

AQA AS Series and parallel circuits

35–40 minutes independent practice + 15–20 minutes review | 53 marks

Specification points covered

• 3.5.1.4 Circuits: resistors in series and parallel; current, potential difference and resistance relationships; conservation of charge and energy in dc circuits.

• 3.5.1.4 Circuits: cells in series and identical cells in parallel; energy $E = IVt$ and power $P = IV = I^2R = V^2/R$; constructing circuits and measuring current and potential difference.

Scenario Remote weather station

Engineers are building an unmanned weather station for a mountain ridge. Its sensor electronics must keep operating when a frost-heater branch is switched off or fails. A cell bank provides emergency power. All resistances are constant. Unless stated otherwise, supplies maintain their quoted voltage; wires and closed switches have negligible resistance. Show working and units. Circuit diagrams use resistor models rather than the station's complete electronics.

Testing a series circuit

1. A remote weather station is tested using a $6.0\ \Omega$ resistor and an $18\ \Omega$ resistor connected in series to a $12\ \text{V}$ supply. Calculate their total resistance. [1 mark]

2. For the test circuit in Question 1, calculate (a) the current in each resistor and (b) the potential difference across the $18\ \Omega$ resistor. [2 marks]

3. Explain why the currents in the two series resistors are equal and why their potential differences add to $12\ \text{V}$. Refer separately to conservation of charge and conservation of energy. [2 marks]

4. A technician claims that both series resistors receive $12\ \text{V}$ because they are connected to a $12\ \text{V}$ supply. Use the energy transferred by a $2.0\ \text{C}$ charge in the circuit to show why this claim cannot be correct. [2 marks]

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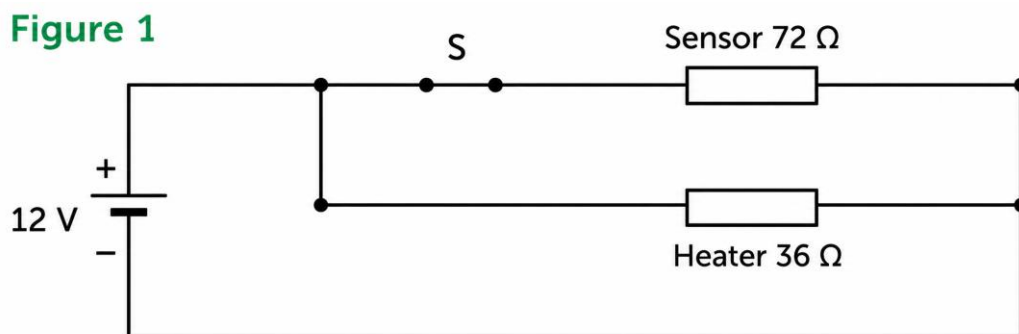
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Keeping the sensor and heater independent

5. Figure 1 models the weather station's sensor electronics and frost heater as constant resistances. Switch S is initially closed. Calculate the current in each branch. [2 marks]



6. Calculate (a) the current supplied to the circuit in Figure 1 and (b) the combined resistance of the two branches. Check that the combined resistance is smaller than either branch resistance. [2 marks]

7. The supply can deliver at most 0.800 A. A third resistive branch is added in parallel with the two existing branches. Calculate the minimum resistance of this new branch that keeps the total current within the limit. [2 marks]

8. The frost heater in Figure 1 operates for 5.00 minutes. Calculate the energy transferred to the heater. Assume its resistance remains constant. [2 marks]

9. Switch S in Figure 1 is opened. State the new sensor current, heater current and total supply current. Explain why the heater's power does not change under the stated ideal-supply assumptions. [3 marks]

