Section
4.4

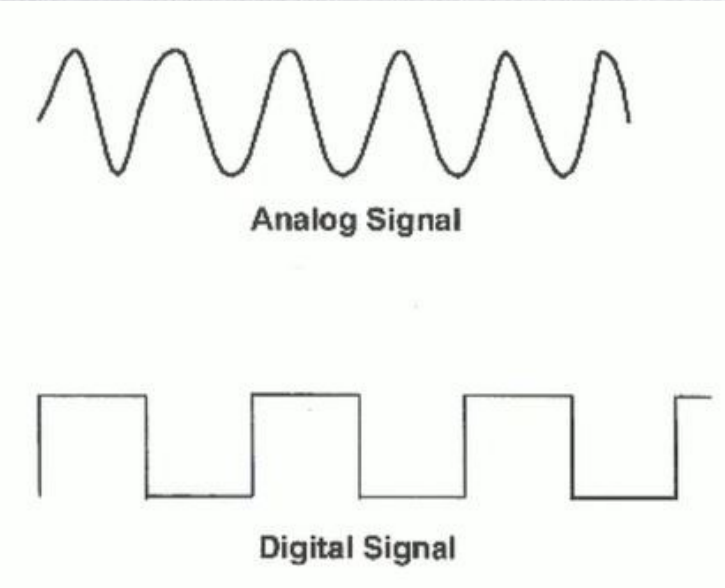
Electric circuits

4.4.1 Circuit components
4.4.2 Combinations of resistors
4.4.3 Electronic circuits
4.4.4 Electrical safety

Analogue and digital

- The output of a **digital** circuit is either **ON or OFF** – there is no in between state. Digital electronic systems are very useful for **storing and transferring information**. Computers, mobile phones and mp3 players all work digitally.
- In digital systems, each piece of information (such as a number or a letter) is represented in **binary** form as a sequence of 1s (**one**s) and 0s (**zero**s).
- In a circuit, a **1 corresponds to a high voltage** (perhaps 6 V). A **0 corresponds to a low voltage** (close to 0 V).
- The opposite of a digital system is an **analogue system**. In an analogue system, **voltages can have any value**, positive or negative.

Digital Electronics



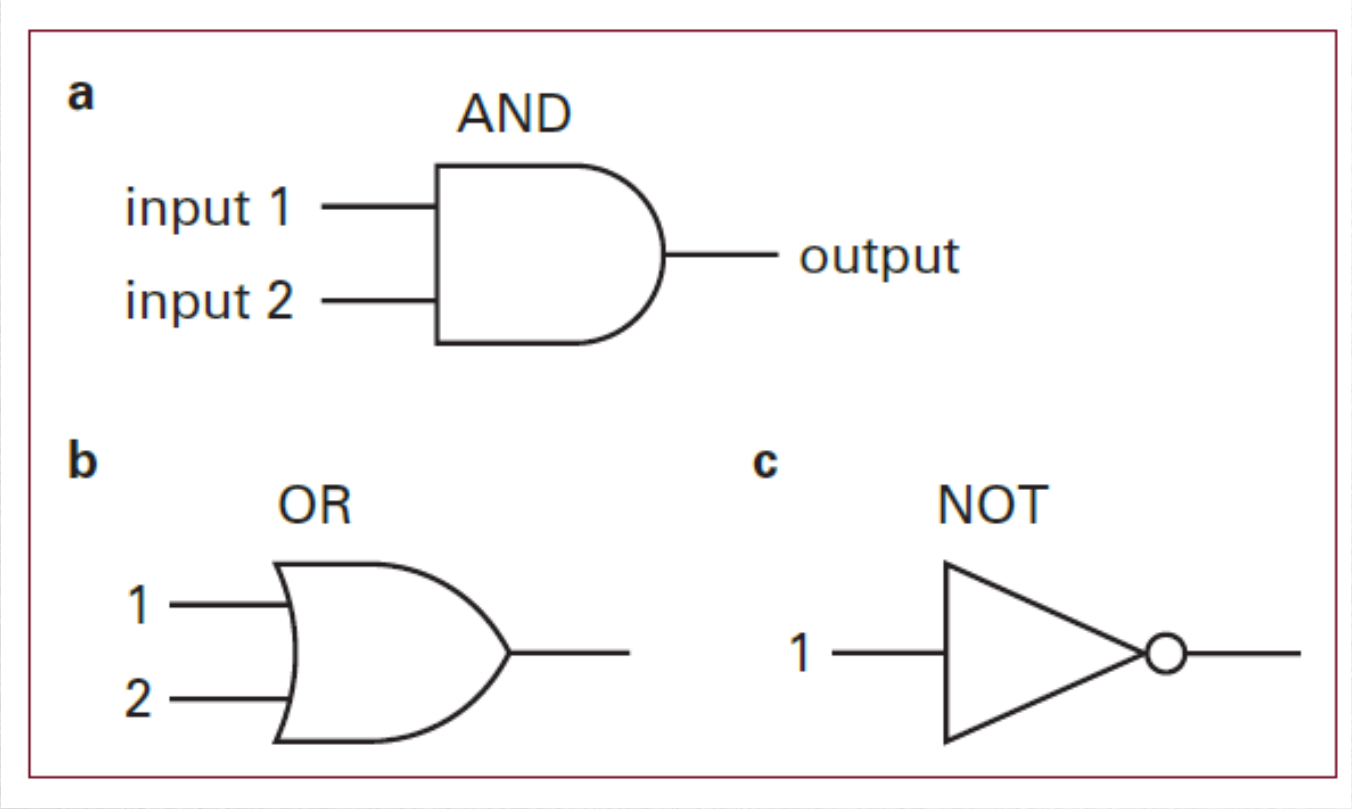
- A digital system includes an **input sensor** and a **processor circuit**, which controls the voltage to an output device.
- The processor circuit consists of a series of **logic gates**.
- Logic gates respond to small voltages which are either on or off. They don't respond to analogue signals.
  - ✓ An **analogue signal** varies **continuously in amplitude**
  - ✓ A **digital signal** has **two states**: high or low (or on and off, or 1 or 0)

Logic Gates

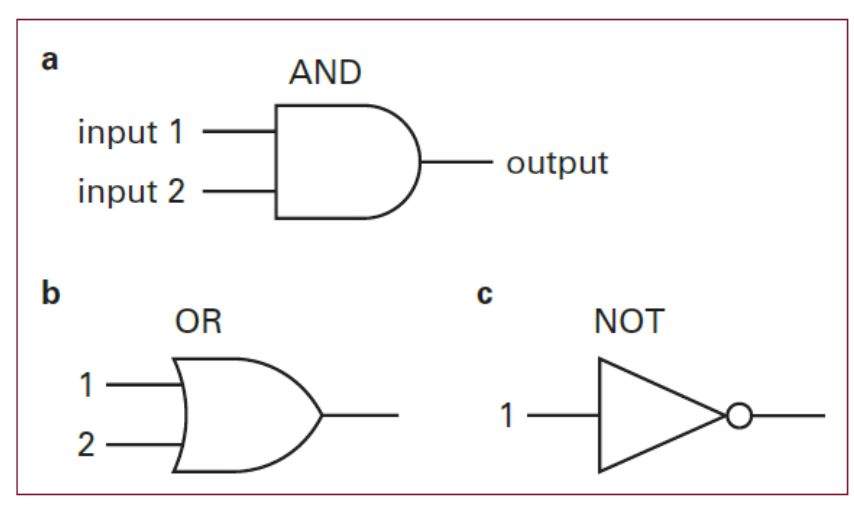
- Logic gates are digital electronic components that engineers use as simple building blocks when they design electronic circuits. Each logic gate has a specific function, and many can be combined together to produce complex effects. Inside each logic gate there are a number of different components, what **goes in to** the logic gate and what **comes out as a result** is the only thing that need to know.
- A logic gate is a device that receives one or more electrical input signals, and produces an output signal that depends on those input signals. These signals are voltages:
  - ✓ a **high voltage** is referred to as **ON**, and is represented by the symbol **1**
  - ✓ a **low voltage** is referred to as **OFF**, and is represented by the symbol **0**.

Logic Gates

- In order to do this, a logic gate needs its own power supply, but this is not usually shown when circuit diagrams are drawn. It is easiest to understand how logic gates operate by looking at three specific examples: the **AND**, **OR** and **NOT** gates.



Logic Gates



The first two symbols (a & b) have two inputs on the left and a single output on the right. The third one (c) has one input on the left and one output on the right.

