OCR A Level Physics A (H556) Physics B (H557)
PAG 4: Investigating electrical circuits
Practice Exam Questions and Mark Scheme

1. Two resistors of resistances 120 Ω and 500 Ω are connected in **parallel**.
The percentage uncertainty in the value of resistance of each resistor is 10%.

What is the correct value of the total resistance and the percentage uncertainty?

A 97 Ω ± 10%
B 97 Ω ± 20%
C 620 Ω ± 10%
D 620 Ω ± 20%

Your answer ☐ **[1]**

2. The resistance R of an unknown resistor is found by measuring the potential difference V across the resistor and the current I through it, using the equation

$$R = \frac{V}{I}.$$

The voltmeter reading has a 2% uncertainty and the ammeter reading has a 3% uncertainty.

What is the best estimate of the uncertainty in the calculated resistance?

A 0.7%
B 3%
C 5%
D 6%

Your answer ☐ **[1]**

3. A metal circular plate is rotated at a constant frequency by an electric motor.
The plate has a small hole close to its rim.
Fig. 17.1 shows an arrangement used by a student to determine the frequency of the rotating plate.

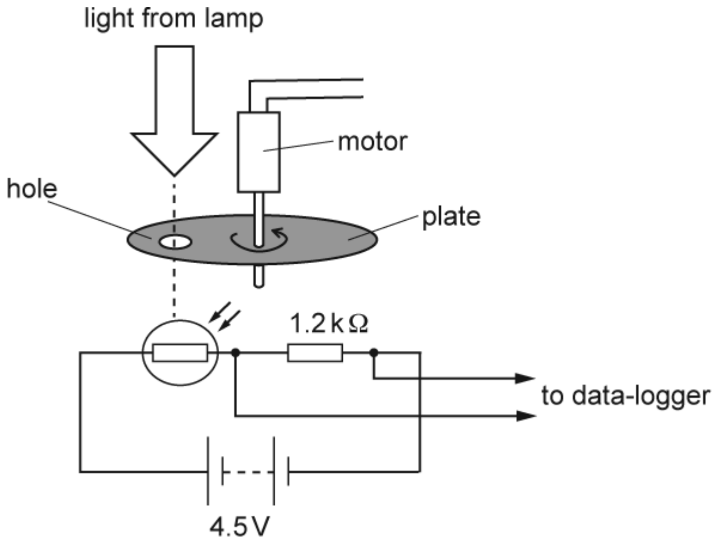


Fig. 17.1

A light-dependent resistor (LDR) and a fixed resistor of resistance 1.2 kΩ are connected in series to a battery. The battery has e.m.f. 4.5 V and has negligible internal resistance. The potential difference V across the resistor is monitored using a data-logger.

Fig. 17.2 shows the variation of V with time t.

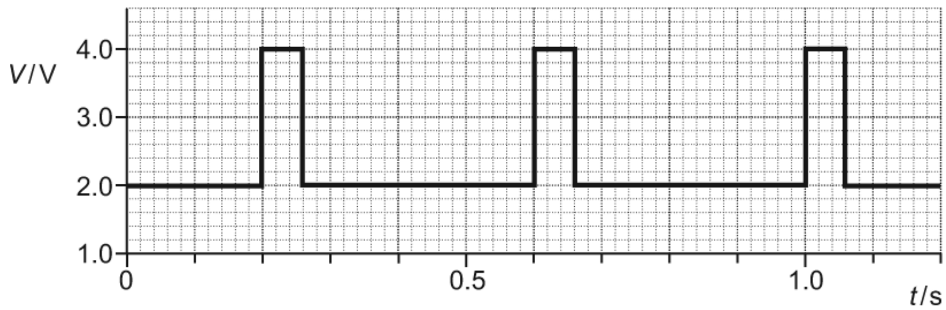


Fig. 17.2

Use your knowledge and understanding of potential divider circuits to explain the shape of the graph shown in Fig. 17.2. Include in your answer the maximum and minimum values of the resistance of the LDR.
Describe how the student can determine the frequency of the rotating plate.

