

Potential dividers worksheet

AQA AS and A level Physics 7407 and 7408

Museum display protection and control

35-40 minutes independent work and 15-20 minutes review 41 marks

Specification points covered

3.5.1.5 Potential dividers supplying constant or variable pd; variable resistors, LDRs and thermistors; circuit design and investigation.

3.5.1.3 Selected content: NTC thermistors as temperature sensors.

3.5.1.4 Selected content: series and parallel resistance, current and pd relationships, electrical power and conservation of charge.

1 Limiting light exposure

A museum display uses a motorised blind to limit light exposure. A sensor measures illuminance in lux (lx). The regulated supply holds the rails in Figure 1 at 6.00 V and 0 V. V_{out} is the pd of M relative to B. The blind is commanded to close when $V_{\text{out}} \leq 2.00$ V. Initially $R = 12.0$ k Ω and the controller draws negligible current. Table 1 gives the LDR data before the blind moves.

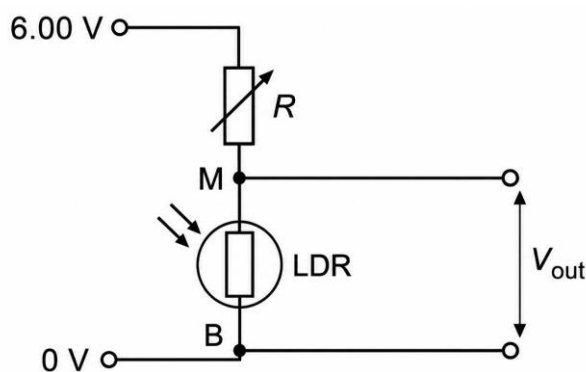


Figure 1 Not to scale

Table 1

Illuminance / lx	20	50	100	200	400
LDR R_L / k Ω	48.0	24.0	12.0	6.00	3.00

1(a) At an illuminance of 50 lx, calculate the current through the LDR. Give your answer in mA. [1 mark]

1(b) Calculate the output potential difference at 50 lx. [1 mark]



1 Selecting the light response

1(c) Starting with $V = IR$, show that $V_{\text{out}} = V_s R_L / (R + R_L)$, where R_L is the LDR resistance. State the condition about output current needed for this result. **[2 marks]**

1(d) Calculate the output potential difference at 100 lx and at 400 lx. For each value, state whether the blind is commanded to close. **[2 marks]**

1(e) Explain why the output potential difference decreases when the light intensity increases, even though the current from the supply increases. **[2 marks]**

1(f) Determine the setting of R required for the blind to start closing at 200 lx when V_{out} reaches 2.00 V. **[2 marks]**

1(g) A technician swaps the positions of R and the LDR, but still measures the output from M to B and uses the same closing rule. Explain why this would not give the intended response as the light intensity increases. **[2 marks]**

1(h) Return to Figure 1 with R fixed at 12.0 k Ω . In very intense light the LDR resistance approaches zero. Determine the maximum power dissipated in R and decide whether a resistor rated at 0.010 W is suitable. **[2 marks]**

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2 Monitoring the display temperature

A separate divider monitors the display case temperature (Figure 2). The top component T is an NTC thermistor. The lower variable resistor is set to $R = 9.00 \text{ k}\Omega$. The output is again the pd of M relative to B , now across R . A cooling fan is commanded to run when $V_{\text{out}} \geq 3.60 \text{ V}$. The fan is powered separately; the control input draws negligible current. Table 2 gives the thermistor calibration.

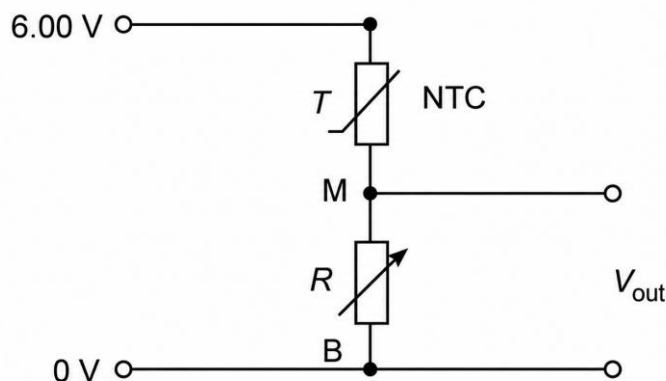


Figure 2 Not to scale

Table 2

Temperature / $^{\circ}\text{C}$	20	30	40	50
Thermistor R_T / $\text{k}\Omega$	24.0	12.0	6.00	3.00

