**Mains power**

A kettle and a lamp are plugged into the same mains circuit.



230 V (AC)

Main fuse

Power = 2000 W

Power = 10 W

Some students are talking about why the kettle has more power than the lamp.

**Finn:** Each coulomb of charge transfers more energy to the kettle than the lamp.

**George:** A bigger current flows through the kettle than the lamp.



**Halima:** The kettle has more power because it has a bigger resistance.

**Isla:** Charge is pushed through the kettle with a bigger force.

**To answer**

1. Who is right about why the kettle has more power?
   * *Explain your answer*
2. Who is wrong about why the kettle has more power?
   * *What would you say to help them understand?*

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

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| **Response activity** |
| **Mains 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: | Explain why power of a component can be calculated using P = I x V. |
| Activity type: | Talking heads |
| Key words: | Potential difference, current, resistance, power |

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

* Diagnostic question: Mystery circuit

**What does the research say?**

The understanding of why power can be calculated using P = I x V begins with the understanding of electric current as a flow of charge. This leads on to the introduction of relationship I = Q/t as a shorthand way of writing this down and of quantifying currents for comparison (Hartley, Fairhurst and Norris, 2021). The next step is to understand that potential difference is linked to energy because it (causes an electromagnetic field that) provides an electrical ‘push’.

With a bigger potential difference across a component, electric charges are ‘pushed’ harder which means they can do work at a higher rate (Hartley et al., 2021). The equation V = E/Q represents this relationship and shows that when the potential difference pushing a certain amount of charge through a component is doubled (or tripled etc.), then two times the amount of energy is shifted – because with two times the ‘push’ on the same charge, the charge can do work at twice the rate.

Both I = Q/t and V = E/Q are derived from a microscope model of current that comprises charged particles caused to move by forces due to an electric field and impeded by collisions with microscopic structures and particles in a conductor (Liu et al., 2022). The two equations can be combined (I x V = Q/t x E/Q = E/t = P) to show that P = I x V; and the microscopic model of current used to explain the relationship.

In solving novel problems using P = I x V, students will need to consider the nature of the interdependence of current, potential difference and resistance, which can vary in different situations.

Without a good scientific understanding, it is likely that some students will interpret the equation V = I x R in a purely mathematical sense, (Liegeois and Mullet, 2002; Chasseigne et al., 2011; Liu et al., 2022).

**Ways to use this activity**

This task is intended for discussion in pairs or small groups. It can be done as a pencil and paper exercise or projected onto a screen.

Students should read the statements and follow the instructions on either the worksheet or the PowerPoint. Listening in to the conversations of each group will often give you insights into how your students are thinking. Each member of a group should be able to report back to the class.

Feedback from each group can be used, with careful teacher questioning, to bring out a clear description or explanation of the science.

*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 the 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.

NB in any class, small group discussions typically improve over time and a persistence with this strategy is often very successful in the medium to long term.

**Expected answers**

1. George is the only one who is right.

The potential difference across the kettle is the same as that across the lamp (and across any other mains appliance). This means that to have more power the kettle must have a bigger current, as indicated by the equation P = I x V.

2. Finn, Halima and Isla are all wrong.

Isla is wrong because the potential difference across each appliance is the same and so charge is pushed through each one with the same sized force.

Finn is wrong, also because the potential difference across each appliance is the same which means that each coulomb of charge transfers the same energy no matter which one it flows through, as indicated by V = E/Q (E = V x Q).

Halima is wrong: because the energy transferred by each coulomb of charge through either the lamp of the kettle is the same, the current through the kettle needs to be bigger in order to transfer energy more quickly. An increase in current can be caused by either an increase in p.d., a decrease in resistance, or both. For mains appliances, the p.d. across each appliance is the same, which means the resistance of the kettle must be *less* than the resistance of the lamp.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG) with kettle by Angali from Pixabay and the lamp by OpenClipart-Vectors from Pixabay.

**References**

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