[6]

4. The maximum power input to a domestic fan heater is 2.6 kW when connected to the 230 V mains supply. The electric circuit of the fan heater consists of two heating elements (resistors) rated at 1.5 kW and 1.0 kW, a motor rated at 100 W and three switches.

With only the first switch closed, the fan rotates; closing the second switch gives the heater an output of 1.5 kW and closing the third switch increases the output to 2.5 kW. The elements will not heat up unless the fan is switched on. The heater cannot give an output of 1.0 kW.

Complete the circuit diagram of Fig. 1.1 to show the fan, the heating elements and the switches connected so that the heater will work as described. Label the switches and the elements.

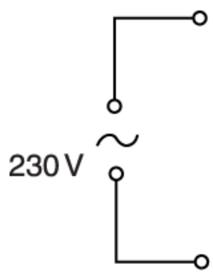


Fig. 1.1

[3]

5(a). Fig. 18.1 shows a circuit.

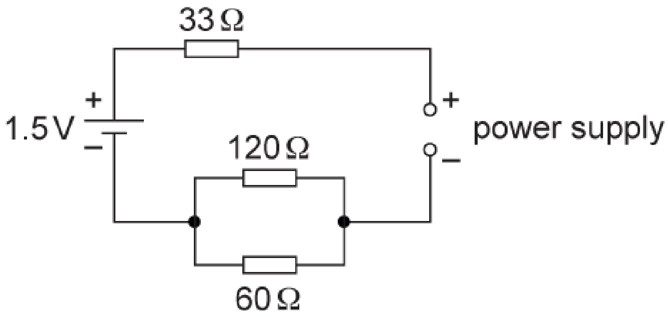


Fig. 18.1

The cell has e.m.f. 1.5 V. The cell and the variable power supply both have negligible internal resistance.

i. The e.m.f. of the power supply is set at 4.2 V.

Calculate the current I in the 33 Ω resistor.

I = ... A **[3]**

ii. The e.m.f. of the variable supply is now slowly decreased from 4.2 V to 0 V.

Describe the effect on the current I in the 33 Ω resistor.

[2]

(b). A group of students are investigating the power dissipated in a variable resistor connected across the terminals of a cell. The cell has e.m.f. 1.5 V.
The students determine the power *P* dissipated in the variable resistor of resistance *R*.

Fig. 18.2 shows the data points plotted by the students on a graph of *P* (*y*-axis) against *R* (*x*-axis).

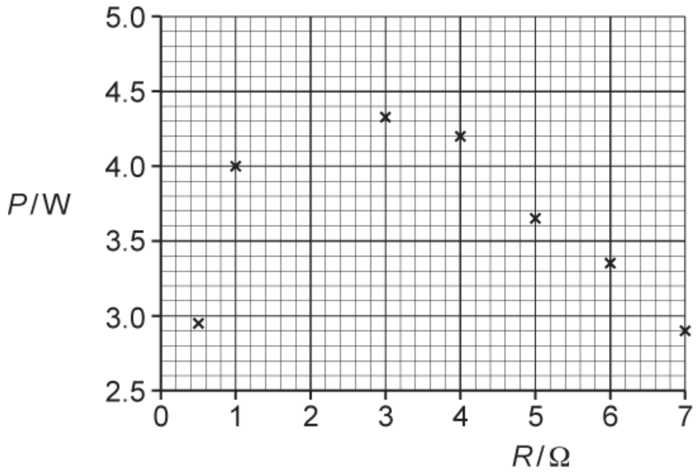


Fig. 18.2

The group of students know that **maximum power** is dissipated in the variable resistor when *R* is equal to the internal resistance *r* of the cell.

Describe, with the help of a suitable circuit diagram, how the students may have determined *P* and *R*.
Use Fig. 18.2 to estimate the internal resistance *r* of the cell and discuss any limitations of the data plotted by the group.

[6]

6(a). State **one** S.I. base quantity other than length, mass and time.

[1]

(b). Fig. 17 shows two resistors **X** and **Y** connected in series.