- a. An AND gate functions like this: **its output is ON if both input 1 and input 2 are ON**.
- b. An OR gate functions like this: **its output is ON if either input 1 or input 2 or both is ON**.
- c. A NOT gate functions like this: **its output is ON if its input is not ON.**

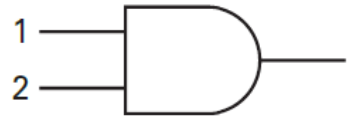
Logic Gates

- A **truth table** shows **all the possible combinations of inputs, and the output that results from each combination**.
- The **NOT gate** has only **one input**, which can be ON or OFF, so this is the simplest table.
- The **AND gate** and **OR gate** both have **two inputs**. So there are **four possible combinations of inputs**, and there is a corresponding output for each.
- For example, you can see from the last line in the truth table for the **AND gate** that two input 1s give an output 1. For all other combinations of inputs, the output is 0.

Logic Gates

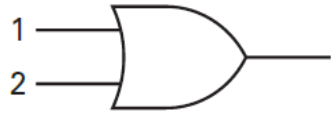
In a truth table, 0 stands for OFF or a low voltage; and 1 stands for ON or a high voltage.

a AND gate



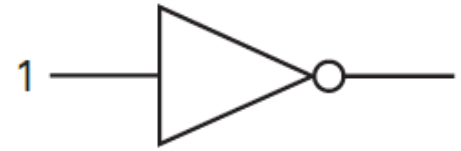
input 1	input 2	input 3
0	0	0
1	0	0
0	1	0
1	1	1

b OR gate



input 1	input 2	input 3
0	0	0
1	0	1
0	1	1
1	1	1

c NOT gate



input 1	output
0	1
1	0

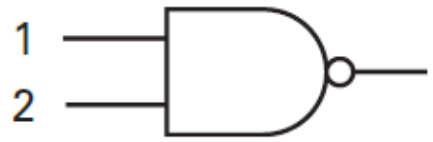
Logic Gates

- The NAND and NOR gates, each of which has **two inputs and a single output**.
- a. A **NAND** gate functions like this: its output is OFF if both input 1 and input 2 are ON.
- A **NOR** gate functions like this: its output is ON if neither input 1 nor input 2 is ON.
- You could construct a NAND gate by connecting a NOT gate to the output of an AND gate, so **AND + NOT = NAND**.
- Similarly, you could construct a NOR gate by connecting a NOT gate to the output of an OR gate, so **OR + NOT = NOR**.

Logic Gates

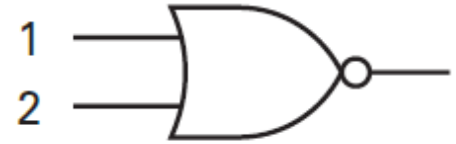
In a truth table, 0 stands for OFF or a low voltage; and 1 stands for ON or a high voltage.

a NAND gate



input 1	input 2	output
0	0	1
1	0	1
0	1	1
1	1	0

b NOR gate



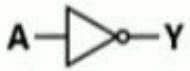
input 1	input 2	output
0	0	1
1	0	0
0	1	0
1	1	0

Logic Gates (Cont'd)

- Logic gates transform a digital input voltage into an output, which depends on the type of logic gate.
- The input voltages are given as **1 or 0 (on or off)** and the input/output of these logic gates can be represented on a **truth table**.
  - ✓ **NOT**: gives an output that is **opposite** of the input
  - ✓ **AND**: only gives an output if the **input A and B are both 1**
  - ✓ **OR**: gives an output if **input A or B is 1**
  - ✓ **NAND**: gives **exact opposite** output as the **AND gate**
  - ✓ **NOR**: gives the **exact opposite** output as the **OR gate**

Logic Gates

NOT gate



A	Y
1	0
0	1

AND gate

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

OR gate

A	B	Y
0	0	0
1	0	1
0	1	1
1	1	1

NAND gate

A	B	Y
0	0	1
1	0	1
0	1	1
1	1	0

NOR gate

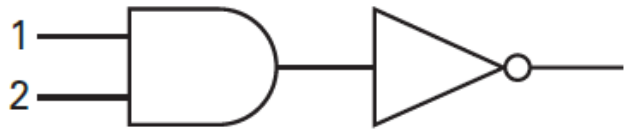
A	B	Y
0	0	1
1	0	0
0	1	0
1	1	0

- A and B represent inputs
- Y represents an output

Combining logic gates

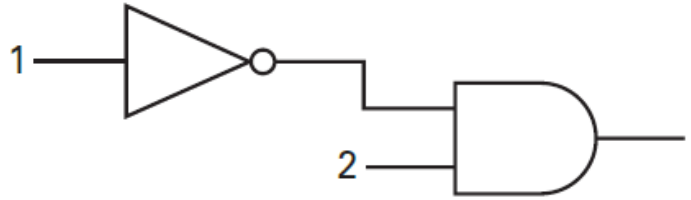
- **The order in which gates are connected together is important**. By combining the same gates in different orders, we can achieve different effects.

a AND NOT



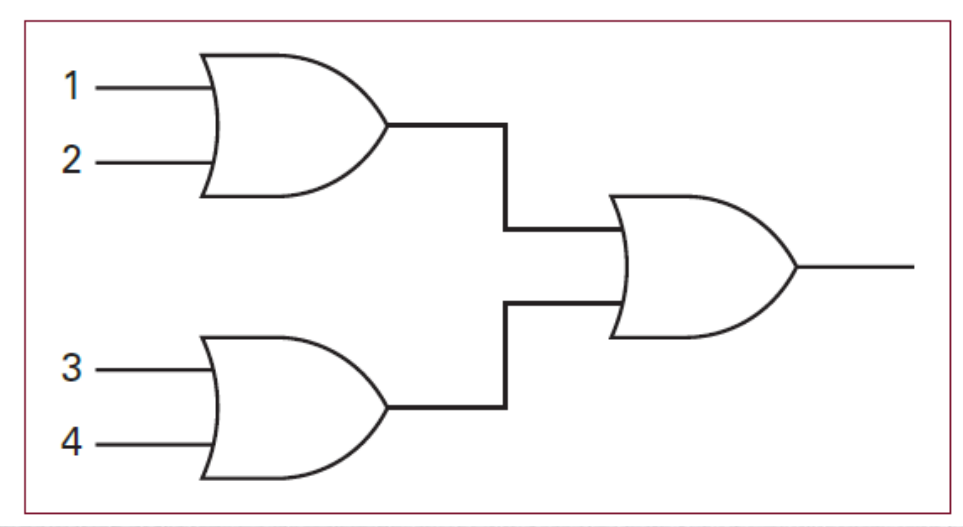
input 1	input 2	output
0	0	1
1	0	1
0	1	1
1	1	0

b NOT AND



input 1	input 2	output
0	0	0
1	0	0
0	1	1
1	1	0

Combining logic gates



- Three OR gates connected together. The combination has *4* inputs, so there are *16* different possible combinations of input signals. If one or more inputs is ON, the output is ON.
- Let us look at a practical example of how this might function. A building has smoke detectors in four different places. Their outputs are connected via this combination of OR gates to a single alarm siren. If any detector gives an ON signal, the siren will be switched on. This saves the expense of a separate siren for each detector.

Study question #1

In the appropriate box, draw the symbol for an AND gate and the symbol for an OR gate.

AND gate	OR gate

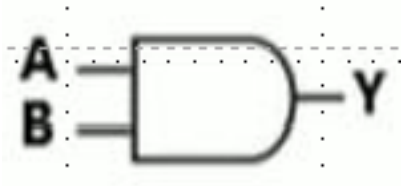
[1]

[Total: 1]

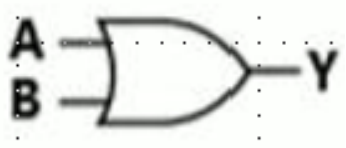
Study question #1

In the appropriate box, draw the symbol for an AND gate and the symbol for an OR gate.

AND gate



OR gate



[1]

[Total: 1]

Study question #2

Complete the truth table for a NAND gate.

input 1	input 2	output
0	0	
0	1	
1	0	
1	1	

[Total: 1]

Study question #2

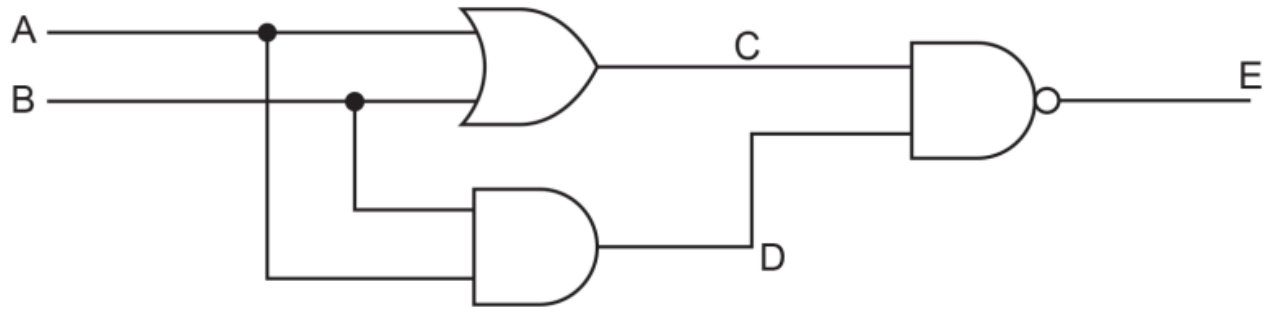
Complete the truth table for a NAND gate.

input 1	input 2	output
0	0	1
0	1	1
1	0	1
1	1	0

[Total: 1]

Study question #3

The diagram shows a digital circuit.



