

Thermistors, LDRs and sensor circuits

AQA GCSE Combined Science Trilogy 8464 and Separate Physics 8463 | Paper 1 | Both tiers

Worked answers and marking guidance | 28 parts | 50 marks

Specification points covered

8463 4.2.1.3 / 8464 6.2.1.3: potential difference, current and resistance ($V = IR$)

8463 4.2.1.4 / 8464 6.2.1.4: thermistors, LDRs and resistance changes

8463 4.2.2 / 8464 6.2.2: current, potential difference and resistance in series/parallel circuits

A seed bank is testing a storage cabinet. One sensor circuit warns when it becomes too warm; another detects light when the lid opens. Use the measurements to decide whether the warnings will work.

Original PhysicsUK practice, not an official AQA resource. Credit equivalent methods and consistent ECF. Supplies stay at 6.0 V; meters are ideal and monitor current and sensor self-heating are negligible.

1 Choosing and checking the sensors

T is an NTC thermistor. The other sensor is a light-dependent resistor (LDR). Table 1 gives calibration data for T.

1(a) As the cabinet warms, what happens to the resistance of T? Compare this with a metal filament lamp as its filament warms. **[2 marks]**

Answer / mark points: T: resistance decreases as temperature increases. [1] Metal filament: resistance increases as temperature increases. [1]

1(b) As more light reaches the lid sensor, what happens to the resistance of the LDR? **[1 mark]**

Answer / mark points: The LDR's resistance decreases as light intensity increases. [1]

Table 1

Temperature / °C	Resistance of T / Ω
10	5000
20	3000
30	2000
40	1000
50	500

1(c) Use two changes from Table 1 to show that resistance does not decrease linearly with temperature. **[2 marks]**

Answer / mark points: For equal 10 °C rises, resistance falls by 2000 Ω from 10 to 20 °C, but by 1000 Ω from 20 to 30 °C. [1 for a valid numerical comparison]

Unequal resistance changes for equal temperature changes show that the relationship is non-linear. [1] Accept other pairs of unequal drops: 1000 Ω from 30 to 40 °C and 500 Ω from 40 to 50 °C.



1(d) In a separate calibration test, T has 4.5 V across it and carries 1.5 mA. Calculate its resistance and identify the matching temperature in Table 1. **[2 marks]**

Answer / mark points: 1.5 mA = 0.0015 A. [1]

$R = V / I = 4.5 / 0.0015 = 3000 \, \Omega$, matching 20 °C. [1] Accept 3.0 k Ω with the matching temperature.

2 Building the temperature circuit

Figure 1 shows T in series with a fixed 1000 Ω resistor. The voltmeter measures the potential difference across the fixed resistor only. For this section, T is at 30 °C; use Table 1.

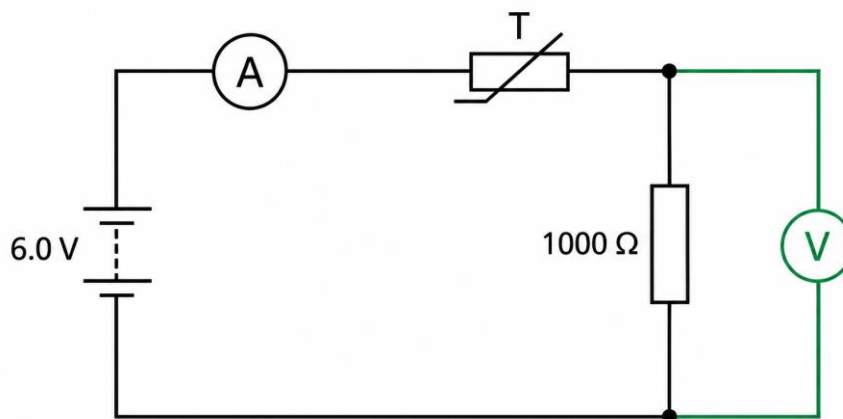


Figure 1

2(a) Calculate the total resistance of the main series circuit at 30 °C. **[1 mark]**

Answer / mark points: $R = 2000 + 1000 = 3000 \, \Omega$. [1] The ideal voltmeter does not provide a conducting shortcut.

