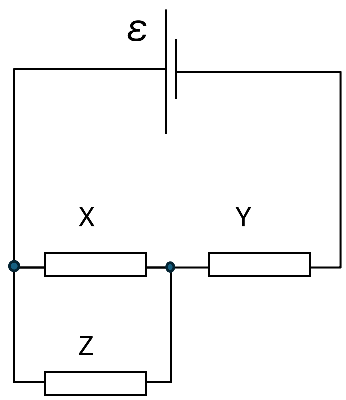
Teacher notes

Topic B

A question students often get wrong.

Three identical resistors are connected as shown. The cell has no internal resistance.



Resistor Z burns out. What happens to the current in X and the current in Y?

Most students say that the current in Y will stay the same and struggle with the current in X. The claim that the current in Y stays the same stems from the fact that Y gets the current sent out by the cell. But this ignores the fact that when Z burns out the total resistance of the circuit changes and so the current will change.

Here are three approaches with decreasing mathematical machinery.

(a) The total resistance in the original circuit is $\frac{R}{2}+R=\frac{3R}{2}$. Hence the current in the cell is $I=\frac{\varepsilon}{\frac{3R}{2}}=\frac{2\varepsilon}{3R}$. Hence X takes a current $I_{\mathrm{X}}=\frac{1}{2}\frac{2\varepsilon}{3R}=\frac{\varepsilon}{3R}$ and Y takes $I_{\mathrm{Y}}=\frac{2\varepsilon}{3R}$.
When Z burns out the total resistance is 2R and the cell current is $I=\frac{\varepsilon}{2R}$. This is the new current in both X and Y. So, we see that the current in X increases and that in Y decreases.

(b) In the original circuit, X has a voltage $V_X = \frac{\varepsilon}{3}$ and Y a voltage $V_Y = \frac{2\varepsilon}{3}$. With Z burnt out both X and Y have a voltage $V_X = V_Y = \frac{\varepsilon}{2}$. So, the voltage across X increases and that across Y decreases. Since $I = \frac{V}{R}$ the current in X will increase and that in Y will decrease.

(c) With Z burnt out the total resistance increases (we lose the parallel connection) and so the cell current decreases, decreasing the current in Y. This decreases the voltage across Y and so increases the voltage across X. Hence, the current in X will increase.