Complete the truth table for this circuit for all possible combinations of input.

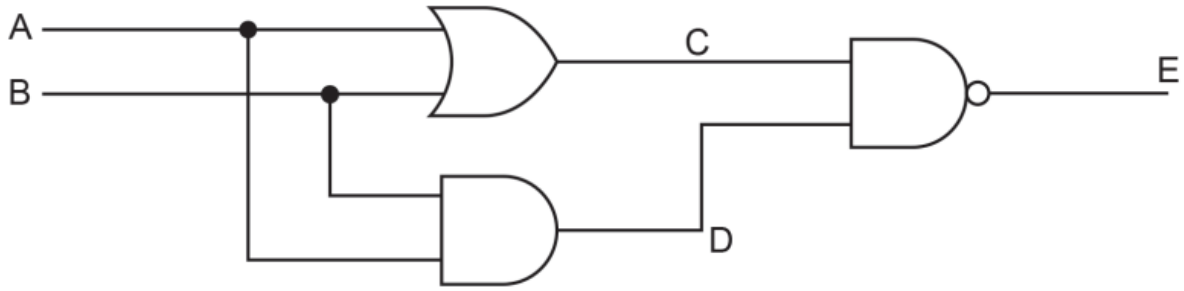
A	B	C	D	E
		1	1	
		1	0	
		1	0	
		0	0	

[4]

[Total: 4]

Study question #3

The diagram shows a digital circuit.



Complete the truth table for this circuit for all possible combinations of input.

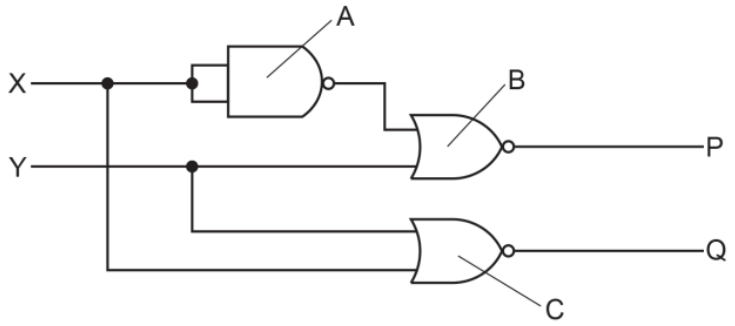
A	B	C	D	E
1	1	1	1	0
1	0	1	0	1
0	1	1	0	1
0	0	0	0	1

[4]

[Total: 4]

Study question #4

An arrangement of logic gates A, B and C is shown in the diagram. The arrangement has two inputs, X and Y and two outputs P and Q.



Output P of logic gate B has logic state 1 (high).

(a) Determine the logic states of the two inputs of logic gate B.

upper input = ...

lower input = ... [1]

(b) Determine and explain the logic state of output Q.

logic state of Q = ...

explanation.....

.....

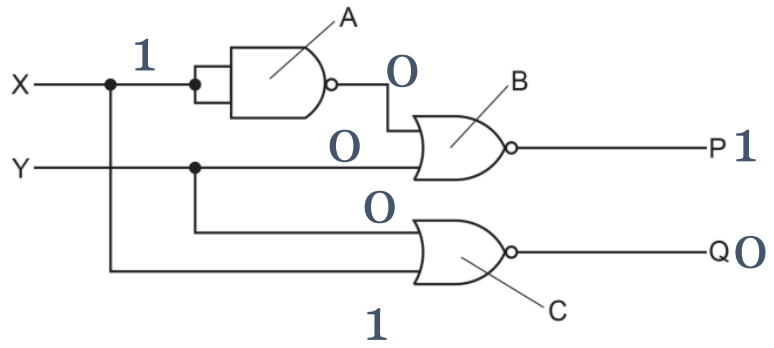
.....

..... [3]

[Total: 4]

Study question #4

An arrangement of logic gates A, B and C is shown in the diagram. The arrangement has two inputs, X and Y and two outputs P and Q.



Output P of logic gate B has logic state 1 (high).

(a) Determine the logic states of the two inputs of logic gate B.

upper input = 0

lower input = 0 [1]

(b) Determine and explain the logic state of output Q.

logic state of Q = 0

explanation Logic gate of C is NOR. The upper input is 0. Two (identical) inputs to NAND gate are ones [1], so lower input to lower NOR gate is 1 [1] [3]

[Total: 4]

Study question #5

The truth table for a logic gate is shown.

input 1	input 2	output
0	0	1
0	1	0
1	0	0
1	1	0

Which type of logic gate is it?

A AND **B** NOR **C** NOT **D** OR

[1]

[Total: 1]

Study question #5

The truth table for a logic gate is shown. B

input 1	input 2	output
0	0	1
0	1	0
1	0	0
1	1	0

Which type of logic gate is it?

A AND **B** NOR **C** NOT **D** OR

[1]

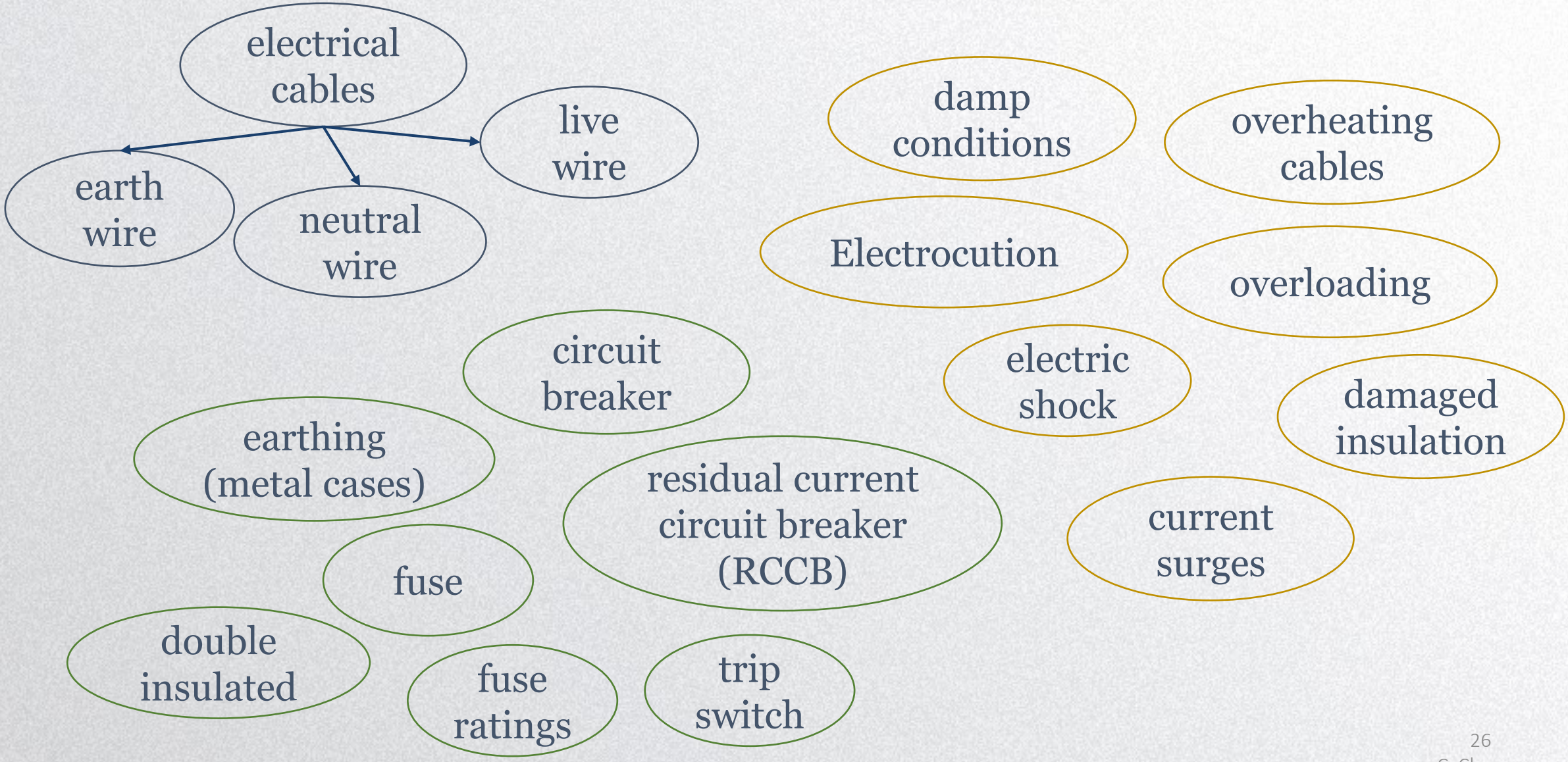
[Total: 1]

