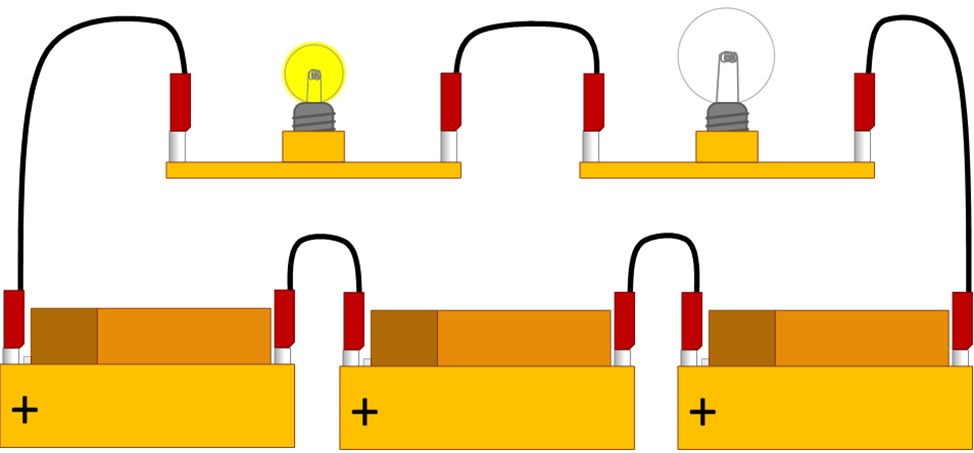
**Mystery circuit**

Two different bulbs (of the same type) are connected in a circuit.

One bulb lights up and the other does not.



***Bulb 1***

***Bulb 2***

Why does bulb 1 light up, but not bulb 2?

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *For each statement, tick (✓)* ***one*** *column to show what you think.* | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Bulb 2 is broken. |  |  |  |  |
| **B** | Bulb 2 has a much lower resistance. |  |  |  |  |
| **C** | There is more current through bulb 1. |  |  |  |  |
| **D** | The p.d. across bulb 1 is bigger. |  |  |  |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Mystery circuit** |

**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: | Explain why power of a component can be calculated using P = I x V. |
| Question type: | Confidence grid |
| Key words: | Potential difference, current, resistance, power |

**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 question**

Students should complete the confidence grid 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.

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.

**Equipment**

For the demonstration:

* A 12 V DC power supply
* One 12V 5W bulb: **Bulb 1** (for example a torch bulb)
* One 12V 24W bulb: **Bulb 2** (for example a car headlamp bulb).

**Technician notes**

Alternative bulbs can be used, to those in the equipment list, but both need to be the same *type* of bulb, both need to have the same working voltage, and **bulb 2** needs to have approximately five times the power rating as **bulb 1**.

A power supply with the same working voltage as each bulb should work well.

**Expected answers**

Statements B and D are right; and statements A and C are wrong.

**How to respond - what next?**

The same current goes through each bulb because they are in a series circuit, and bulb 2 must be working for the current to flow. Bulb 2 does not light up because it has a much smaller resistance than bulb 1, which means that for each amount (coulomb) of charge pushed through it, less energy is transferred. In other words, the potential difference is much smaller across bulb 2 than bulb 1 (and the p.d. across each bulb adds up to the p.d. across the battery).

Often students have the misunderstanding that current flows sequentially through a circuit, in this case from the battery, through bulb 1, and then through bulb 2. This can lead to some thinking wrongly that statement A or statement C is correct, or both.

A Students who think this statement is correct are probably thinking of bulb 2 in isolation and not as part of a series circuit. When presented with a novel situation, like this one, some students may revert to earlier misunderstandings.

B Some students (as in A) may wrongly think that bulb 2 does not light up because there is very little if any current flowing through it. These students may consequentially think that very little current flows through bulb 2 because it has a higher resistance.

C Students who think this statement is correct are probably thinking of bulb 1 in isolation and not as part of a series circuit. Again, when presented with a novel situation like this one, some students may revert to earlier misunderstandings.

D It is likely that most students will identify this statement as correct, but may not be able to explain that it is because bulb 1 has a higher resistance and that the charges transfer more energy as they are pushed through it.

If students have misunderstandings about explaining why power of a component can be calculated using P = I x V, it can help to provide students with an opportunity to develop and consolidate an understanding of a microscope model of current that comprises charged particles caused to move by forces due to a potential difference and impeded by collisions with microscopic structures and particles in a conductor.

One way to do this is to ask students to work in pairs or small groups to use their understanding of electric charge in a circuit to explain in their own words why bulb 1 lights up brightly and bulb 2 does not.

The following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Mains power

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG), based on the ‘Mystery circuit’ activity in *Voltage, energy and power in electric circuits* (DCFS, 2008).

Images by Peter Fairhurst (UYSEG).

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