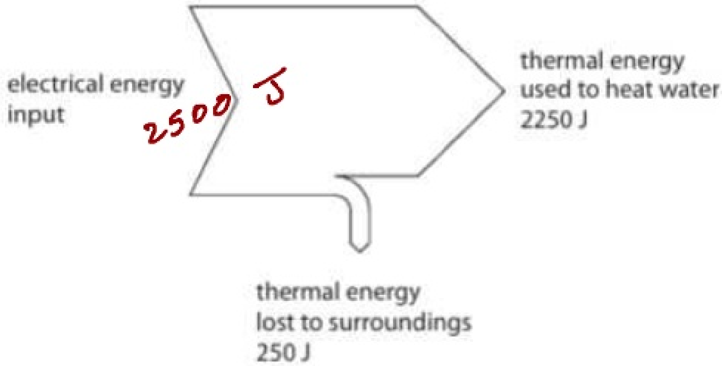
fuse must be little greater than normal current

6) 4 PH0 – S 2018 1PR – Q3

3 The diagram shows an electric kettle.



(a) The Sankey diagram shows the energy transfers that take place in one second when the kettle heats some water.



What is the energy input in one second?

(1)

☐ **A** 250 J

☐ **B** 2000 J

☐ **C** 2250 J

☒ **D** 2500 J

(b) There is a large insulated coil of wire inside the kettle.

Explain why this coil of wire gets hot when the kettle is switched on.

(2)

because there is a current passing in a wire (coil) which has a resistance so electrical energy is converted to thermal energy.

(c) The power of the kettle is 2.5 kW when operating at a voltage of 230 V.

(i) State the equation linking power, current and voltage.

(1)

$P = IV$ while $V = IR$

(ii) Show that the current in the kettle is about 11 A.

(2)

$I = \frac{P}{V} = \frac{2500}{230} = 10.86A$

which is approximately $= 11$ A

(iii) The plug of the kettle is fitted with a 13A fuse.

Describe how the fuse prevents the coil of wire from overheating.

(3)

melts

when I exceeds 13 A

cuts off circuit

prevent of overheating ...

(Total for Question 3 = 9 marks)