Section
4.4

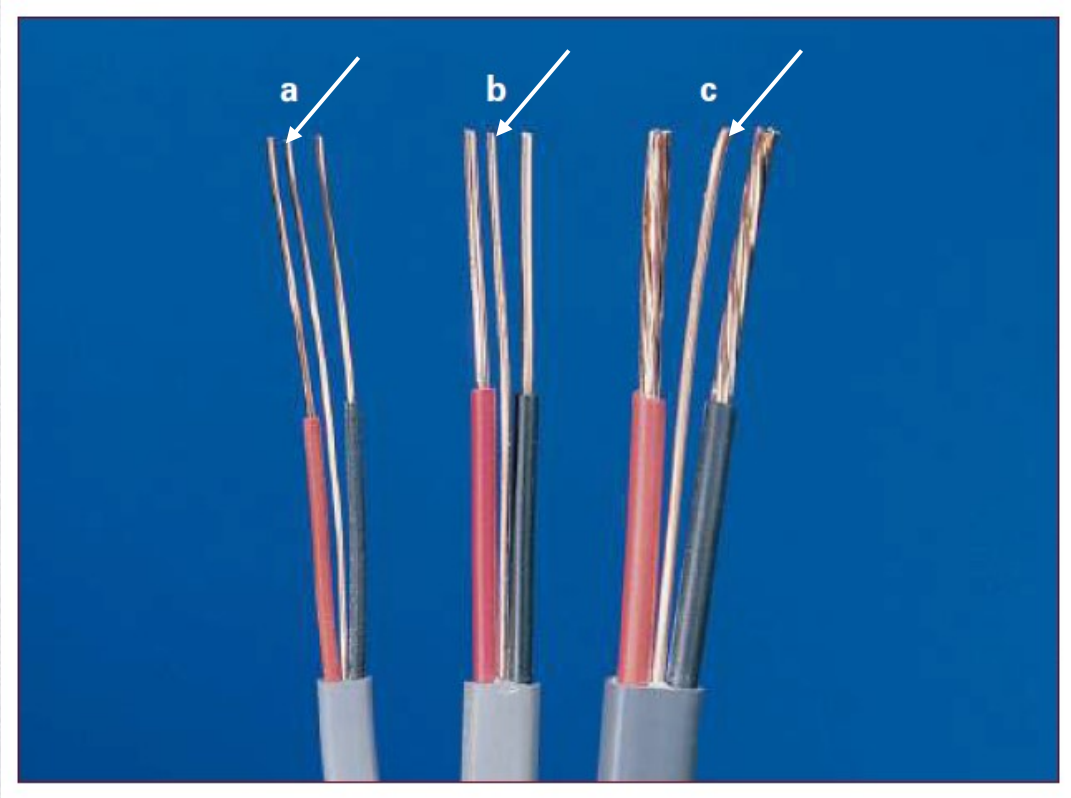
Electric circuits

4.4.1 Circuit components
4.4.2 Combinations of resistors
4.4.3 Electronic circuits
4.4.4 Electrical safety

Electrical Safety & Electrical Hazards

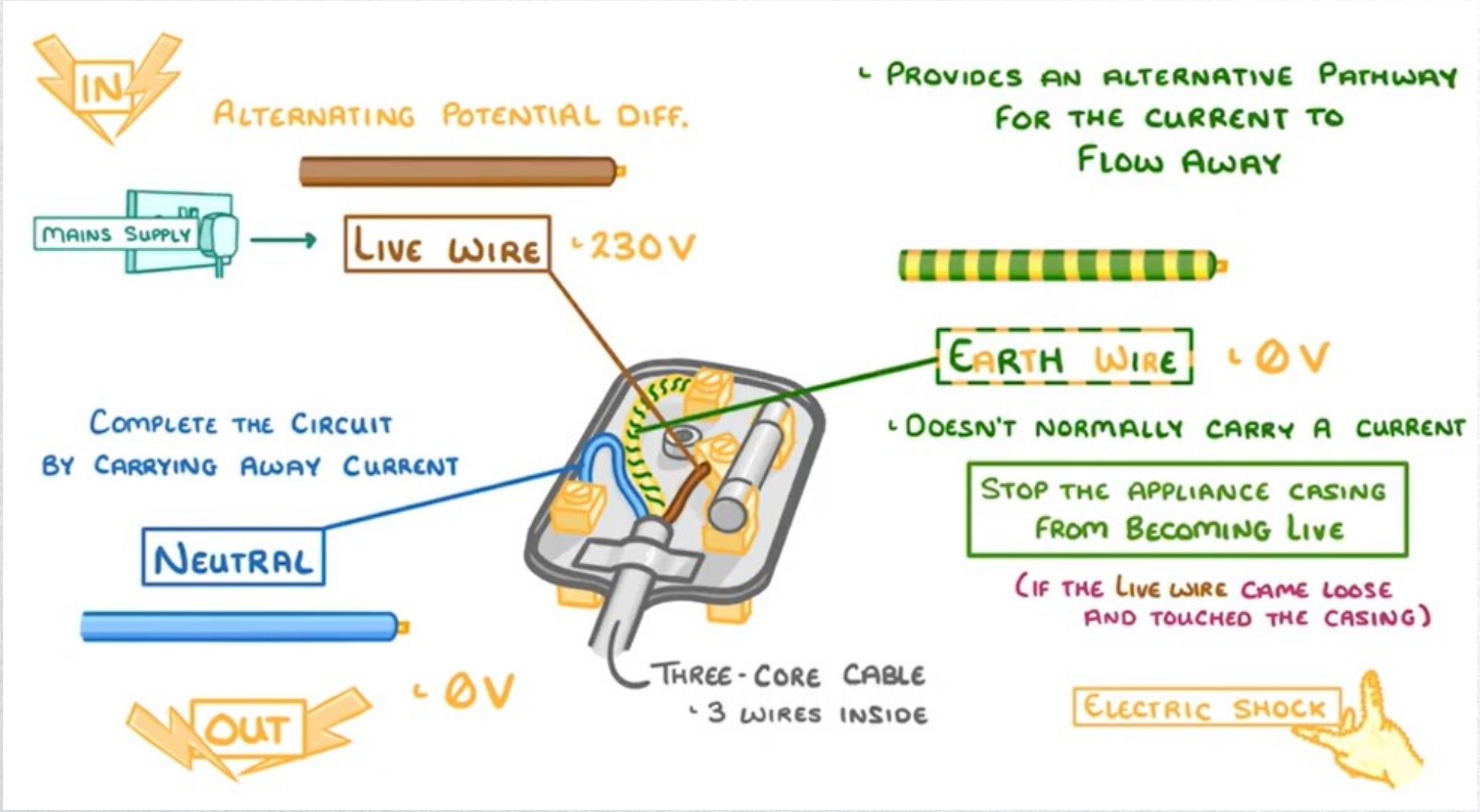


Electrical cables

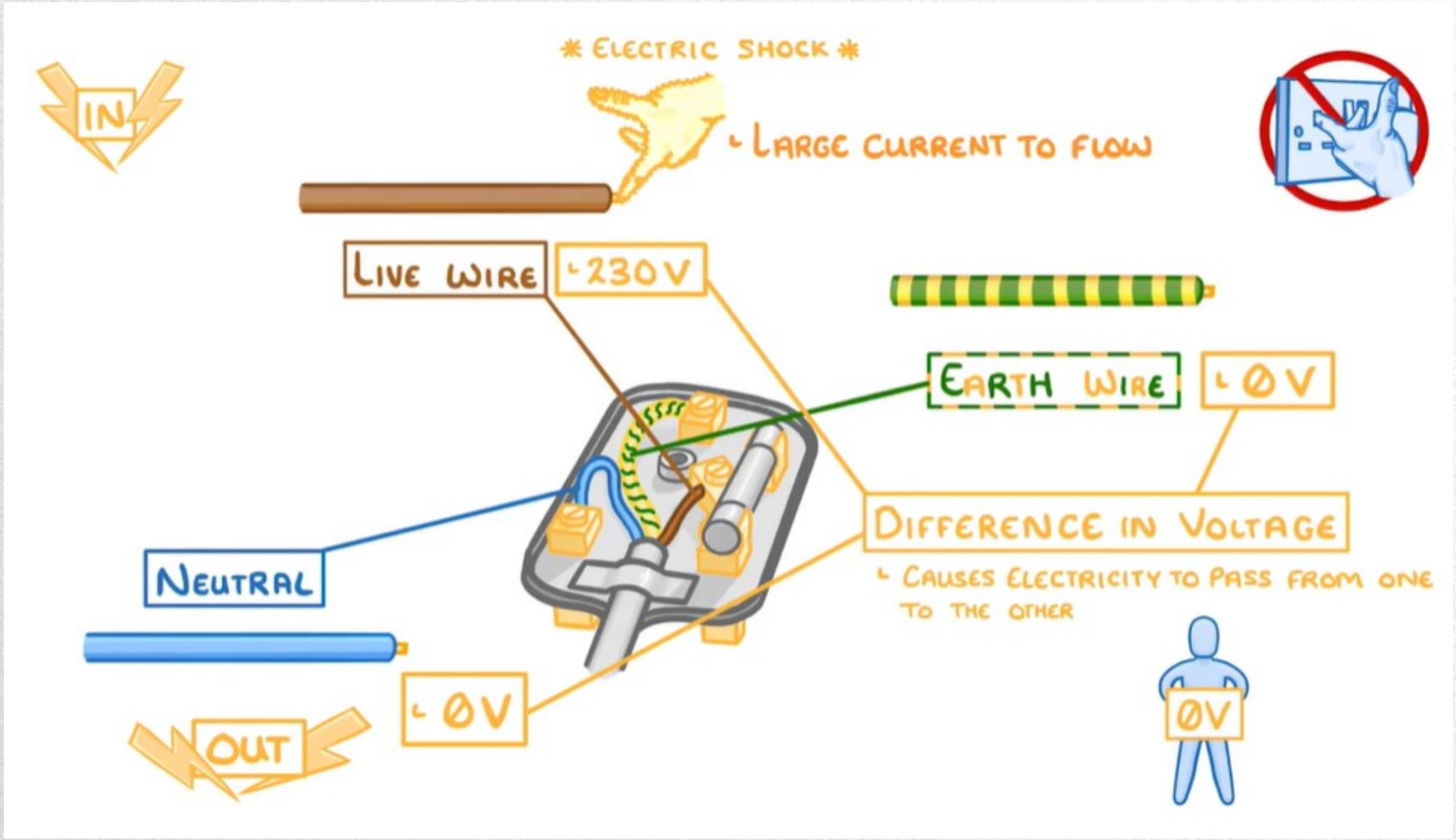


- Cables of different thicknesses are chosen according to the maximum current that they are likely to have flowing through them: a. 5 A, b. 15 A and c. 30 A.
- Each cable has live, neutral and earth wires, which are colour coded.
- In these cables, the earth wire does not have its own insulation.

Mains supply in the UK



Mains supply in the UK



Mains supply in the UK

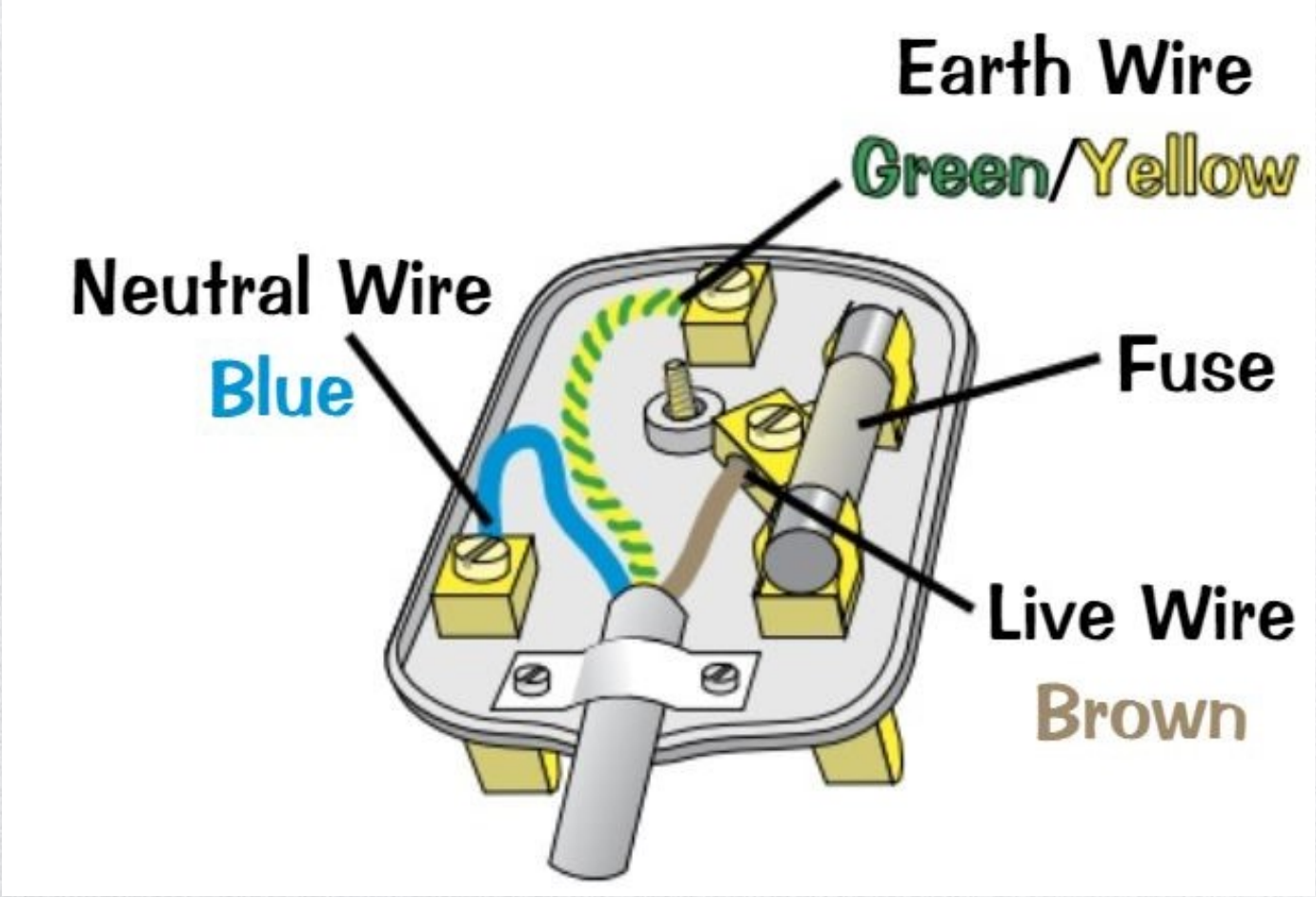
1) The UK mains electricity supply is ***230 volts***.

2) Mains supply is alternating current (a.c.), battery (or cell) supply is direct current (d.c.):