2(b) Calculate the ammeter reading at 30 °C. Give your answer in mA. **[2 marks]**

Answer / mark points: $I = V / R = 6.0 / 3000 = 0.0020 \, \text{A}$. [1]

0.0020 A = 2.0 mA. [1] Apply ECF from 2(a).

2(c) Calculate the voltage across the fixed 1000 Ω resistor at 30 °C. **[1 mark]**

Answer / mark points: $V = IR = 0.0020 \times 1000 = 2.0 \, \text{V}$. [1] Use current in amperes; apply ECF from 2(b).

2(d) Calculate the voltage across T at 30 °C. **[1 mark]**

Answer / mark points: V across T = 6.0 – 2.0 = 4.0 V. [1] Accept $V = 0.0020 \times 2000 = 4.0 \, \text{V}$; apply ECF.

2(e) A trainee says the fixed resistor carries less current than T because T uses some current up. Correct this claim. **[1 mark]**

Answer / mark points: The same current flows through both series components; current is not used up. [1] The ideal voltmeter draws no current. Do not accept that charge is consumed.



3 Will the temperature warning work

The temperature warning activates when the voltage across the fixed $1000\ \Omega$ resistor in Figure 1 is 2.5 V or greater. Keep the same circuit and use Table 1 unless a fault is stated.

3(a) T warms to $40\ ^\circ\text{C}$. Calculate the main circuit current in mA and the voltage across the fixed resistor. **[2 marks]**

Answer / mark points: Total resistance = $1000 + 1000 = 2000\ \Omega$; $I = 6.0 / 2000 = 0.0030\ \text{A} = 3.0\ \text{mA}$. [1]
V across fixed resistor = $0.0030 \times 1000 = 3.0\ \text{V}$. [1]

3(b) Will the temperature warning be active at $40\ ^\circ\text{C}$? Use your result from 3(a). **[1 mark]**

Answer / mark points: Yes: 3.0 V is greater than the 2.5 V trigger value. [1] Apply ECF if their value supports their decision.

3(c) Explain why warming T increases the voltage across the fixed resistor. Link resistance, current and potential difference. **[3 marks]**

Answer / mark points: The NTC resistance decreases, reducing total series resistance. [1] With the same supply voltage, current increases. [1] The fixed resistance is unchanged, so its voltage increases because $V = IR$. [1] Do not accept "more voltage because it gets hotter" without a circuit link.

3(d) A trainee says the warning must first activate at exactly $35\ ^\circ\text{C}$ because this is halfway between $30\ ^\circ\text{C}$ and $40\ ^\circ\text{C}$. Explain why the measurements do not establish this. **[2 marks]**

Answer / mark points: The warning is off at $30\ ^\circ\text{C}$ (2.0 V) and on at $40\ ^\circ\text{C}$ (3.0 V), so the onset is between these temperatures, not established at the midpoint. [1] The calibration is non-linear; more measurements near the trigger are needed to identify the onset temperature. [1] Accept that the circuit voltage has not been shown to vary linearly with temperature.

3(e) A lead breaks and disconnects T. Predict the main circuit current and the fixed-resistor voltage, then state whether a hot cabinet would still trigger the warning. **[2 marks]**

Answer / mark points: The main circuit is open: current = 0 A and voltage across the fixed resistor = 0 V. [1 for both]
The warning stays off even if the cabinet is hot, because 0 V is below the trigger. [1]

3(f) A wire accidentally bridges T, giving a zero-resistance path around it. Calculate the fixed-resistor voltage and decide whether a warning now proves that the cabinet is hot. **[2 marks]**

Answer / mark points: T is bypassed, leaving the fixed resistor across the supply: $V = 6.0\ \text{V}$. [1]
Alternatively $I = 6.0 / 1000 = 0.0060\ \text{A}$, then $V = IR = 6.0\ \text{V}$.
The warning activates, but does not prove the cabinet is hot: the wiring fault can cause it at any temperature. [1]



4 Detecting an open lid

Figure 2 has a fixed $2000\ \Omega$ resistor in series with an LDR. Unlike Figure 1, its voltmeter measures across the sensor itself. The lid alarm activates when this LDR voltage is $2.5\ \text{V}$ or less. Table 2 gives LDR readings; assume constant temperature.