Fig. 17

The resistors are wires. Both wires have the same length L and diameter d. The material of **X** has resistivity ρ and the material of **Y** has resistivity 2ρ.

i. Show that the total resistance R of the wires is given by the equation

$$R = \frac{12\rho L}{\pi d^2}.$$

[2]

ii. A student uses the equation in **(i)** to determine R.
The table below shows the data recorded by the student in her lab book.

Quantity	**Value**
ρ	4.7×10^{-7} Ω m
L	9.5 ± 0.1 cm
d	0.270 ± 0.003 mm

1. Name the likely instruments used by the student to measure L and d.

L: ....

d: ....

[1]

2. Use the data in the table and the equation in **(i)** to determine R and the absolute uncertainty. Write your answer to the correct number of significant figures.

R = ... ± .... Ω **[4]**

3. The instrument used to measure d has a zero-error. The measured d is much **larger** than the actual value.

Discuss how the actual value of R compares with the value calculated above.

[1]

7. A student is investigating an unidentified component found in the laboratory.

The table shows the results from the lab book of the student.

V / V	I / mA
− 5.0	− 5.0
+ 5.0	+ 5.0
+ 10.0	+ 30.0

The potential difference across the component is V and the current through it is I.

i. Calculate the power dissipated by the component when V is +10.0 V.

power = ____________________ W **[1]**

ii. Analyse the data in the table and hence identify the component.

____

____

____

____

____

____

____

____ **[3]**

Note - The following Physics B questions may have some marks that are more applicable to Physics B assessments.

8. This question is about strain gauges that can be fixed to an object to measure its extension or compression.

To make a sensing circuit, a student connects a potential divider circuit with the strained gauge **X** connected in series with another identical, unstrained strain gauge **Y** as shown in Fig. 38.3.

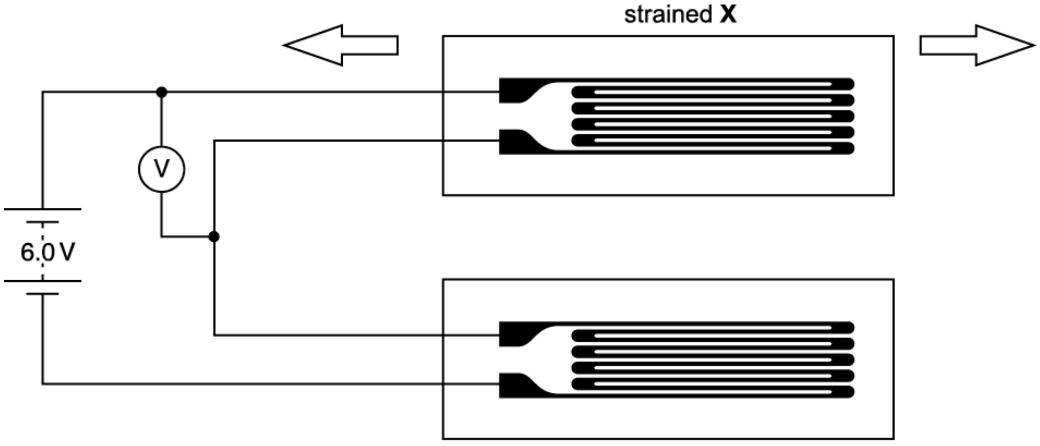


Fig. 38.3

i. Fig. 38.4 shows the calibration graph for this strain sensor.

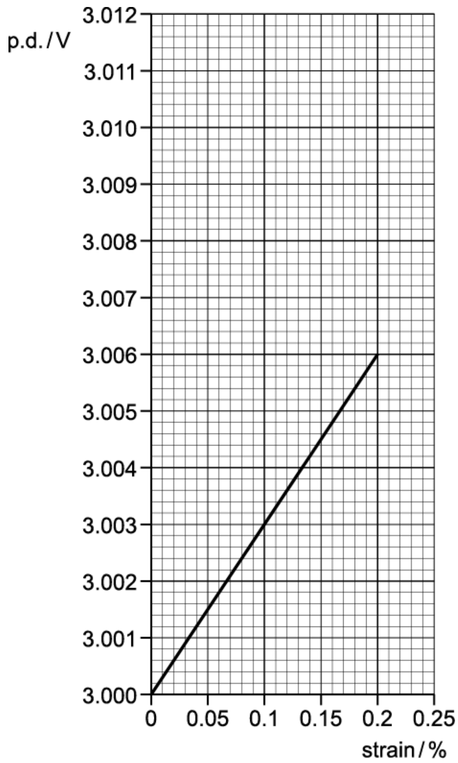


Fig. 38.4

Use data from Fig. 38.4 to calculate the sensitivity of the strain gauge sensor.