alternating current (a.c.): the current is *constantly changing* direction

direct current (d.c.): the current keeps flowing in *the same direction*

Plugs & Wires


Earth Wire
Green/Yellow
Neutral Wire
Blue
Fuse
Live Wire
Brown

Plugs & Wires

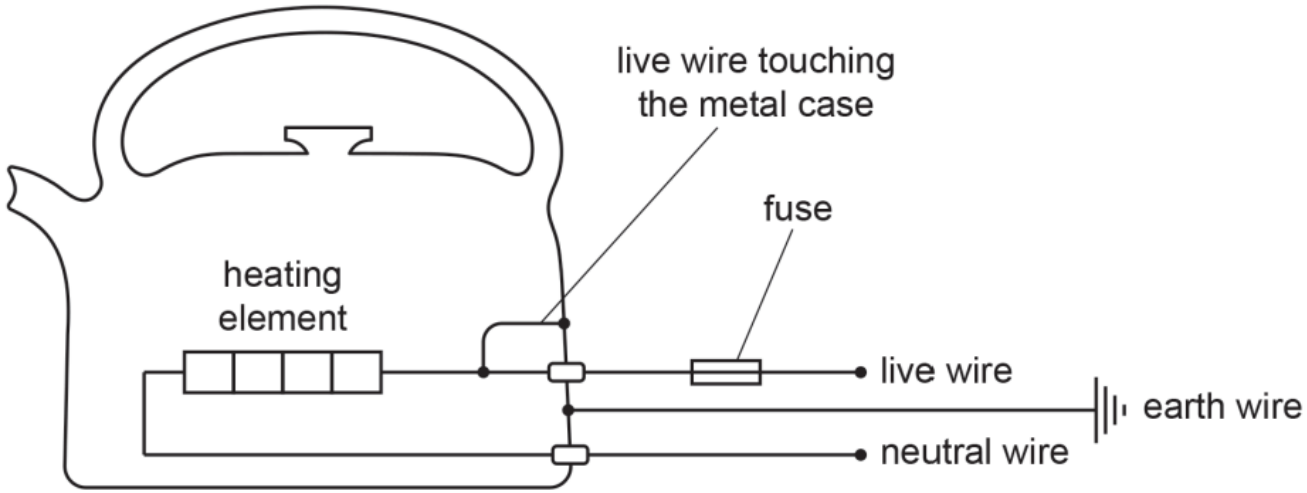
- There are 3 wires in a plug: ***live***, ***neutral***, and ***earth***.
- Only the live and neutral wires are usually needed, but if something goes wrong, the earth wire stops you from getting hurt.
- The **live wire** alternated between a high +ve and –ve voltage of about ***230*** **V** (in UK).
- The **neutral wire** is always at ***0 V***.
- Electricity normally flows in through **the live wire and the neutral wire**.
- The **earth wire** and **fuse (or circuit breaker)** are just for **safety** and work together.

