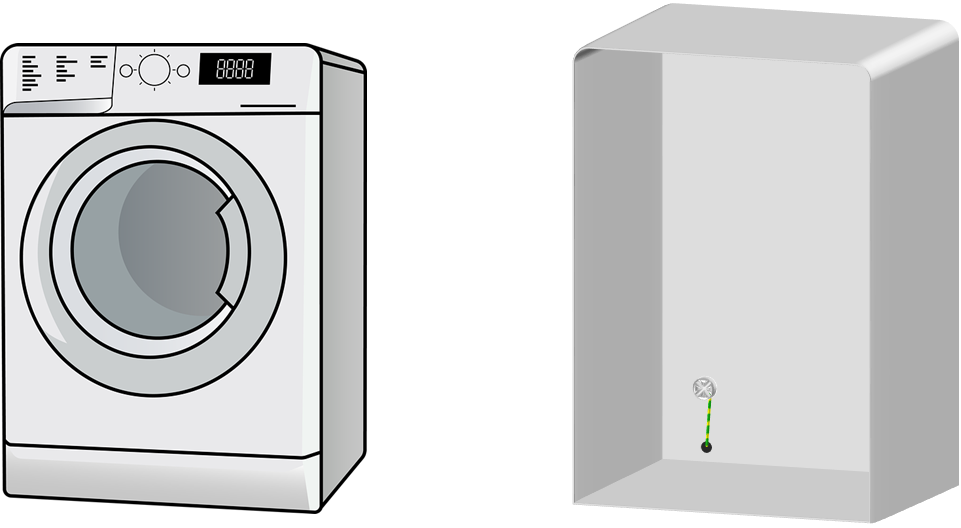
**Earthing**

The case of this washing machine is made of metal.

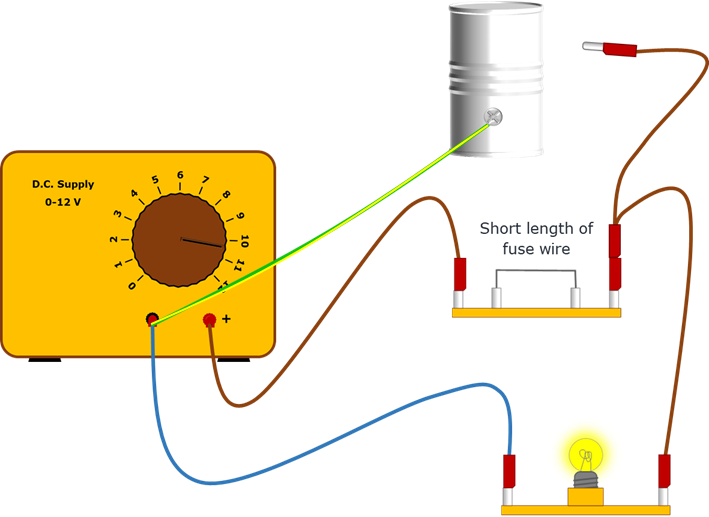
An earth wire is screwed onto the inside of the metal case.



The earth wire completes a circuit **only** if a live wire touches the metal case.

This is a model of the circuit connected to the washing machine.

The tin can represents the metal case of the washing machine.

****

*An earth wire is coloured green and yellow.*

**Predict**

What will happen if the loose wire touches the metal case?

**Explain**

Why do you think this will happen?

|  |
| --- |
| **Observe what happens when the loose wire touches the metal case.** |

**Observe**

What happens?

**Explain**

1. Were your prediction and explanation correct?

Try to improve your first explanation to explain what happens more clearly.

2. What would happen if there was no earth wire when the loose wire touches?

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

|  |
| --- |
| **Response activity** |
| **Earthing** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Fuses, circuit breakers and earth connections, used correctly, can prevent excess mains current and electric shocks. |
| Observable learning outcome: | Explain how earth wires can protect people from electric shock. |
| Activity type: | Predict, explain; observe, explain (PEOE) |
| Key words: | Metal case, short circuit, earth wire, fuse |

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

* Diagnostic question: Metal case

**What does the research say?**

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 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**

Students should complete this activity in pairs or small groups, and the focus should be on the discussions. It is through the discussions that students can check their understanding and rehearse their explanations.

