**Rope power**

A group of students want to model the power of an electric circuit.

They use a loop of rope.

‘bulb’

‘electric charge’

‘battery’

**To answer**

1. How could they use the model to show how energy is transferred by an electric circuit?

1. How could they use the model to show the effect of increasing current on the power of a circuit?

1. How could they use the model to show the effect of increasing p.d. on the power of a circuit?

*Physics > Big idea PEM: Electricity and magnetism > Topic PEM8: Mains electricity > Key concept PEM8.2: Paying for electricity*

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| **Response activity** |
| **Rope power** |

**Overview**

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| Learning focus: | The amount of energy that an electrical appliance transfers is proportional to time; and its power is proportional to the potential difference across it *and* the current through it. |
| Observable learning outcome: | Describe how the power of an electric circuit depends on current through it.Explain why the power of a component depends on the potential difference across it. |
| Activity type: | Clarifying - demonstration |
| Key words: | Power, energy, potential difference, current |

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

* Diagnostic question: Power and current
* Diagnostic question: Power and p.d.

**What does the research say?**

Novice learners typically lack a scientific understanding of how a circuit works and rely on memorising equations and procedures. They may be able to solve routine circuit calculations correctly, but often cannot predict or explain the behaviour of a circuit (Liu et al., 2022).

Some common misunderstandings that students may continue to hold, which are relevant to understanding how electrical power is proportional to current, are:

* that most students do not discriminate sufficiently between current, voltage, energy and power (Gott, 1984; Shipstone, 1985; Driver et al., 1994; Engelhardt and Beichner, 2004)
* the amount of current provided by a battery is always the same no matter what circuit it is connected to (Driver et al., 1994; Engelhardt and Beichner, 2004)
* a circuit can be analysed sequentially moving around a circuit in one direction, so changes to components ‘further around a circuit’ do not affect earlier parts of the circuit (Driver et al., 1994; Stocklmayer and Treagust, 1996; Duit and von Rhoneck, 1997)
* and a bulb or appliance gets the energy ‘it demands’ regardless of the potential difference of the source (van den Berg and Grosheide, 1997).

A useful bridge between addressing common misunderstandings and developing understanding of energy and power in an electric circuit, in relation to current and potential difference, is the rope-loop analogy used in earlier BEST key concepts: *PEM1.2 Electric current* and *PEM1.3 Voltage*. This model can be used to: review ideas of current, charge and potential difference in simple circuits; to introduce ideas of energy shifting from a ‘battery’ to a ‘bulb’; and to reason about the effects on energy transfer caused by changing currents, resistances or potential differences (DCFS, 2008).

**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:

* Introduce the rope model to the class:

For the rope model, a group of four to six students stand in a circle and each holds out both hands, palms upwards. A continuous loop of rope (or string) passes from person to person, right around the circle. One student now acts as a ‘battery’, making the rope move slowly round, passing over everyone’s hands as it goes. Another student acts as a bulb and squeezes their hands more tightly to slow down, and not to stop, the rope. The moving rope represents electrons (charge) moving round the circuit.

* Challenge the students to use the model to explain the mechanism of how energy is transferred by the circuit.

Ask them to extend this understanding to explain how the model can be used to show what happens to the rate at which energy is transferred (the power of the circuit) when current is increased.

* Introduce a second ‘battery’ and a second ‘bulb’ to the rope model and use careful questioning to elicit the understanding that:
	+ The second ‘battery’ doubles the p.d. ‘pushing’ charge through the ‘bulbs’.
	+ The second ‘bulb’ doubles the resistance of the circuit, making it twice as hard for the ‘battery’ to push charge through the bulbs.
	+ The current is the same with two ‘batteries’ and two ‘bulbs’ as for one ‘battery’ and one ‘bulb’.
	+ With two ‘batteries’ and two ‘bulbs’, the power of the circuit is twice a big – twice the p.d. with the same current.

The worksheet provides opportunity for students to record their own answers, following a demonstration.

*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 class:

For the demonstration: A rope (or string) loop.

**Technician notes**

The ideal rope is non-synthetic so that it is not too slippery, with a diameter in the order of 1 cm. The ends are tied together to form a loop with a circumference of approximately 6 m.

A 6 m length of rope should be long enough to allow 4-6 students to hold the rope whilst standing in a ring, and short enough so that one of the students can, relatively easily, act as the battery and pull the rope round through the other students’ hands.

The particular length of rope that makes this is possible is likely to depend on the specific rope used and should be trialled in advance.

**Health and safety**

Pulling ropes too quickly and with too much force through hands could potentially cause friction burns.

Carried out in several small groups, as a class practical, would involve significant movement of students throughout.

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**

There are several ways to answer these questions. One example is provided below:

1. One student (the battery) makes the electric charge (represented by the rope) move through the bulb. The student who is the bulb grips the rope which heats up their hand, which represents how electrical charge heats up a bulb’s filament and causes it to emit light. The ‘bulb’ could call out the word ‘warm’ more quickly or less quickly depending on how much friction they are feeling, to represent the brightness of the bulb in a real circuit.
2. The student who represents the battery can pull the electric charge (rope) round more quickly, and the rate at which the ‘bulb’ called out the word ‘warm’ observed – to get faster with a bigger current.
3. Two students could act as ‘batteries’ and two more as bulbs. The ‘batteries’ push current round and the ‘bulbs’ call our ‘warm’ as before. The rate at which the two ‘bulbs’ together call out ‘warm’ is compared to the situation of one battery and one bulb, when p.d. is smaller and current is the same.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG), with hands from MS Word Online 3D Models

**References**

DCFS (2008). The National Strategies / Secondary: Voltage, energy and power in electric circuits. London: Department for children, schools and families.

Driver, R., et al. (1994). *Making Sense of Secondary Science: Research into Children's Ideas,* London, UK: Routledge.

Duit, R. and von Rhoneck, C. (1997). Learning and understanding key concepts of electricity. In Tiberghien, A., Jossem, E. L. & Barojas, J. (eds.) *Connecting Research in Physics Education with Teacher Education.* International Commision on Physics Education.

Engelhardt, P. V. and Beichner, R. J. (2004). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics,* 72(1)**,** 98-115.

Gott, R. (1984). Electricity at age 15: a report on the performance of pupils at age 15 on questions in electricity. London: Department of Education and Science, Welsh Office, Department of Education for Northern Ireland.

Liu, Z., et al. (2022). Assessment of knowledge integration in student learning of simple electric circuits. *Physical Review Physics Education Research,* 18(2)**,** 020102.

Shipstone, D. M. (1985). Electricity in simple circuits. In Driver, R., Guesne, E. & Tiberghien, A. (eds.) *Children's Ideas In Science.* Milton Keynes: Open University Press.

Stocklmayer, S. M. and Treagust, D. F. (1996). Images of electrcity: How do novices and experts model electric current? *International Journal of Science Education,* 18(2)**,** 163-178.

van den Berg, E. and Grosheide, W. (1997). Learning and teaching about energy, power, current and voltage. *School Science Review,* 78(284)**,** 89-94.