Electrical Hazards

- **Damaged insulation:**
  - ✓ Electrocution can result in death.
  - ✓ All electrical wires are therefore insulated.
  - ✓ A damaged insulation can therefore be hazardous as it may result in an electricity leak.
- **Overheating cables:**
  - ✓ Overheating cables can result in the melting of the wire insulation and a consequent fire.
- **Damp conditions:**
  - ✓ Wet conditions coupled with unsafe handling of electrical appliances may lead to extremely large currents passing through the body.
- **Overloading:**
  - ✓ Excess current from overloading of plugs, extension leads, single and multiple sockets when using a mains supply

Study question #1

The diagram shows a metal kettle used for heating water. The kettle is connected to the mains power supply. The metal case is connected to earth. A fault causes the live wire to come loose and touch the metal case, as shown.



The kettle is switched on. There is a very large electric current in the live wire.

Explain why the kettle is **not** safe to use with the fuse connected into the neutral wire instead of the live wire.

.....

..... [1]

[Total: 1]

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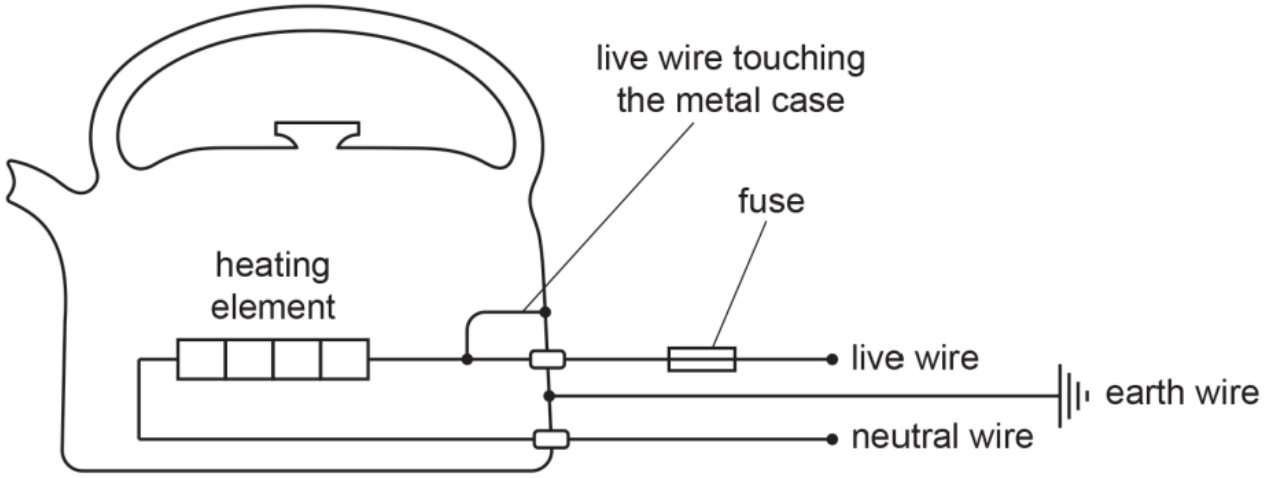


The kettle is switched on. There is a very large electric current in the live wire.

Explain why the kettle is **not** safe to use with the fuse connected into the neutral wire instead of the live wire.

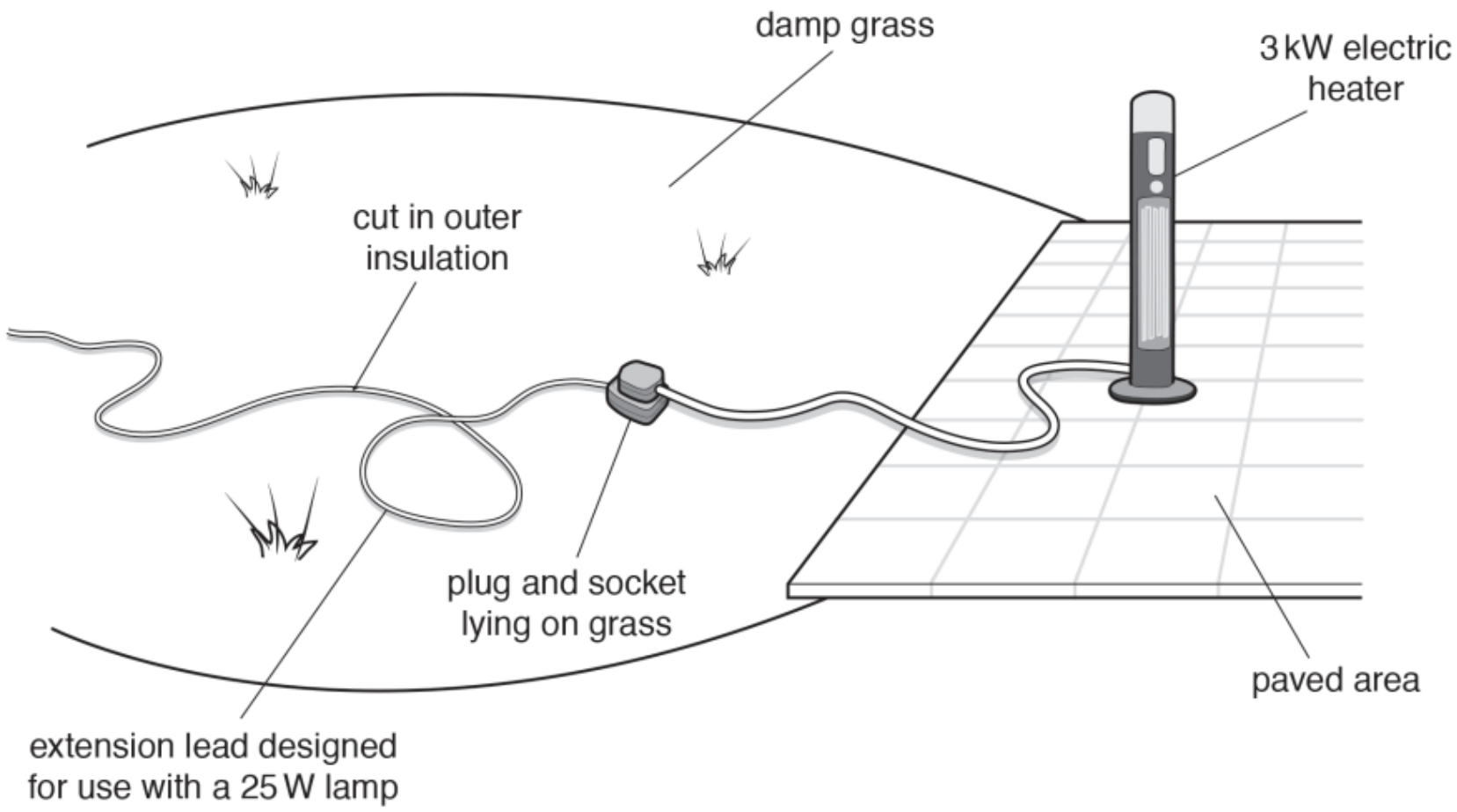
metal case would still be live OR

metal case would still be connected to 240 V (mains) when fuse has melted [1]

[Total: 1]

Study question #2

The diagram shows an extension lead used to supply power to a 3 kW electric heater on a cool evening.



Study question #2

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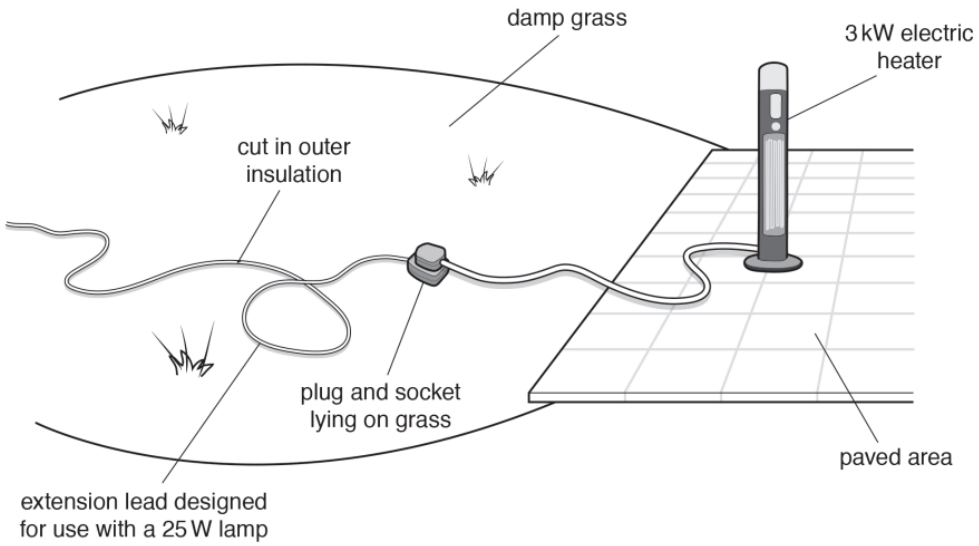


State and explain three dangers with this arrangement.

danger 1 .....

