

AQA AS Potential dividers, emf and internal resistance

35–40 minutes independent practice + 15–20 minutes review | 54 marks

Specification points covered

• 3.5.1.5 Potential divider: supplying fixed or adjustable potential differences; applications using variable resistors, thermistors and LDRs; designing and investigating divider circuits.

• 3.5.1.6 Electromotive force and internal resistance: $\epsilon = E/Q$; terminal pd and $\epsilon = I(R + r)$. Required practical 6: determine cell/battery emf and internal resistance from terminal-pd and current measurements.

Scenario: Automated mountain greenhouse

A research greenhouse uses a light sensor to position a shading screen and a temperature sensor to control ventilation. A regulated 9.00 V supply powers the dividers; a separate unregulated battery powers the fan drive.

Unless a finite input resistance is stated, control inputs draw negligible current. Treat meters as ideal. Use constant ϵ and r for each stated battery model, show working and units, and observe the practical's current limit.

Energy per charge and dividing a supply voltage

1. State what is meant by the electromotive force (emf) of a battery. [1 mark]

2. The greenhouse's backup battery has an emf of 12.0 V. Calculate the energy transferred from chemical energy to electrical energy when it supplies 2.50 C of charge. [1 mark]

3. A regulated supply of potential difference $V(\text{in})$ powers two resistors R_1 and R_2 in series. A control input takes negligible current and measures $V(\text{out})$ across R_2 . Starting with $V = IR$, derive $V(\text{out}) = V(\text{in})R_2/(R_1 + R_2)$. [2 marks]

4. During a bench test, a 2.00 k Ω resistor and a 4.00 k Ω resistor are in series across the regulated 9.00 V supply. Calculate (a) the series current and (b) the output potential difference across the 4.00 k Ω resistor. [2 marks]

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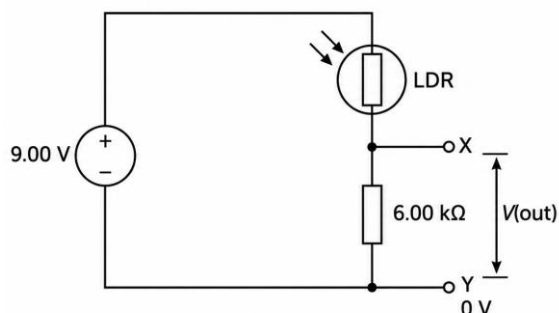
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Controlling the shading screen

5. Figure 1 controls a greenhouse shading screen. The output is measured between X and Y by a control input of effectively infinite resistance. The LDR resistance is $12.0\text{ k}\Omega$ in overcast conditions and $3.00\text{ k}\Omega$ in bright sunlight. Calculate $V(\text{out})$ for each condition. [2 marks]

Figure 1.



6. The shading screen closes when $V(\text{out})$ is at least 5.40 V . Calculate the greatest LDR resistance that will trigger it in Figure 1. [2 marks]

7. Explain why $V(\text{out})$ in Figure 1 increases as the light intensity increases. Refer to the LDR resistance, the circuit current and the potential difference across the fixed resistor. [3 marks]

8. The shading threshold must instead occur when the LDR resistance is $3.00\text{ k}\Omega$, still at $V(\text{out}) = 5.40\text{ V}$. Calculate the new value of the fixed resistor. The control input still draws negligible current. [2 marks]

9. Return to the original $6.00\text{ k}\Omega$ fixed resistor in Figure 1. A replacement control input has resistance $6.00\text{ k}\Omega$ between X and Y. In bright sunlight the LDR resistance is $3.00\text{ k}\Omega$. Calculate the loaded output voltage and decide whether it reaches the 5.40 V shading threshold. [3 marks]

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Temperature sensing and adjustable outputs

Table 1 Thermistor calibration

Temperature / °C	10	20	30	40
Resistance / kΩ	18.0	12.0	8.00	5.00

10. A second control circuit replaces the LDR in Figure 1 with an NTC thermistor, retaining the 6.00 kΩ fixed resistor and 9.00 V supply. Its calibration is given in Table 1. Explain why the output voltage increases as the temperature increases. The control input draws negligible current. [2 marks]

11. The ventilation fan is commanded on when the thermistor circuit's output is at least 4.50 V. Calculate the output at 20 °C and at 40 °C, and decide whether the fan is commanded on at each temperature. [3 marks]

12. Calculate the thermistor resistance at the 4.50 V switching threshold. Use Table 1 to identify the 10 °C interval containing the switching temperature. Do not assume that the complete resistance–temperature relationship is linear. [3 marks]

13. For a manual test, the upper sensor in Figure 1 is replaced by a variable resistor adjustable from 0 to 12.0 kΩ. The lower resistor remains 6.00 kΩ. Calculate the minimum and maximum output voltages and state which upper-resistor setting produces each. [2 marks]

14. Describe a bench method to check the thermistor circuit's switching temperature. Include how to obtain paired temperature and output-voltage readings, how to ensure the thermistor is at the measured temperature, and how to limit self-heating. [3 marks]

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Can the battery start the ventilation fan?