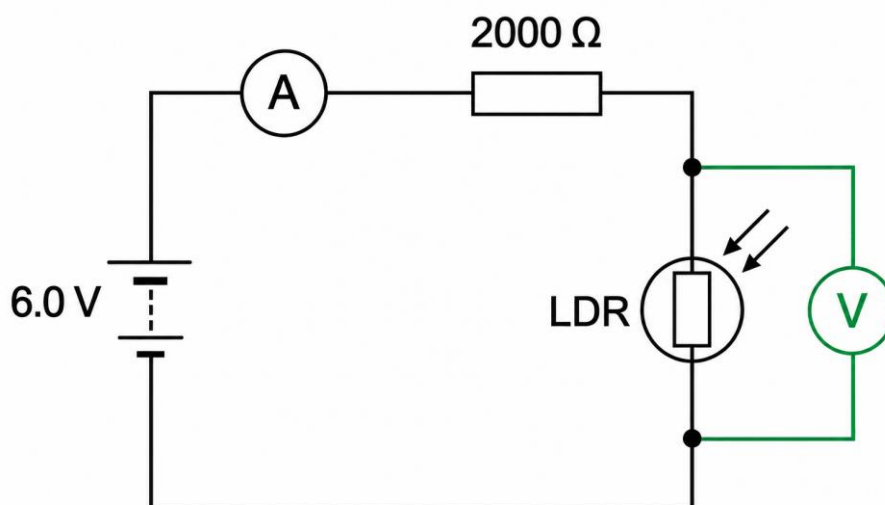


Figure 2

Table 2

Cabinet condition	Light at LDR	LDR resistance / Ω
Lid closed	Dark	6000
Lid partly open	Shaded	2000
Lid fully open	Bright	1000

4(a) The lid is fully open in bright light. Calculate the main circuit's total resistance. **[1 mark]**

Answer / mark points: $R = 2000 + 1000 = 3000\ \Omega$. [1]

4(b) Calculate the ammeter reading with the lid fully open in bright light. Give your answer in mA. **[2 marks]**

Answer / mark points: $I = 6.0 / 3000 = 0.0020\ \text{A}$. [1]

$I = 2.0\ \text{mA}$. [1] Apply ECF from 4(a).

4(c) Calculate the voltage across the LDR with the lid fully open in bright light. **[1 mark]**

Answer / mark points: $V = IR = 0.0020 \times 1000 = 2.0\ \text{V}$. [1] Apply ECF from 4(b).

4(d) Does the alarm activate with the lid fully open in bright light? Justify your answer using the voltage. **[1 mark]**

Answer / mark points: Yes: $2.0\ \text{V}$ is less than the $2.5\ \text{V}$ trigger value. [1] Apply ECF with a consistent decision.



4 Detecting an open lid continued

4(e) The lid is closed and the LDR is dark. Calculate the current in the main circuit in amperes. [2 marks]

Answer / mark points: Total resistance = $2000 + 6000 = 8000 \Omega$. [1]
 $I = 6.0 / 8000 = 0.00075 \text{ A}$. [1] This is 0.75 mA.

4(f) Calculate the voltage across the dark LDR. [1 mark]

Answer / mark points: $V = IR = 0.00075 \times 6000 = 4.5 \text{ V}$. [1] Apply ECF from 4(e). The fixed resistor has the remaining 1.5 V.

5 Checking the alarm design

Use the Figure 2 circuit and Table 2. The alarm activates at an LDR voltage of 2.5 V or less. Keep the fixed resistor at 2000Ω except where a change is explicitly stated.