.....

.....

danger 2 .....

.....

.....

danger 3.....

.....

..... [4]

Danger 1:

High current / power; trip hazard AND cut in insulation. Plug and socket on damp grass (1)

Danger 2:

overheating / fire in extension lead (1)

Danger 3:

short circuit / shock / electrocution through cut in insulation (1)

short circuit / shock / electrocution through plug and socket on damp grass (1)

Safety Circuit Components

- **Fuse**
  - ✓ A fuse is a thin piece of wire designed to carry a set maximum electrical current
  - ✓ Current that is higher than the maximum will melt from the heat
  - ✓ When it melts, it breaks the circuit and thus stops the current flowing.
  - ✓ **Fuse ratings**: fuses have current ratings and should be rated as near as possible but just higher than the **normal operating current**.
    - ❖ To work out the fuse needed, you need to know the **current** that the item will normally use.

Safety Circuit Components (Cont'd)

- Usually, fuses are contained in cartridges, which make it easy to replace them, but some fuses use fuse wire.
- **The thicker the wire, the higher the current that is needed to make it 'blow'.** A fuse represents a weak link in the electricity supply chain.
- **Replacing a fuse** is preferable to having to rewire a whole house.

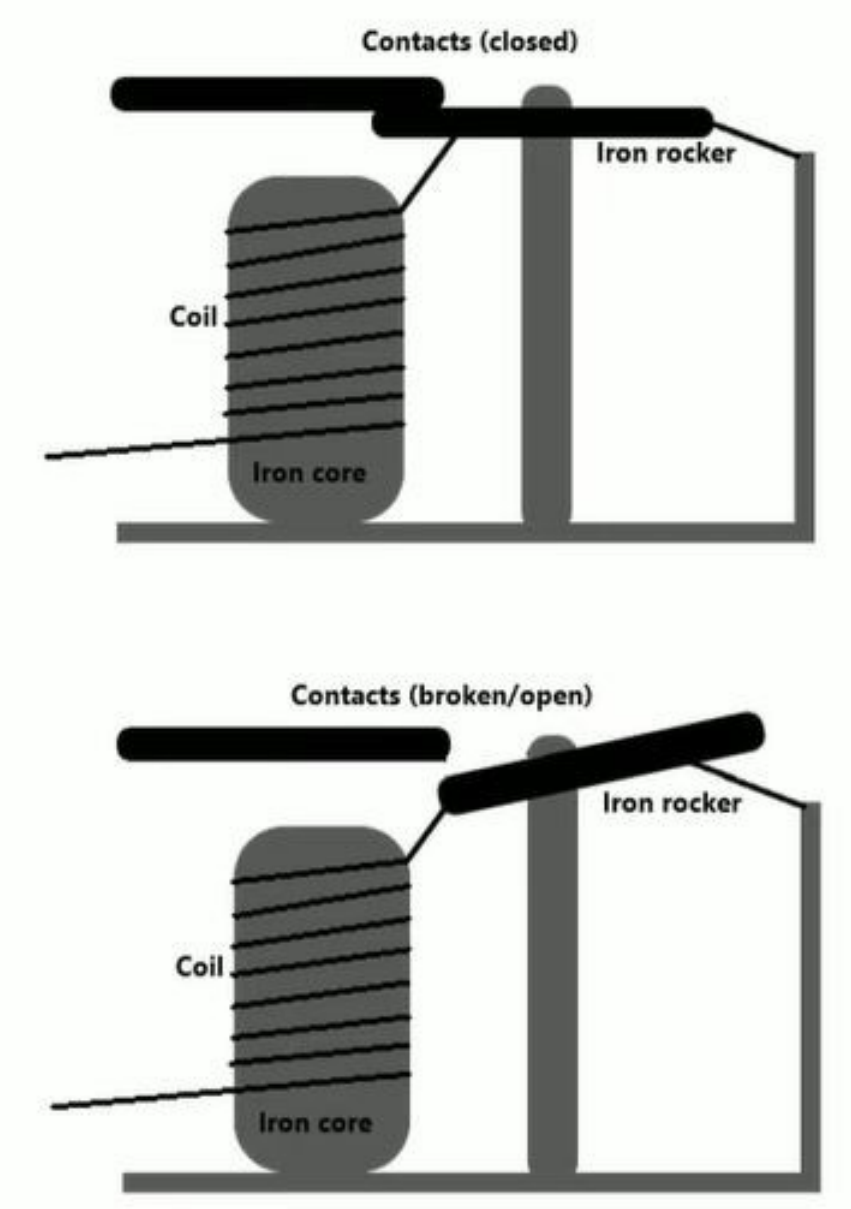
Safety Circuit Components (Cont'd)

Circuit breaker

There are two types of circuit breaker used in electrical safety, both work using electromagnets.

- A **trip switch** can replace a fuse. When the current flowing through the trip switch *exceeds a certain value*, the switch 'trips', breaking the circuit.
- A **residual-current device (RCD)** protects the user rather than an appliance or cable. *In normal circumstances, the currents flowing in the live and neutral wires are the same,* because they form part of a series circuit. *When more current is flowing in the live wire than in the neutral*, the RCD detects this and *switches off the supply*.

Safety Circuit Components (Cont'd)



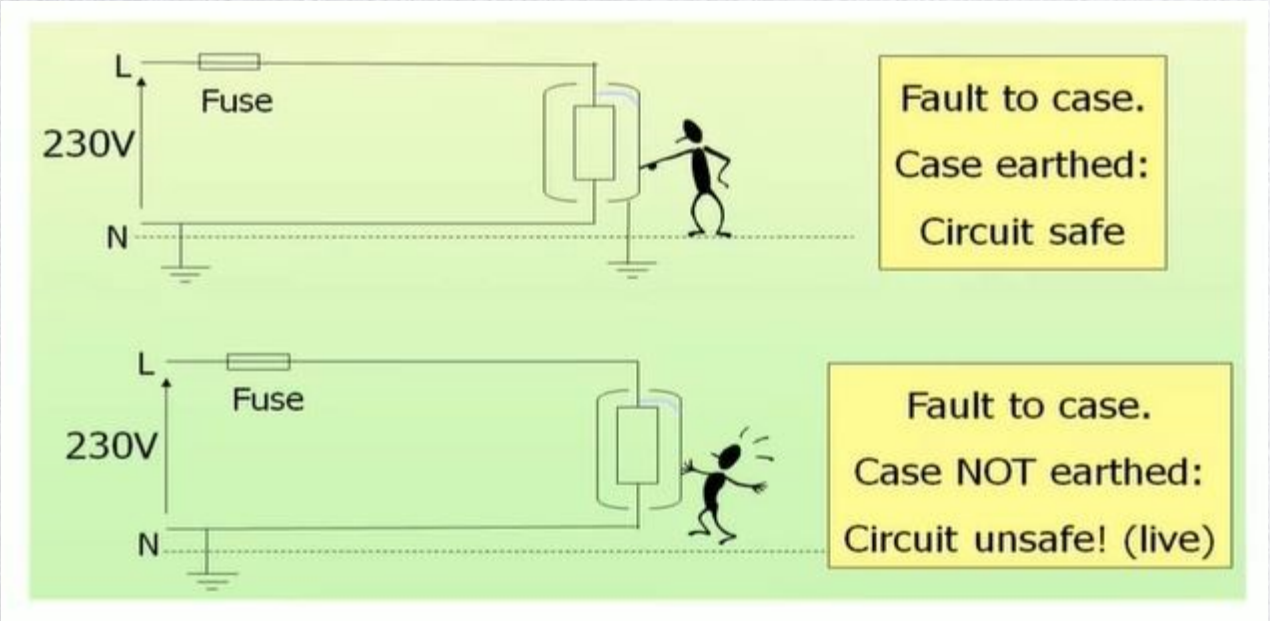
- **Circuit breaker**
  - ✓ Prevents excessive current passing through the circuit
  - ✓ It is an automated switch which interrupts current flow when abnormally high current is detected
  - ✓ A current in the coil will magnetize the iron core which attracts the iron rocker
  - ✓ The larger the current the stronger the magnetic pull
  - ✓ When the current becomes too high, the iron rocker will separate from the contacts therefore breaking the circuit

Safety Circuit Components (Cont'd)

- **Circuit breakers** have some **advantages** over fuses.

