**A working fuse**

In the UK, electric plugs contain a fuse on the **live wire**.

If current is dangerously big, a fuse melts and turns off the electricity.

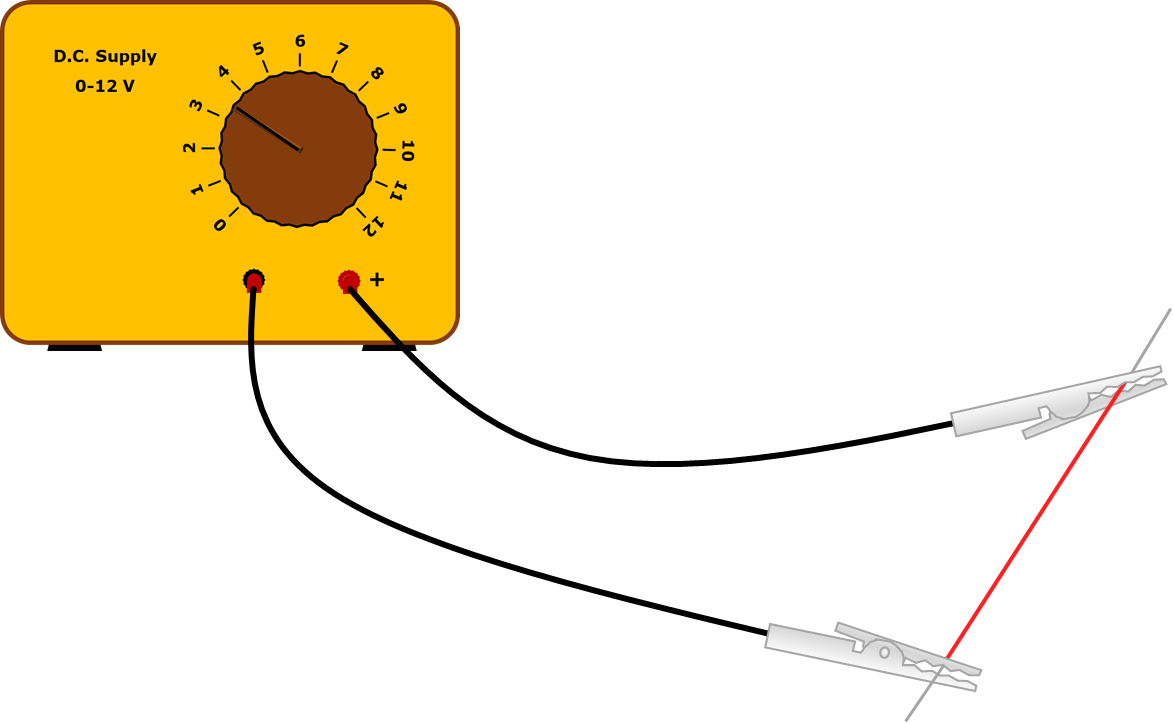
This helps prevent fire and further damage to an appliance.



Fuses turn off appliances to make them safe.

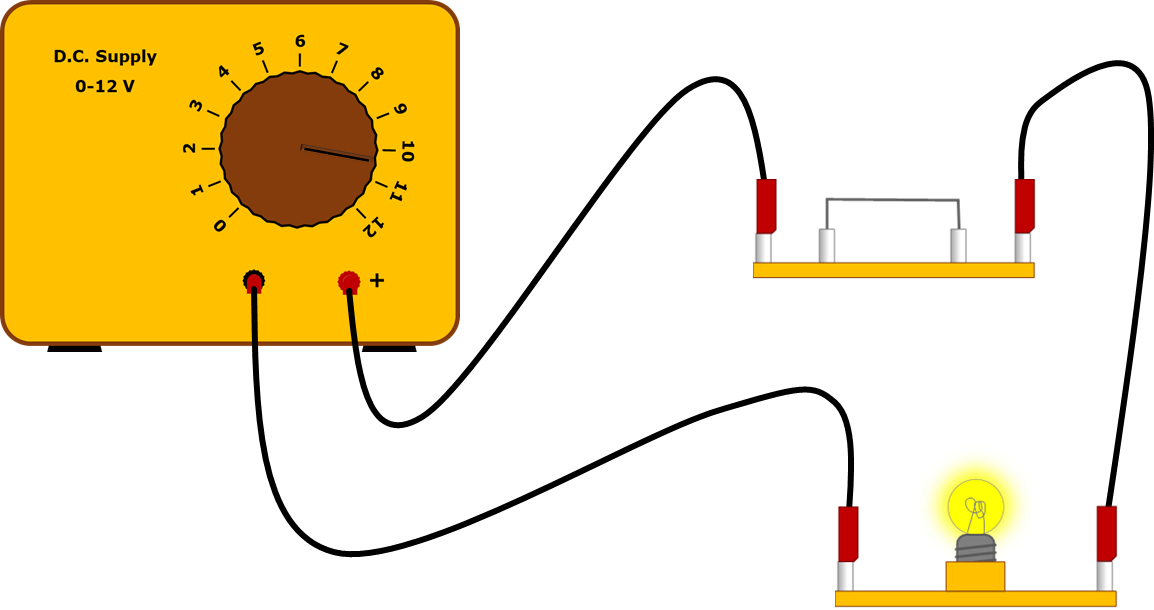
Fuses **do not prevent electric shocks** if a wire is cut by mistake (perhaps with a lawn mower or hedge cutter).