sensitivity = ... V unit strain^{-1} **[2]**

ii. Explain how there can be a systematic error in strain measurement if the strained gauge **X** is in a hotter environment than the unstrained gauge **Y**.

Use these order of magnitude statements about metal properties to help you answer:

fractional change in resistivity per kelvin $\frac{\Delta\rho}{\rho\Delta T} \approx +10^{-3}\ \text{K}^{-1}$ and

fractional change in length per kelvin $\frac{\Delta L}{L\Delta T} \approx +10^{-5}\ \text{K}^{-1}$.

[4]

iii. In the case of a bending beam the upper surface is stretched and the lower surface is compressed as shown in Fig. 38.5.

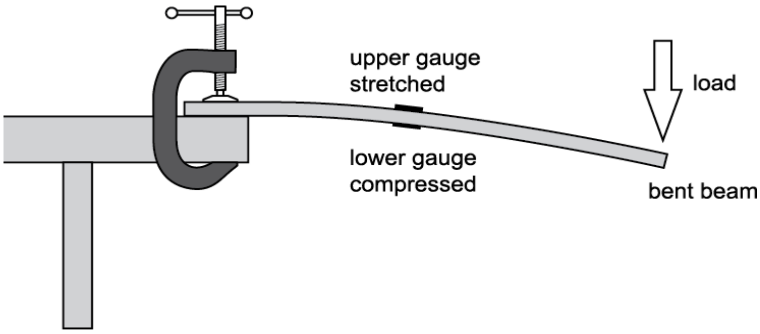


Fig. 38.5

The circuit in Fig. 38.3 is used with the strain gauge **X** attached to the upper surface of the beam, and strain gauge **Y** on the lower surface.

Draw on Fig. 38.4 the calibration graph you would expect for this arrangement of gauges.

[1]

9(a). This question is about a temperature sensor.

It contains a thermistor in a potential divider circuit as shown in Fig. 29.1.
Fig. 29.2 shows the output p.d. *V* against temperature *θ* graph for the sensor.

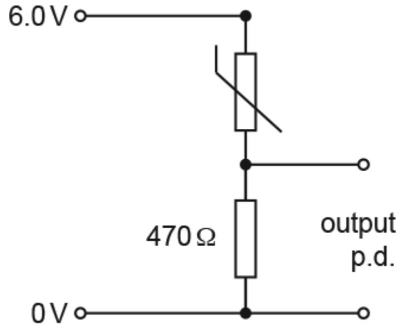


Fig. 29.1

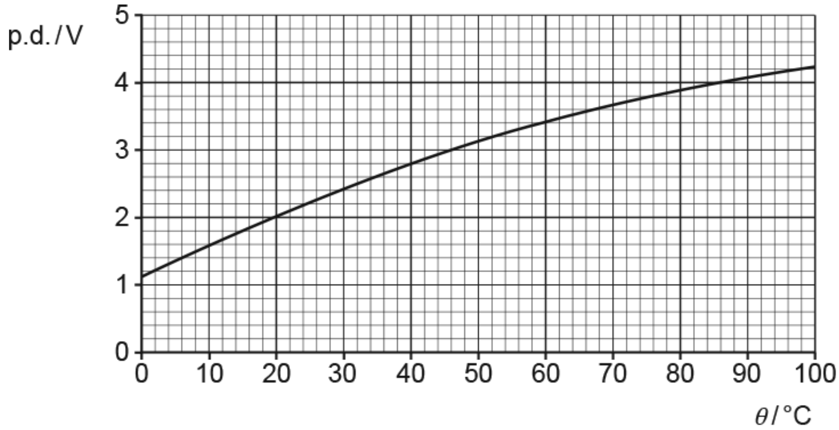


Fig. 29.2

The readings of p.d. for Fig. 29.2 were taken with a digital voltmeter.
Five consecutive values were recorded at each temperature.
The calculated mean output p.d. data for five of the temperatures are shown in the table with calculated uncertainty values.