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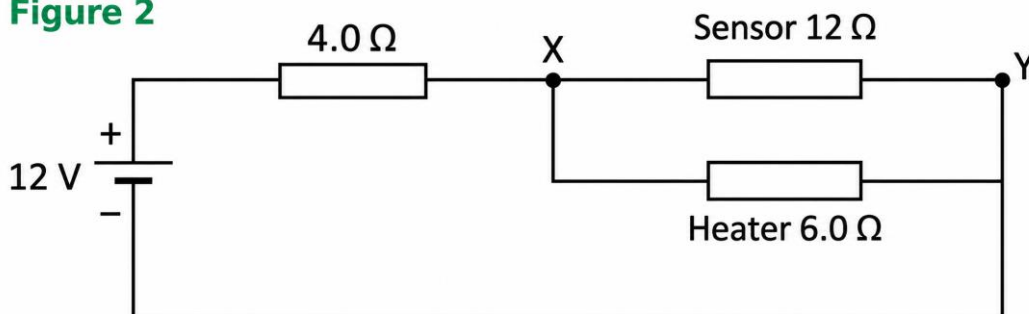
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When the branches share a series resistor

10. Figure 2 shows an alternative test circuit. The $4.0\ \Omega$ resistor is in series with the parallel combination of a $12\ \Omega$ sensor model and a $6.0\ \Omega$ heater model. Calculate the total resistance seen by the supply. [2 marks]

Figure 2



11. For Figure 2, calculate (a) the supply current and (b) the potential difference between junctions X and Y. [2 marks]

12. Calculate the currents in the $12\ \Omega$ and $6.0\ \Omega$ branches in Figure 2. Show that your results satisfy conservation of charge at X. [2 marks]

13. Calculate the power dissipated in each of the three resistors in Figure 2. Show that their total equals the power supplied by the $12\ \text{V}$ source. [4 marks]

14. The $6.0\ \Omega$ heater branch in Figure 2 fails open-circuit. Calculate the new supply current and the new power dissipated in the $12\ \Omega$ sensor model. Explain why this sensor is now at greater risk of overheating. [3 marks]



Choosing an emergency cell bank

15. The station has four identical cells, each providing a constant 1.50 V. Draw two circuit diagrams, each connected to a single $6.0\ \Omega$ test heater: arrangement A has all four cells in series; arrangement B has all four cells in parallel. Show cell polarity correctly and label A and B. [2 marks]

16. Calculate the potential difference across, and current through, the $6.0\ \Omega$ heater for each cell arrangement in Question 15. Assume ideal identical cells and ideal connecting wires. [4 marks]

17. In arrangement B, the four identical cells share the supply current equally. Calculate the current supplied by one cell. [1 mark]

18. Each cell can supply 4.00 A h of charge before it is exhausted. Using the cell currents for arrangements A and B, calculate the operating time of each arrangement in hours. Calculate the ratio of heater powers $P(A)/P(B)$, and explain why comparing operating times alone is misleading. Assume constant cell voltage, complete use of the quoted charge and constant heater resistance. [4 marks]

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Designing and testing the final circuit

19. For a constant-resistance heater, start with $P = IV$ and $V = IR$ to derive both $P = I^2R$ and $P = V^2/R$. Show the substitution used for each expression. [2 marks]

20. Return to Figure 1 with S closed. The $36\ \Omega$ heater is replaced by a heater designed to transfer $6.00\ \text{W}$ at $12\ \text{V}$. Calculate its required resistance and the new total supply current. Decide whether the $0.800\ \text{A}$ supply limit is met. [3 marks]

21. Plan a low-voltage bench test of the series and parallel resistance rules using two known resistors, an ammeter and a voltmeter. Describe meter placement, the readings and analysis for each arrangement, and one precaution to keep the resistor temperatures approximately constant. [4 marks]

22. A loose wire makes a direct connection between the two supply terminals, bypassing the loads. Explain why this is a short circuit and give one protective device that should be fitted to the real weather station. [2 marks]

Review and improve

Check the voltage and current used in each power calculation.

Correct any explanation that says current is used up, or assumes a shared series resistor leaves branch voltages unchanged.

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