Lesson 2 fuses and circuit breakers

Recap from last lesson

Below is a diagram of a three-pin plug. Can you answer the questions and recall the information from the last lesson? (look back to lesson 1 to double check your answers)

1. What is the potential difference of the live wire?
2. What is the potential difference of the earth wire?
3. What is the potential difference of the neutral wire?
4. What does the live wire do?
5. What does the earth wire do?
6. What does the neutral wire do?
7. Why is the casing of the plug plastic?
8. What material is the inside of the wire made of? Why?



Fuses

The circuit symbol for a fuse.

To reduce the risk of fires and electric shocks, fuses are used in circuits. Small fuses are placed inside most electrical appliances in the UK, and larger ones are used in fuseboxes to protect household circuits.

**Remember:**

When a current flows through a wire, the wire heats up due to the free electrons colliding with the ions that make up the lattice. These collisions transfer energy from the electrons to the ions, making the ions vibrate and causing the wire to heat up.

Fuses contain a thin piece of wire. When a current flows through the wire, the wire heats up. If the current increases beyond a certain point (called the fuse rating), the wire gets too hot and melts. The fuse ‘blows’, the circuit is broken and the electricity cannot flow.

Fuses should be rated slightly above, but as near as possible to their operating current. The larger the current, the thicker the cable you need to carry it (to stop the cable getting too hot and melting). So the fuse rating for cables usually increases with cable thickness.

Videos

This video shows fuses melting as too much current flows. If you skip to 0.56 seconds, this fuse is the easiest to see. <https://www.youtube.com/watch?v=GVLzf0CTCMY&t=38s>

Example 1

An electrician has a 3A, a 5A and a 10A fuse.

He is replacing a broken fuse in an appliance.

The current flowing through the appliance is 4.34A.

Determine the fuse that the electrician should use in this appliance.

**If the electrician chose the 3A fuse,** every time the appliance was switched on, 4.34A would attempt to flow through the fuse. The current is much higher than that of the fuse and so the fuse would get too hot and melt.

**If the electrician chose the 5A fuse,** every time the appliance was switched on, 4.34A would attempt to flow through the fuse. Because the fuse rating is higher than the appliance current, the current would be able to flow. This fuse rating is also very close to the 4.34A rating of the appliance. This means that if there is a fault with the appliance and too much current would flow, the fuse would then get too hot and melt.

**If the electrician chose the 10A fuse,** every time the appliance was switched on, 4.34A would attempt to flow through the fuse. Because the fuse rating is higher than the appliance current, the current would be able to flow. If there was a fault with the appliance and too much current was flowing, the fuse would not melt and break the circuit because the value of the fuse is so much higher than the appliance. This could potentially cause a fire. Choosing a fuse that is much higher than the appliance rating makes an appliance unsafe.

Example 2

An electrician has three fuses, of rating 3A, 5A and 10A.

The electrician is replacing a broken fuse in an appliance.

The appliance has a power rating of 650W and it is plugged into mains supply, at 230V.

Determine the fuse that should be used in the appliance.

We first must find the current of the appliance, using the power and voltage given.

P = 650W

V = 230V

P = I x V

I = P ÷ V

I = 650 ÷ 230 = 2.82A

We now must choose between the 3A, 5A and 10A fuse for this 2.82A appliance.

The 3A fuse is the best for this appliance because it is greater than the appliance current rating, so will allow the current to flow to the appliance without melting and breaking. If the 5A or 10A fuse was chosen, this would again allow current to flow to the appliance however, if there was a fault, the fuse would not melt and break and would be dangerous.

Circuit Breakers

Instead of melting a household fuse, a large current may instead ‘trip’ (turn off) a circuit breaker. Circuit breakers are great because they turn off quicker than the time taken for a fuse to melt if there’s a current surge. They can also be reset, which is much easier than having to replace a fuse. However, circuit breakers are expensive than fuses.

Questions

*Show all your working for the first 4 questions. For question 5, consider starting by bullet pointing what you know then writing the information together as one answer.*

1. I have an appliance with a current of 4A. which of the following fuses should be used?
	1. 3A
	2. 5A
	3. 10A
2. My kettle has a power rating of 2600W and I connect it to UK mains, which is at 230V. which of the following fuses should be used?
	1. 3A
	2. 5A
	3. 10A
	4. 13A
3. My toaster has a power rating of 800W and I connect it to UK mains, which is at 230V. which of the following fuses should be used?
	1. 3A
	2. 5A
	3. 10A
4. My kettle has a power rating of 1800W and I connect it to UK mains supply, which is at 230V. Which of the following fuses should be used?
	1. 3A
	2. 5A
	3. 10A
5. A kettle with a metal casing is linked to the mains electricity using a three-core cable. The three-core cable has a live wire, an earth wire and neutral wire inside it. The kettle’s cable is frayed, and the live wire is exposed so that it touches the metal casing. Explain how this could cause a fire and how a fuse can be used to reduce this risk. [6 marks]
6. Name an advantage of using circuit breakers rather than fuses to make electronic circuits safer.

Answers

1. I have an appliance with a current of 4A. which of the following fuses should be used

A 5A should be used. This will allow current to flow without melting the fuse however if too much current flows, the fuse will melt and prevent a fire.

1. My kettle has a power rating of 2600W and I connect it to UK mains, which is at 230V. which of the following fuses should be used?

P = 2600W

V = 230V

P = I x V

I = P ÷ V

I = 2600 ÷ 230 = 11.3A

A 13A fuse should be used. This will allow the current to flow without melting the fuse however if too much current flows, the fuse will melt and prevent a fire.

1. My toaster has a power rating of 800W and I connect it to UK mains, which is at 230V. which of the following fuses should be used?

P = 800W

V = 230V

P = I x V

I = P ÷ V

I = 800 ÷ 230 = 3.47A

A 5A fuse should be used. This will allow the current to flow without melting the fuse however if too much current flows, the fuse will melt and prevent a fire.

1. My kettle has a power rating of 1800W and I connect it to UK mains supply, which is at 230V. Which of the following fuses should be used?

P = 1800W

V = 230V

P = I x V

I = P ÷ V

I = 1800 ÷ 230 = 7.83A

A 10A fuse should be used. This will allow the current to flow without melting the fuse however if too much current flows, the fuse will melt and prevent a fire.

1. A kettle with a metal casing is linked to the mains electricity using a three-core cable. The three-core cable has a live wire, an earth wire and neutral wire inside it. The kettle’s cable is frayed, and the live wire is exposed so that it touches the metal casing. Explain how this could cause a fire and how a fuse can be used to reduce this risk.
* The fault allows current to flow through the case of the kettle.
* The earth wire is connected to the metal case, so a current flows through the earth wire.
* This causes a large current to flow, because the resistance of the earth wire is low.
* When a current flows through a wire, it causes the live wire to heat up as work is done against electrical resistance.
* The larger the current, the more the live wire heats up.
* This heating may lead to a fire if it is not stopped.
* Fuses melt when the current through them exceeds their rating.
* The larger the current through the kettle would cause the fuse to melt.
* This breaks the circuit and tops the current from reaching the kettle.
* This stops the heating effect and prevents a fire from starting.
1. Name an advantage of using circuit breakers rather than fuses to make electronic circuits safer.
* Circuit breakers turn off quicker than the time taken for a fuse to melt if there’s a current surge
* Circuit breakers can be reset, which is much easier than having to replace a fuse