2(a) Calculate the output potential difference when the thermistor is at 30°C . [1 mark]

2(b) Explain why increasing the thermistor temperature increases the output potential difference in Figure 2. [2 marks]

2(c) Identify the lowest temperature listed in Table 2 at which the fan is commanded to run. Support your answer with output potential differences at this temperature and the preceding listed temperature. [2 marks]

2(d) The museum wants the fan to start at a lower temperature without changing its 3.60 V trigger. Should R be increased or decreased? Explain your answer. [2 marks]



2 Calibrating and installing the sensor

2(e) Describe a laboratory method to calibrate the complete temperature-divider circuit before installation. Include how temperature and output potential difference are measured, how dependable readings are obtained, and how the readings are used to find the fan trigger temperature. **[4 marks]**

2(f) The fan must respond to the air temperature inside the display case. A technician attaches the thermistor directly to the warm lamp housing. Explain why this could start the fan too early and suggest a better sensor position. **[2 marks]**

3 Setting a reference potential difference

Figure 3 sets an adjustable controller reference. Uniform track AB is 60.0 mm long with resistance 12.0 k Ω . A is at 6.00 V and B at 0 V. Sliding contact C draws negligible current. The output is the pd of C relative to B. Do not measure the diagram.

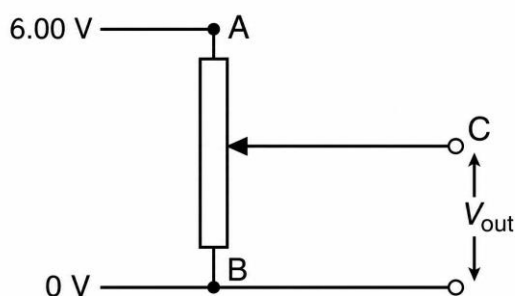


Figure 3 Not to scale

3(a) The controller requires a reference of 3.30 V. Determine the distance from B to C along the resistive track. **[2 marks]**

3(b) An alternative places a variable resistor, maximum 12.0 k Ω , in series with a 4.00 k Ω input across 6.00 V. Calculate the minimum pd across the input. Explain why the unloaded three-terminal slider is preferable for a reference adjustable from 0 V to 6.00 V. **[2 marks]**



4 Investigating controller loading

The replacement blind controller behaves as a $12.0\text{ k}\Omega$ resistor across M and B (Figure 4). It still commands closing when $V_{\text{out}} \leq 2.00\text{ V}$. Set the upper R to $12.0\text{ k}\Omega$. Use the same 6.00 V supply and Table 1, with negligible LDR self-heating. Analyse the light level before the blind moves.

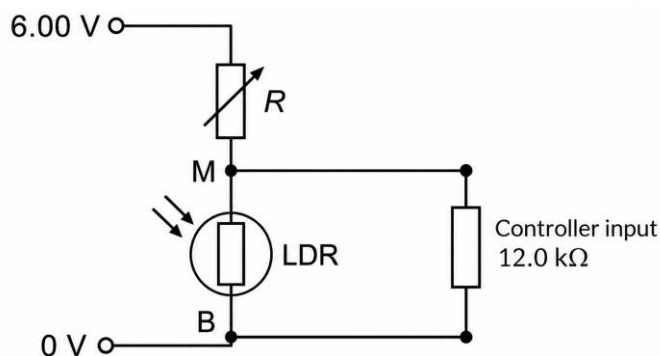


Figure 4 Not to scale

4(a) At 200 lx , determine the effective resistance between M and B and the loaded output potential difference. State whether the blind is commanded to close. **[3 marks]**

4(b) Determine the LDR resistance when the loaded circuit first reaches the 2.00 V closing threshold. Use Table 1 to identify the corresponding illuminance and explain how this changes the intended operation. **[3 marks]**

4(c) A replacement controller has an input resistance of $12.0\text{ M}\Omega$. At 200 lx , calculate its loaded output potential difference and percentage difference from the unloaded value. Decide whether it meets a requirement that loading changes the output by less than 1% . **[2 marks]**

4(d) Compare the currents with the unloaded divider at the same illuminance of 200 lx . Explain why connecting the $12.0\text{ k}\Omega$ controller increases the current from the supply but decreases the current through the LDR. **[2 marks]**