temperature / °C		0	20	40	60	100
output p.d. / V	mean	1.127	2.041	2.795	3.389	4.097
	uncertainty	± 0.003	± 0.024	± 0.020	± 0.012	± 0.003

Analyse and comment on the uncertainties in the data in the table.
Suggest a cause of the limitations in the data and what might be done to improve the procedure or apparatus used in the calibration to avoid the limitations.

[4]

(b). State suitable apparatus (other than indicated in Fig. 29.1) and describe how to use it to obtain the calibration graph shown in Fig. 29.2.
You may wish to include a labelled diagram in your answer.

[4]

10. This question is about a light dependent resistor (LDR) in a light sensing circuit.

i. An LDR and a fixed resistor R are connected as a potential divider to the 6.0 V battery shown in Fig. 8.1 to make a sensing circuit.

Draw the potential divider on Fig. 8.1 to complete the circuit.
Label the components R and LDR on the diagram.

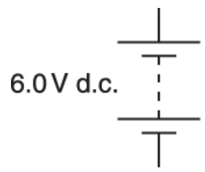


Fig. 8.1

[1]

ii. A voltmeter is to be connected to the circuit to indicate an **increasing** output p.d. when the sensor detects an **increasing** light intensity.

The resistance of the LDR **decreases** when the light intensity incident upon it increases.

Explain clearly why the voltmeter should be connected across the fixed resistor.

Make the steps in your reasoning clear.

[3]

11. This question is about sensor circuits.
Fig. 3.1 shows a circuit which can be used as a simple light meter. The light-dependent resistor **X** has a resistance R_X which decreases when it is more brightly lit.
R_X varies with light intensity as shown in Fig. 3.2.

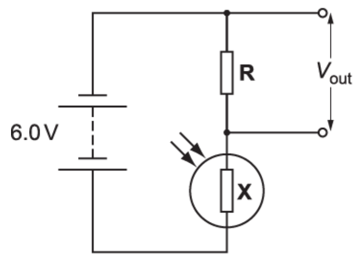


Fig. 3.1

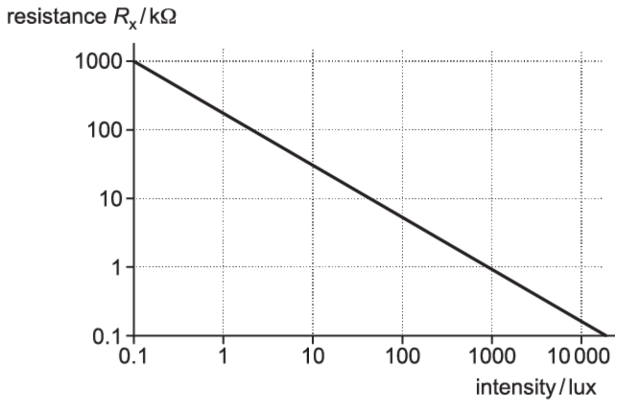


Fig. 3.2

The table below shows typical values of light intensity in different situations.
The SI unit of intensity is the lux.

Situation	night sky with full moon	home lighting	office lighting	full daylight
Intensity / lux	1	100	500	10 000

Use the data given to choose an appropriate value of resistance *R* of the fixed resistor **R** to use in a circuit to measure the light intensity in homes and offices.