To begin, each group should discuss the activity and use their scientific understanding, firstly to predict *what* they think will happen, and then to explain *why* they think they are going to be right. If students in any group cannot agree, you may be able to direct them with some careful questioning.

Students now watch a demonstration.

After the practical each group should be given the opportunity to change, or improve their explanation. A good way to review your students’ thinking might be through a structured class discussion. You could ask several groups for their *explanations* and put these on the whiteboard. Then ask other groups to suggest which explanation is the most accurate and the most clearly expressed, and through careful questioning work up a clear ‘class explanation’.

A useful follow up is for individual students to then write down explanations in their own words – without reference to the class explanation on the board (i.e. cover it up).

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in each group. For example, you may choose to select a student with strong prior knowledge as a scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

**Equipment**

For the demonstration:

* Electrical supply
* 12V bulb in a holder
* Component holder
* Length of constantan wire
* Tin can (empty)
* Connecting leads

**Technician notes**

The component holder needs to be able to hold a short length of constantan wire. The constantan wire should be thick enough to enable a 12 V bulb to light brightly, and thin enough to melt quickly when the loose lead completes a circuit by making contact with the tin can.

Colours of the wires shown in the diagram are indicative of the colours of wires found in mains electrical circuits. If possible, replicate these colours – perhaps using lengths of stripped down mains cable.

The earth wire needs to be connected to the tin can so that it forms a conducting connection. A nut, bolt and washer through a drilled hole works well.

**Health and safety**

The fuse wire is red hot as it melts.

A short circuit made without a fuse wire will cause the wires in that circuit to heat up and trip the circuit breaker (or melt the fuse) in the electrical supply.

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**

1. The fuse melts and the bulb goes out.

This happens immediately that the loose wire touches the can and completes a circuit through the earth wire, which enables a very large current to flow through the short circuit. The large current melts the fuse. As soon as the fuse melts, the electric circuit to the ‘washing machine’ is turned off, the ‘washing machine’ stops working and its metal case does not have a live connection. Anyone touching the metal case now will not get an electric shock.

2. The bulb does not go out and anyone touching the metal case could get an electric shock.

The live wire touches the metal case and does not complete a circuit because there is no earth wire. Anyone touching the metal case now may complete a circuit if they are connected to earth (perhaps they have bare feet, or are touching something like a water tap that is connected to earth). Completing a circuit would give a person an electric shock.

**Guidance notes:**

*Why is the live wire more dangerous than the neutral wire when they are opposite ends of the mains circuit?*

There is a common misunderstanding that a battery contains ‘electricity’ and that when current flows around a circuit the electricity flows from the battery.

In science teaching for ages 14-16, it is rarely explained clearly why a fuse needs to be placed on the live wire and not on the neutral wire; and it is a small leap for students into misunderstanding that all of the electricity flows from the National Grid and into the house through live wires and out again through the neutral – when most of it has been used up (sic).

To support the correct explanation, the live wire can be thought of as one end of a ‘mains battery’ whose voltage (more accurately potential) varies between +230 V and -230 V. The neutral wire can be thought of as the other end of the ‘mains battery’ which has a voltage (potential) close to 0 V, which is pretty much the same as the ground (earth). A current will flow round a complete circuit made between a live wire and a neutral wire or between a live wire and the ground because there is a potential difference across it. If a complete circuit is connected between the neutral wire and the ground, there is only a very small potential difference between the connections and any current will be very small.

In other words, completing a circuit between the neutral wire and the ground can be thought of as connecting both ends of the circuit to the same end of a high voltage battery. This means that it is quite safe for a person to be connected between a neutral wire and the ground, but not between a live wire and the ground – although it should be noted that neither should be attempted (it is not completely unknown for live and neutral wires to have been connected the wrong way round).

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: washing machine by Lerele from Pixabay, 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.