**Calculating energy**

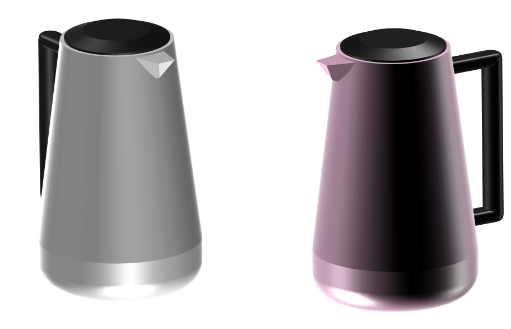
Kettle 1 and kettle 2 are identical.

Kettle 1

(2000 W)

Kettle 2

(2000 W)



They both have the same power rating.

Kettle 1 is filled with two times the amount of water as kettle 2.

**1.** How long do the kettles take to boil?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | Kettle 2 takes two times as long to boil. |  |
|  |  |  |
| **B** | They both take the same time to boil. |  |
|  |  |  |
| **C** | Kettle 1 takes a little bit longer to boil. |  |
|  |  |  |
| **D** | Kettle 1 takes two times as long to boil. |  |

**2.** Which ***two*** equations are correct?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | Power = Energy x time (P = E x t). |  |
|  |  |  |
| **B** | Power = Energy / time (P = E / t). |  |
|  |  |  |
| **C** | Energy = Power x time (E = P x t). |  |
|  |  |  |
| **D** | Energy = Power / time (E = P / t) |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Calculating energy** |

**Overview**

|  |  |
| --- | --- |
| 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 the difference between energy transferred and power. |
| Question type: | Simple multiple choice |
| Key words: | Power, energy, time |

|  |  |
| --- | --- |
| **P** | **PRIOR UNDERSTANDING**  This diagnostic question probes understanding of ideas that are usually taught at age 11-14, to aid transition from earlier stages of learning. |

**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).

Most students do not discriminate sufficiently between current, voltage, energy and power (Gott, 1984; Shipstone, 1985; Driver et al., 1994; Engelhardt and Beichner, 2004)

**Ways to use this question**

Students should complete the questions individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation.

The answers to the questions will show you whether students understood the concept sufficiently well to apply it correctly.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations, it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

1. D 2. B and C

**How to respond - what next?**

1. Boiling two times the amount of water requires two times the amount of energy. As the power of each kettle is identical, kettle 1 will take two times longer to boil than kettle 2.

2. This is because power is the rate of transfer of energy, P = E / t, and therefore, energy is equal to power multiplied by the time that the kettle is on for, E = P x t.

***Question 1*** requires students to understand the difference between power and energy. If they understand this, they should understand that each kettle transfers energy to the water it contains at the same rate (power) and that it takes two times longer to transfer the energy needed to boil two times the amount of water.

A Some students may have the correct understanding but confuse which kettle takes two times longer to boil, perhaps because they have used proportionality wrongly.

B A few students may have the misunderstanding that a kettle boils any amount of water in the same amount of time. These students probably do not understand what is meant by *power*.

C This option is likely to be the most common wrong choice, because students are likely to have experience of kettles taking longer to boil when more water is added and have based their answer on experience, rather than by working out the time based on the time it takes for an amount of energy to be transferred.

***Question 2*** requires students to apply their understanding of the relationship between power and energy to work out the short-hand way of expressing this with equations.

A A few students may select this option if they are confusing power (rate of transfer of energy) with energy.

D Some students may understand the difference between energy and power, but rearrange equation B in the wrong way. These students are likely to have selected option B for question 1.

If students have misunderstandings about describing the difference between energy and power, it can help to model power and energy. One method involves transferring sweets from one person to another. Each sweet represents and amount of energy, and the more sweets that are passed each second, the quicker energy is transferred and the greater the power.

Students could work in pairs or in small groups to write definitions of power in their own words, to explain the relationship between energy and power (and time).

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images by Peter Fairhurst (UYSEG).

**References**

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

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.