5(a) The lid is partly open but the sensor is shaded. Calculate the LDR voltage and decide whether the alarm activates. Show your steps. [3 marks]

Answer / mark points: Total resistance = $2000 + 2000 = 4000 \Omega$; $I = 6.0 / 4000 = 0.0015 \text{ A}$. [1]
 LDR voltage = $0.0015 \times 2000 = 3.0 \text{ V}$. [1]
 The alarm does not activate: 3.0 V is above 2.5 V. [1] The circuit senses light at the sensor, not lid position directly.

5(b) Compare the closed-dark and open-bright results. Explain how the LDR voltage can decrease even though the current increases. Refer to both components. [3 marks]

Answer / mark points: In brighter light, LDR resistance decreases and the total series resistance decreases, so current increases. [1] The fixed 2000Ω resistor therefore takes a larger voltage (1.5 V to 4.0 V). [1] The supply remains 6.0 V, so the LDR voltage decreases from 4.5 V to 2.0 V. [1]
 Accept a correct quantitative comparison using $V = IR$ for the LDR, with its changing resistance explicitly recognised.

5(c) Dust covers the LDR, so it remains dark when the lid opens. Explain why the absence of an alarm is not reliable evidence that the lid is closed. [2 marks]

Answer / mark points: The covered LDR keeps a high resistance and a high voltage across it (4.5 V for the dark reading). [1] This is above the trigger, so the alarm can stay off with the lid open; the sensor detects light, not lid position directly. [1]



5 Checking the alarm design continued

5(d) The fixed resistor in Figure 2 is replaced by a $1000\ \Omega$ resistor. In bright light the LDR is still $1000\ \Omega$. Calculate the LDR voltage and decide whether this change improves detection of the open lid. **[3 marks]**

Answer / mark points: Total resistance = $1000 + 1000 = 2000\ \Omega$; $I = 6.0 / 2000 = 0.0030\ \text{A}$. [1]

LDR voltage = $0.0030 \times 1000 = 3.0\ \text{V}$. [1]

No: $3.0\ \text{V}$ is above the $2.5\ \text{V}$ trigger, so the open-bright lid no longer activates the alarm. [1] Accept equal series resistances share the $6.0\ \text{V}$ equally as a valid alternative route.

6 An alternative board: parallel branches

A technician rewires the temperature board. T is connected directly across the $6.0\ \text{V}$ supply in one branch. The fixed $1000\ \Omega$ resistor is connected directly across the same supply in a separate parallel branch. This is NOT the Figure 1 series circuit. The supply stays at $6.0\ \text{V}$.

6(a) Calculate the current through the fixed $1000\ \Omega$ resistor on this parallel board. **[1 mark]**

Answer / mark points: Each branch has $6.0\ \text{V}$, so $I = 6.0 / 1000 = 0.0060\ \text{A} = 6.0\ \text{mA}$. [1]

6(b) T is at $10\ ^\circ\text{C}$ on the parallel board. Calculate its branch current and the total current from the supply. Give both in mA. **[2 marks]**

Answer / mark points: Thermistor current = $6.0 / 5000 = 0.0012\ \text{A} = 1.2\ \text{mA}$. [1]

Supply current = $1.2 + 6.0 = 7.2\ \text{mA}$. [1] Branch currents add.

6(c) T warms to $40\ ^\circ\text{C}$ on the parallel board. Calculate the new total supply current. Explain why the fixed-resistor current stays unchanged, unlike in Figure 1. **[3 marks]**

Answer / mark points: Thermistor current = $6.0 / 1000 = 0.0060\ \text{A} = 6.0\ \text{mA}$; total supply current = $6.0 + 6.0 = 12\ \text{mA}$. [1]

The fixed resistor still has the full steady $6.0\ \text{V}$ across its branch. [1] Its resistance is unchanged, so $I = V / R$ stays at $6.0\ \text{mA}$; unlike series Figure 1, the branches do not share one current. [1]

Review and improve

Review language: name the sensor, state its resistance change, link this to circuit current, then identify the measured component. Voltage across a changing sensor need not increase when current increases. Timing is an estimate awaiting classroom trial. No required-practical completion claim.

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