**1.** Effect of excessive current.



**To answer:** What happens to a piece of paper placed against the hot wire?

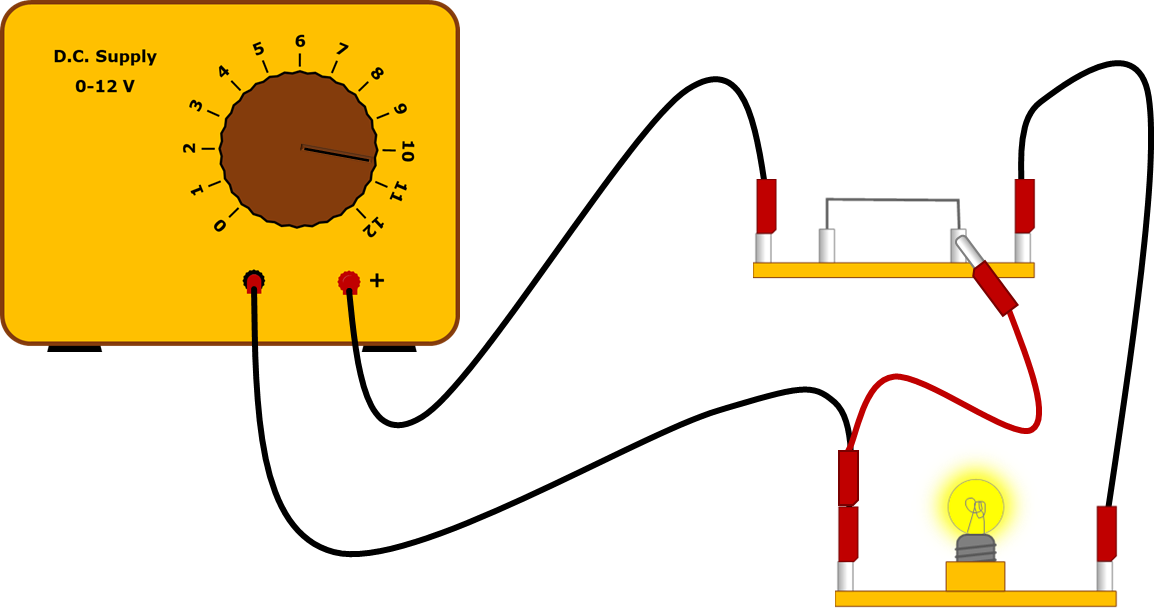
**2.** A fuse in a circuit.



Short length of fuse wire

This circuit is working normally.

**To answer:** What happens if the red wire makes a **short circuit**?



red wire

Short circuits are often caused by pulling on mains leads.

A wire can become loose and move inside a plug or appliance.

*Physics > Big idea PEM: Electricity and magnetism > Topic PEM8: Mains electricity > Key concept PEM8.1: Electrical safety*

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| **Response activity** |
| **A working fuse** |

**Overview**

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| Learning focus: | Fuses, circuit breakers and earth connections, used correctly, can prevent excess mains current and electric shocks. |
| Observable learning outcome: | Explain the effects of a short circuit in an appliance or in a mains circuit. |
| Activity type: | Clarifying - demonstration |
| Key words: | Short circuit, fuse, excessive current |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic questions:

* Diagnostic question: Consumer unit
* Diagnostic question: Mains electricity
* Diagnostic question: Short circuit

**What does the research say?**

In a study of 41 pre-service teachers, Önder, Senyigit and Silay (2017) found that 69% could not explain a short circuit using scientific understanding. 20% described a short circuit as a circuit that did not work, a further 15% that it didn’t work because components had been damaged by excess current, and 12% described a short circuit as an incomplete circuit. Rather, a short circuit is formed by an extra connection between parts of a circuit that provides a very low resistance path for current to flow, leading to increased current in that part of the circuit.