Explain your reasoning clearly.

resistance = ...Ω **[3]**

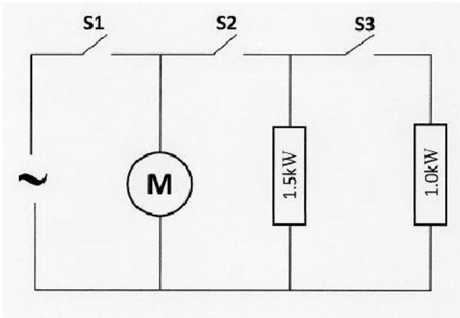
Total: 57

END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			**A**	**1**	
			Total	**1**	
2			**C**	**1**	
			Total	**1**	

3			**Level 3 (5–6 marks)**
			Clear explanation, some description **and** both resistance values correct
			
			There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.
			
			Level 2 (3–4 marks)
			Some explanation, limited or no description **and** both resistance values correct
			OR
			Clear explanation, limited or no description **and** calculations mostly correct / one correct calculation
			OR
			Clear explanation, some description **and** no calculations
			
			There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.
			
			Level 1 (1–2 marks)
				B1 × 6	**Indicative scientific points may include:**
					
					Explanation of trace
					
					• The 'trace' is because of light reaching and not reaching LDR
					• Resistance of LDR varies with (intensity) of light
					• In light
					    ○ resistance of LDR is low
					    ○ p.d. across LDR is low
					    ○ p.d across resistor (or *V*) is high
					    ○ current in circuit is large
					• In darkness
					    ○ resistance of LDR is high
					    ○ p.d. across LDR is high
					    ○ p.d across resistor (or *V*) is low
					    ○ current in circuit is small
					• V_{max} = 4.0 V; V_{min} = 2.0 V
					• Potential divider equation quoted
					• Substitution into potential divider equation
					
					Description of determining frequency

			Some explanation **OR** Some description **OR** Some calculation *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit		• Time between pulses is constant because of constant speed • Time between pulses = 0.4 (s) • *f = 1/T* • frequency = 2.5 (Hz) **Calculations** • Resistance of LDR is 150 (Ω) in light • Resistance of LDR is 1500 (Ω) in darkness
			Total	**6**	
4			resistors and motor wired in parallel to supply switches correctly placed (open or closed) any suitably labelled symbols; components in correct order	B1 M1 A1	do not expect switches to be labelled
			Total	**3**	
5	a	i	Resistance of parallel combination = 40 (Ω) $I = \frac{4.2 - 1.5}{40 + 33}$ *I* = 0.037 (A)	**C1** **C1** **A1**	**Allow** (1/60 + 1/120)$^{-1}$ **Allow** 2 marks for $I = \frac{4.2 + 1.5}{40 + 33} = 0.078$ (A)
		ii	Any <u>two</u> from:	**B1×2**	

			The current decreases up to 1.5 V The current is zero at 1.5 V The current changes direction / is negative when < 1.5 V The current increases below 1.5 V		**Allow** 'current is zero when the e.m.f.s are the same'
	b		**Level 3 (5-6 marks)** Clear description including a reasonable estimate of *r* **and** clear limitations *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Some description with an attempt to estimate *r* **and** some limitations *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1 -2 marks)** Limited description *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**B1×6**	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2ˆ for 3 marks, etc. **Indicative scientific points may include:** **Description and estimation** • Correct circuit with (variable) resistor, ammeter and voltmeter • Correct symbols used for all the components • *R* changed to get different values for *P* • $R = V / I$ (using ammeter and voltmeter readings) or *R* measured directly using an ohmmeter with the variable resistor isolated from the circuit or *R* read directly from a resistance box • Power calculated using $P = V^2/R$ or $P = VI$ or $P = I^2R$ • The value of *r* is between 1.0 to 3.0 Ω • A smooth curve drawn on Fig. 18.2 (to determine *r*) • A better approximation from sketched graph or *r* is between 1.5 and 2.7 Ω • Any attempt at using $E = V + Ir$, with or without the power equation(s) to determine *r* - even if the value is incorrect **Limitations** • 'More data' required • Data point necessary at *R* = 2.0 Ω / More data (points) needed between 1 to 3 Ω • No evidence of averaging / Error bars necessary (for both *P* and *R* values)
			Total	**11**	
6	a		Any <u>one</u> from: current, temperature, light intensity and amount of substance / matter	**B1**	**Not:** ampere, kelvin, candela and mole **Not** correct quantity with its unit, e.g. current in A or current (A)