15. The fan drive is powered directly by the unregulated backup battery, not from the divider output. The battery has emf 12.0 V and internal resistance 1.20 Ω . During normal operation, the fan drive is modelled by a 4.80 Ω load resistance. Calculate the battery current and terminal potential difference. [2 marks]

16. For the operating conditions in Question 15, calculate (a) the power dissipated inside the battery and (b) the power delivered to the fan drive. Show that their sum equals the total rate at which the battery transfers energy to electrical form. [3 marks]

17. During start-up, the fan drive is modelled by a load resistance of 1.80 Ω . It requires at least 8.00 V across its input. The battery's emf and internal resistance are unchanged. Calculate its current and terminal potential difference, then explain whether the battery meets the start-up voltage requirement. [3 marks]

18. Two load tests on another battery give $I = 0.400$ A, $V = 11.6$ V and $I = 2.40$ A, $V = 9.60$ V. Assuming constant emf and internal resistance, determine both values. [2 marks]

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Required practical 6: Measuring emf and internal resistance

19. Figure 2 is used for Required practical 6 to investigate a replacement battery. The manufacturer specifies a maximum test current of 2.0 A. Describe a method under these headings: connections and readings; varying current and controlling conditions; graphical analysis. Explain how the method gives both emf and internal resistance. Do not exceed the stated current limit. [6 marks]

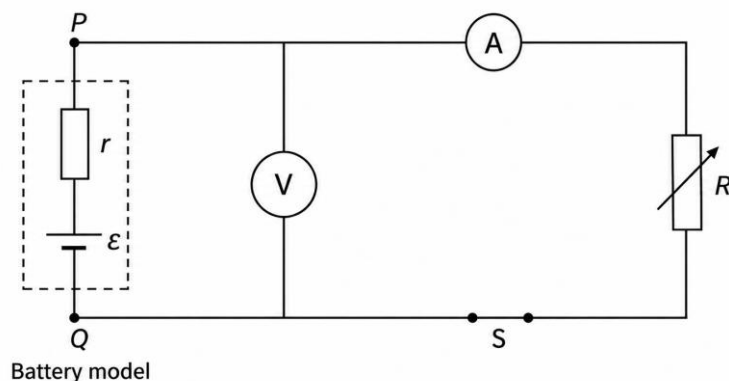


Figure 2.



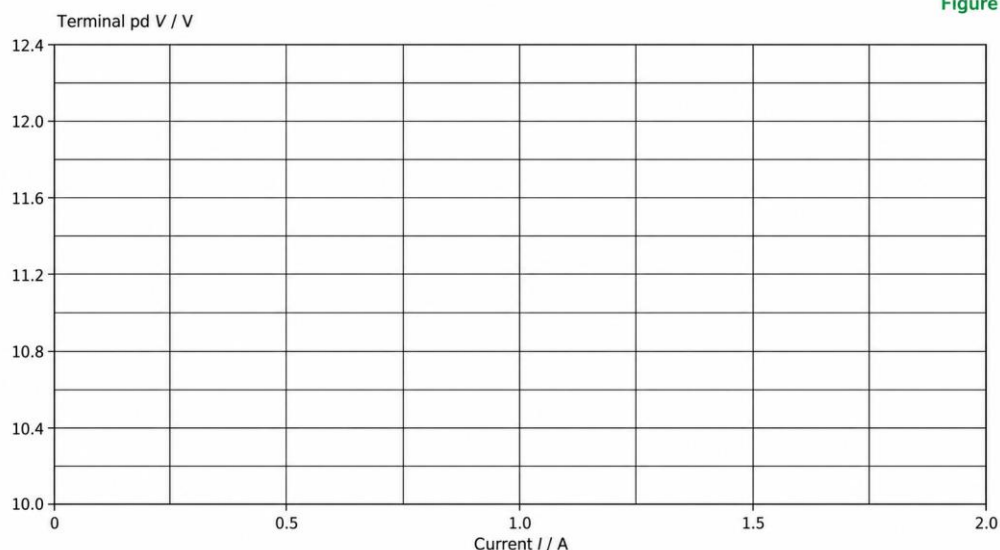
Analysing the replacement battery

Table 2 Replacement battery readings

Current I / A	0.25	0.75	1.25	1.75
Terminal pd V / V	11.8	11.4	11.0	10.6

20. Table 2 gives four pairs of readings for the replacement battery. Plot all four points on Figure 3 using crosses and draw a straight best-fit line, extending it to the vertical axis. [2 marks]

Figure 3.



21. Using $V = \mathcal{E} - Ir$, explain the meaning of the intercept and gradient of your Figure 3 graph. Determine the emf and internal resistance. Show a large gradient triangle or state two widely separated coordinates from your best-fit line. [3 marks]

22. The fan drive must receive at least 9.60 V from the replacement battery. Use your values of $\mathcal{E}$ and r to calculate the maximum current allowed by this voltage requirement alone. State the actual maximum permitted test current when the manufacturer's 2.0 A limit is also applied. [2 marks]

Review and improve

Check which component or terminal pair each voltage refers to.

Correct any statement that confuses emf with force, makes r negative, or ignores the effect of an output load.

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