It is a common misunderstanding that if the plug connecting an appliance to the mains contains a fuse, then the appliance cannot give a person an electric shock (Goodenough, 2007). This is not true because a current of 0.15 A through a person can kill them in about 0.1 s and the smallest fuse in a mains plug (in the UK) stops current flowing only when it exceeds 3 A.

A residual current circuit breaker (RCCB) would stop current flowing through the person being shocked in about 0.04 seconds. Without a RCCB fitted, a person touching an exposed live connection from the mains could receive a fatal electric shock, which is why electric lawnmowers and hedge-trimmers should always be used with a RCCB, because accidentally cutting trailing wires is relatively common.

However, a fuse can turn off the current *before* a person touches the live metal casing of a faulty appliance, if the appliance is wired correctly. Common causes of a metal casing becoming live is a movement and pulling on connecting cables that cause the live wire to become loose, or physical damage to the appliance. The casing of a metal appliance should be connected to an earth wire. If the live wire touches the casing there will then be a short circuit, a large current will flow, and the fuse will melt, turning off the current. This happens the first time the appliance is turned on after the fault is caused. Some demonstrations, of how a fuse works, risk giving the false impression that excess current only flows and the fuse makes the appliance safe when it is touched by a person (Harrison, 2017).

**Ways to use this activity**

This demonstration gives you the opportunity to re-teach a challenging concept, and show your students how it builds up from simpler ideas, using a structured teacher-led discussion.

You should use carefully selected questions to check your students’ understanding of each step, before progressing onto the next one.

The steps you follow in this demonstration might be:

* Show the class a selection of fuses and discuss their similarities and differences.
* **Set up circuit 1** with the resistance wire on a heat resistant mat.
* With the electrical supply voltage initially set to zero, slowly increase the current through the resistance wire until it becomes red hot.
* Show the class how the wire can burn a trail through a piece of paper, perhaps setting it alight.
* **Set up circuit 2** with a short length of fuse wire – the wire selected so that a 12V bulb lights up brightly.
* Add a red wire and show what happens if it creates a short circuit.
* Focus attention on the fuse wire melting, breaking the circuit and turning off the bulb.
* Perhaps note that it takes a fraction (a significant fraction) of a second for the fuse to melt, during which time current continues to flow.
* Note that for the bulb to work again, the loose wire must be fixed and a new fuse fitted.

*Differentiation*

You could challenge different individuals by asking them follow-up questions to clarify or to extend their original answer. If a student is having difficulty with a particular question, it is often helpful to break it into smaller *chunks*, to lead them to a fuller answer. This technique models more thorough answers, and can be used to support an open classroom culture in which students are encouraged to ‘have a go’.

**Equipment**

For the demonstration:

Electrical supply

12V bulb in a holder

Component holder

x2 crocodile clips

Connecting leads

Length of constantan wire

A sheet of paper

Scissors

Heat resistant mat

**Technician notes**

The component holder should have two crocodile clip connections in which to clamp a short length of constantan wire.

The gauge and length of constantan wire should be chosen so that it glows red hot in circuit 1, allows current to flow to light the bulb in circuit 2 but melts when there is a short circuit. Appropriate lengths and voltages should be tested in advance and written down for the demonstrator to refer to.

**Health and safety**

* Constantan wire glows red hot and can burn. It can be hot enough to burn when it is not red hot.
* The crocodile clips attached to the wire can become hot enough to cause a burn.
* The paper used may burst into flames.

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Expected answers**

**Circuit 1**

With excessive current, a short length of constantan wire will burn through a piece of paper – the paper may be set alight.

**Circuit 2**

A large current flows through the fuse because there is less resistance along this route; the bulb goes out; the fuse wire melts; the circuit is broken and no electricity flows at all.

It takes a moment for the fuse to melt, during which time excessive current is flowing around the circuit.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Image of fuses from Shutterstock, other images by Peter Fairhurst (UYSEG).

**References**

Goodenough, H. (2007). Electrical safety. *Catalyst.* Oxfordshire: Philip Allan Updates.

Harrison, M. (2017). Demonstrating Earth connections and fuses working together. *Physics Education,* 52(2)**,** 023008.

Önder, F., Senyigit, Ç. and Silay, I. (2017). The Effects of Misconceptions on Pre-Service Teachers' Ability to Constructing Simple Electric Circuits. *European Journal of Physics Education,* 8(1)**,** 1-10.