	b	i	$R = \frac{\rho L}{A}$ **and** $A = \pi\left(\frac{d}{2}\right)^2$ $R_X = \frac{4\rho L}{\pi d^2}$ and $R_Y = \frac{8\rho L}{\pi d^2}$ Clear steps leading to $R = \frac{12\rho L}{\pi d^2}$	M1 A1	
		ii	**1** Ruler / tape measure (for *L*) **and** micrometer (for *d*) **2** R = 2.3(4) (Ω) $\frac{0.1}{9.5}$ or $2\times\frac{0.003}{0.270}$ $\frac{0.1}{9.5}+2\times\frac{0.003}{0.270}$ or 0.0327 or 3.27% absolute uncertainty in R = 0.0327 × 2.34 = 0.077 R = 2.3 ± 0.1 (Ω) **3** (The actual) *R* is large(r) **because** (the actual) *d* is small(er) or (the actual) *A* is small(er) or $R \propto 1/d^2$	B1 C1 C1 C1 A1 B1	**Allow** (vernier / digital) calipers or travelling microscope for micrometer **Allow** other correct methods for getting 2.3 ± 0.1 (Ω) **Allow** 2 or more sf for this C1 mark **Note** 0.0105 or 1.05% or 0.0222 or 2.22% scores this mark, allow 2sf or more **Allow:** 2.34 ± 0.08 (Ω) **Note** use of R_X or R_Y instead of *R* can score the second and third C1 marks only **Allow:** The calculated *R* is small(er) **because** (the measured) *A* is large(r) or $R \propto 1/d^2$
			Total	**9**	
7		i	($P = VI$ = 10.0 × 0.030) power = 0.30 (W)	B1	**Allow** 0.3 (W) without any SF penalty **Allow** 300 **m**(W)
		ii	The component is (an NTC) thermistor. (As *V* or *I* increases the) resistance of the component decreases	B1 B1	 **Allow** calculations at 5 V and 10 V to support this, **ignore** POT errors

			Any <u>one</u> from: Component cannot be a diode / LED because of current in one direction only (AW) (As *V* or *I* increases the) component gets warmer / increase in number density (of free charge carriers)	**B1**	
			Total	**4**	
8		i	sensitivity = $\Delta V / \Delta\varepsilon$ OR = 0.006 / 0.002 ✓ = 3.0 (V per unit strain) ✓	2	method **accept** in numbers / gradient evaluation **allow** 1 mark for 0.030 **POT**
		ii	*T* increases ρ and *R* ✓ *T* increases dimensions of wire ✓ *R* would decrease due to expansion alone because% increase in *L* is ½ % increase in *A* ($R \propto L / A$) ✓ fractional change in ρ K^{-1} ≈ strain OR fractional change *L* in the gauge so this effect could be important ✓ OR fractional change in ρ K^{-1} >> fractional change *L* K^{-1}so expansion is a less important temperature than change in ρ	4	**not** just *T* affects ρ and *R* **accept** % increase in *A* is 2 × % increase in *L* ($R \propto L / A$) **accept** % expansion K^{-1} ≈ 1/100 % increase ρ K^{-1} so could be ignored to first approximation
		iii	Fig. 37.4 ∝ line added of 2 × gradient of original ✓	1	**expect** line through {0, 3.000} and {0.2, 3.012}, gradient = 0.0060
			Total	**7**	
9	a		Smallest uncertainties (±3 mV) at highest and lowest temperatures / largest uncertainties at intermediate temperatures ✓ Uncertainties fall between 20 to 60 °C / uncertainties occur as repeated values different / uncertainty will be calculated by half of range of values ✓ Calculation of a percentage error OR observation ✓	**Max 4**	**Max 3** for **analysis and comment** **1** for simple **comment** accept valid alternatives **1** for more detailed **comment** accept valid alternatives **1** for simple percentage uncertainty **analysis** **allow** one percentage calculation e.g. 1.2% at 20 °C **allow** percentage errors are smallest at extremities / largest at intermediate values / fall between