1) They **operate much faster than fuses** – they break the circuit as soon as there is a current surge – no time is wasted waiting for the current to melt a fuse. This makes them safer.
2) Circuit breakers even **work for small current changes** that might not be large enough to melt a fuse. Since even small current could be fatal, this means circuit breakers are more effective at protecting against electrocution.
3) A circuit breaker (and the circuit they're in) ***can easily be reset*** by flicking a switch on the device. This makes them more convenient than **fuses** – which have to **be replaced** once they've melted.

Earthing metal cases



- ✓ An electric shock can occur if a live wire inside an electrical appliance came loose and touched the metal casing (which is of course a conductor).
- ✓ To prevent this from happening, the earth terminal can be connected to the metal casing so that the electricity can pass through the earth instead of the human body, and therefore avoiding electrocution.

Earthing metal cases (Cont'd)

- Appliances must **be earthed** or **insulated**
- All appliances with metal cases must be "earthed" to reduce the danger of electric shock. "**Earthing**" just means the case must **be attached to an earth wire**. An earthed conductor can never become live.
- If the appliance has **a plastic casing and no metal parts** showing then it's said to be **double insulated**.
- The plastic is an insulator, so it stops a current flowing – which means you can't get a shock.
- Anything with double insulation doesn't need an earth wire – just a live and neutral.

Earthing & Fuses

- Earthing and fuses prevent fires and shocks.
- If a fault develops in which the live somehow touches the metal case, then because the case is earthed, a big current flows through the live wire, the case, and the earth wire.
- This **surge** in current "blows" (melts) the fuse (or trips the circuit breaker) which cuts off the live supply.
- This isolates the whole appliance, making it impossible to get an electric shock from the case. It also prevents the risk of fire caused by the **heating effect of a large current**.

Study question #3

A fuse is made out of a short length of wire.

Explain why fuses of a higher rating are made of thicker wire.

.....

.....

.....

.....

..... [3]

[Total: 3]

Study question #3

A fuse is made out of a short length of wire.

Explain why fuses of a higher rating are made of thicker wire.

Fuse ratings refer to current.

Resistance inversely proportional to area, so resistance of thicker wire is lower [1];

Fuse will melt at higher current [1] because heating effect = I^2 * R

OR less heating effect (for same current) [1]

[3]

[Total: 3]

Study question #4

In an electrical circuit, what is the purpose of a fuse?

A to connect the metal case of an appliance to the earth

B to cut off the electrical supply if the current is too large

C to keep an electrical appliance dry in damp conditions

D to maintain a steady voltage as the current varies

[1]

[Total: 1]

Study question #4

In an electrical circuit, what is the purpose of a fuse? ***B***

A to connect the metal case of an appliance to the earth

B to cut off the electrical supply if the current is too large

C to keep an electrical appliance dry in damp conditions

D to maintain a steady voltage as the current varies

[1]

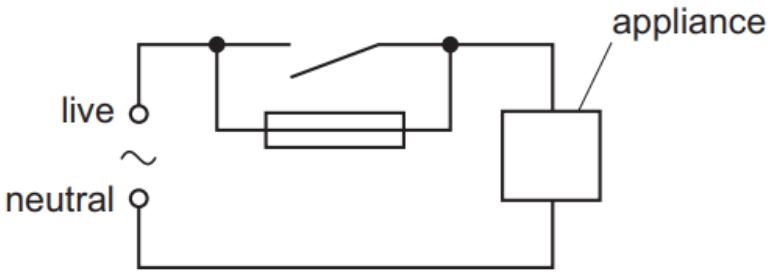
[Total: 1]

Study question #5

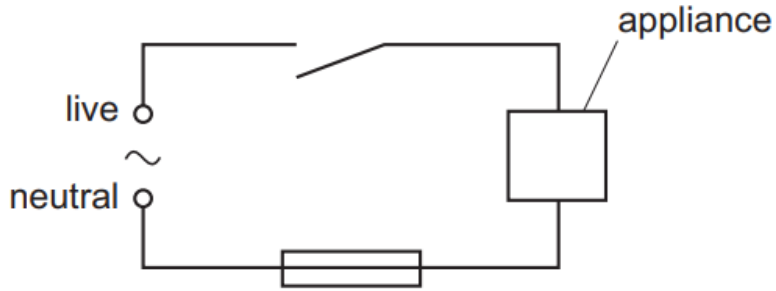
An appliance is connected to a mains supply. Its circuit also contains a switch and a fuse.

Which circuit shows the fuse in the correct position?

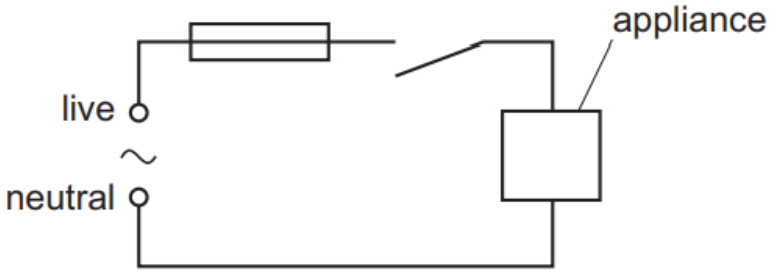
A



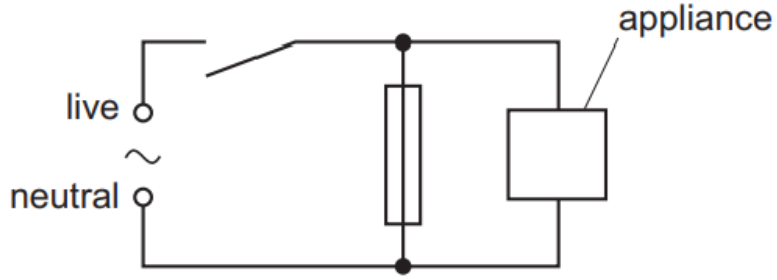
B



C



D



[1]

[Total: 1]

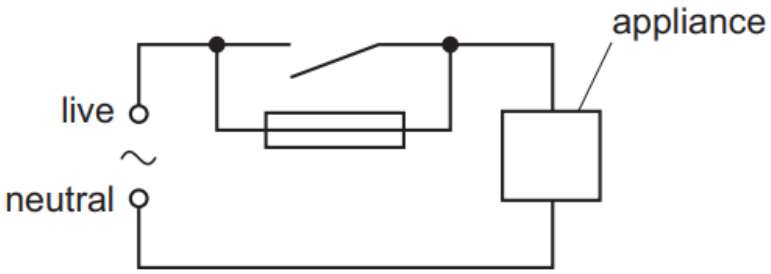
Study question #5

An appliance is connected to a mains supply. Its circuit also contains a switch and a fuse.

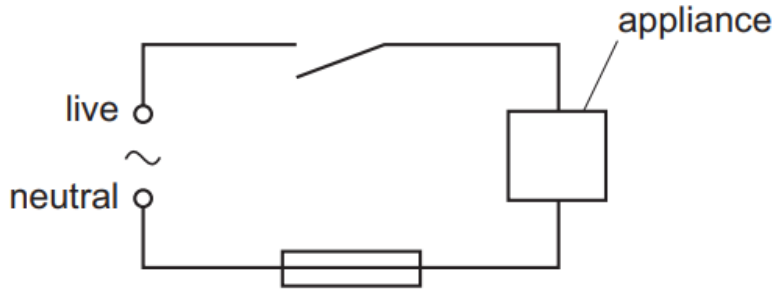
Which circuit shows the fuse in the correct position?

C

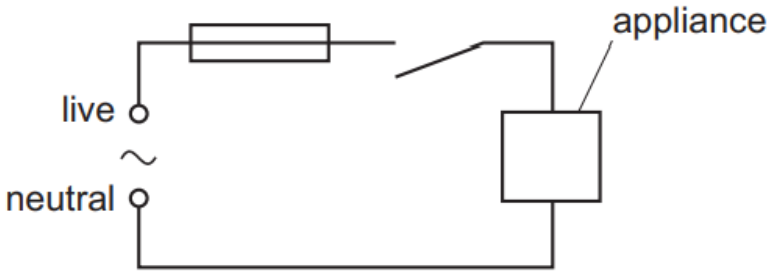
A



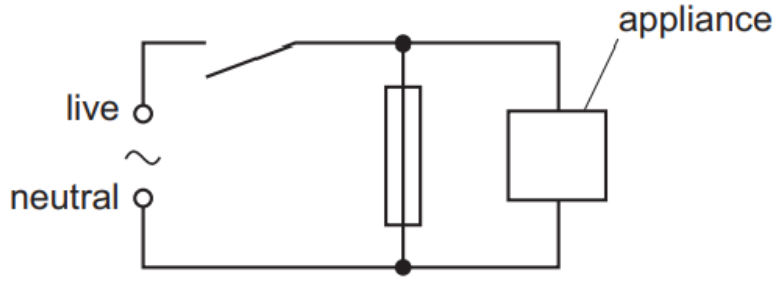
B



C



D



[1]

[Total: 1]

THANK YOU