			Calculation of (at least) two percentage error calculations with comment ✓ in fixed point temperatures / in ice and steam points because temperatures are stable larger systematic errors in the other readings because of temperature drift / thermistor still warming during measurement interval uncertainty decreases (from ± 24 mV to ± 12 mV) with rising *T* because sensitivity also decreases with *T* noise signal persists into drift readings because they are not linearly increasing in small time interval (✓✓) improve systematic / drift errors by stopping heating / stirring water / giving time for thermistor to equilibrate to water temperature / use water bath with thermostat start with hot water and cool slowly to reduce temperature fluctuations improve small random errors using a less noisy DVM (✓✓)		20 to 60 °C 1 for more detailed **percentage** uncertainty **analysis** e.g. calculation of percentage errors at 0 °C and 100 °C and relevant/appropriate comment **Max 2** for **causes** of data limitations. Accept valid alternatives. **Max 2** for **improvements**. Accept valid alternatives. **expect** good level of response **not** just use better DVM
	b		1st marking point: apparatus. Voltmeter / DVM (across output) and thermometer, with one other of	**1**	**allow** suitable alternatives. Can be shown on **labelled** diagram. **allow** datalogger, temperature sensor and voltage sensor for voltmeter and thermometer).

			beaker of water (and stirrer), heater. ✓ 2nd marking point: T at either fixed point explained ✓	1	e.g. immerse thermistor in (melting/crushed) ice in water for lower fixed 0 °C, OR boiling water at 100 °C for upper fixed point. **allow** heat to 100 °C IF heat source mentioned (e.g. with heater).
			3rd marking point: indication of measurements of V (or output) at **regular** T intervals ✓	1	**allow** named ΔT intervals e.g. 5 or 10 °C **allow** heat (and record V) at ΔT = 10 °C
			th marking point: relevant experimental detail ✓	1	e.g. heat slowly so temperature measurement is accurate / stop heating and stir before taking temperature measurement / take temperature and p.d. readings of $V(T)$ at same time / place thermistor and thermometer close together / repeat **and** average results. Use of datalogger, temperature sensor and voltage sensor can score 3rd and 4th marking points if clear. **allow** start with boiling/hot water and add cool/cold water/ice to cool
			Total	**8**	
10		i	R and LDR correct symbols in complete series circuit	1	either way round **ignore** labelling / Voltmeter if drawn **accept** for LDR (with / without) circle and 2 arrows / variable resistor / general transducer symbol for LDR (thermistor) **not** LED or lamp or fuse or photodiode or other symbols
		ii	resistance ratio changes / voltage is shared (between resistors); correct direction of change in resistance ratio (R_f / R_{LDR} increases or v.v.); Link resistance to p.d. by : use of potential divider equation or voltage ratio = resistance ratio **OR** as light intensity rises R_{LDR} falls so R_{total} falls; current increases; p.d. across R_{FIXED} rises / p.d. across LDR falls	1 1 1	applying the potential divider or voltage ratio equation with correct sense can score all 3 marks **expect** candidates to make clear which R they are talking about **accept** voltage is shared in proportion to the resistances **not** current is constant (in series circuit) **QoWC** 3rd mark only if steps in reasoning are clear and no logical errors
			Total	**4**	

11			intensity should go from (about) 100 lux to (about) 500 lux /≈ between home and office conditions (1); corresponds to R_X between 1 kΩ and 10 kΩ (1); R should be similar to / in the range of R_X (1)	3	MP1 is identifying the appropriate intensity which could be a single value in the range. There should be a range stated or implied by the chosen value(s) of R_X for this mark. MP1 is about processing the data in the table. MP2 is reading appropriate resistance(s) for the intensity / intensities of MP1. This marking point can be inferred from choice of R. MP2 is about estimating resistance value(s) of R_X from the log-log graph. If candidate finds a mean R_X over the range of intensities, then the chosen R should be that value. If there is only one value of R_X chosen, then the answer on the dotted line should be that one. MP3 is about recognising that the two resistors in the potential divider need to be similar in magnitude.
			Total	**3**	