Physics A (H156, H556)

Exploring - Potential dividers ppq
KSA Physics

Please note that you may see slight differences between this paper and the original.

Candidates answer on the Question paper.

OCR supplied materials:
Additional resources may be supplied with this paper.

Other materials required:
- Pencil
- Ruler (cm/mm)

Duration: Not set

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions, unless your teacher tells you otherwise.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Where space is provided below the question, please write your answer there.
- You may use additional paper, or a specific Answer sheet if one is provided, but you must clearly show your candidate number, centre number and question number(s).

INFORMATION FOR CANDIDATES

- The quality of written communication is assessed in questions marked with either a pencil or an asterisk. In History and Geography a *Quality of extended response* question is marked with an asterisk, while a pencil is used for questions in which *Spelling, punctuation and grammar and the use of specialist terminology* is assessed.
- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **47**.
- The total number of marks may take into account some 'either/or' question choices.

1 As light passes through a substance its intensity decreases exponentially with distance.

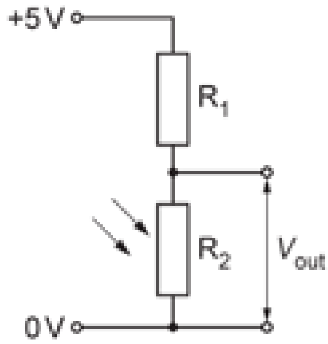
$I_x = I_0 \, e^{-\mu x}$

I_x is the intensity of light at a given thickness of jelly
I_0 is the intensity of light immediately before it enters the jelly
μ is the constant of proportionality
x is the thickness of the jelly that the light has passed through.

Some students are studying the absorption of visible light by red jelly. They set up the experiment below.

- The power to the bulb is kept constant.
- The distance between the bulb and the light meter is kept constant.
- Blocks of jelly of different thickness are used.
- They measure the intensity of light using a light meter.

The students decide to make their own light meter using this circuit.



The value of R_1 is 5 kΩ. The value of R_2 was 100 Ω when 1 mm jelly was used and 8 kΩ when 5 mm jelly was used.

i. Calculate the output voltage range obtained in this experiment.

range = ... V **[2]**

ii. Describe **two** ways the output voltage range could be increased.

1 ____

____

2 ____

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[2]

iii. Explain how the circuit responds to a change in light intensity.

____

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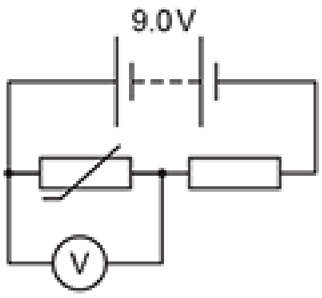
____ [1]

2 A potential divider circuit is shown below.



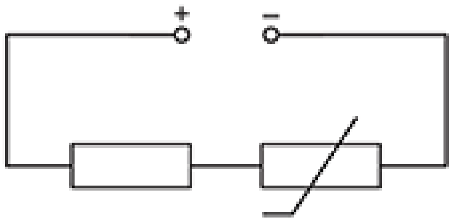
The battery has electromotive force (e.m.f.) 9.0 V and negligible internal resistance.
At room temperature the potential difference (p.d.) across the thermistor is 4.5 V.
The temperature of the thermistor is increased and its resistance decreases by 20% from its previous value.

What is the p.d. across the thermistor now?

A 3.6 V
B 4.0 V
C 5.0 V
D 5.4 V

Your answer [1]

3 A circuit with a thermistor is shown below.



The resistance of the resistor is R and the resistance of the thermistor is $2.5R$.
The potential difference (p.d.) across the thermistor is 5.0 V.

What is the total p.d. across both components?

A 2.0 V

B 7.0 V

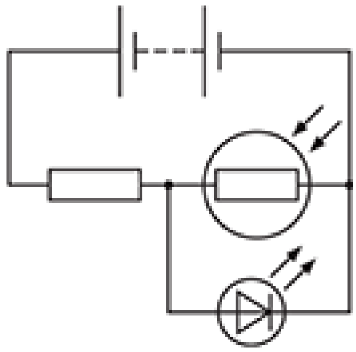
C 12.5 V

D 17.5 V

Your answer [1]

4 A light-emitting diode (LED) emits red light when it is positively biased and has a potential difference (p.d.) greater than about 1.8 V.

The diagram below shows a circuit designed by a student.



The LED is very close to, and facing the light dependent resistor (LDR).
The circuit is taken into a dark room.

i. The student thought that the LED would switch on.
Instead, the LED was found to repeatedly switch on and off.

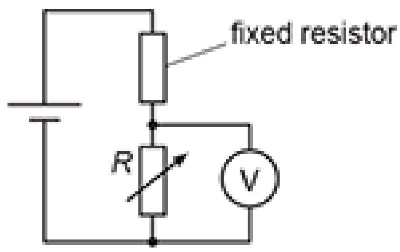
Explain this behaviour of the LED in this potential divider circuit.

--- **[2]**

ii. Suggest a possible refinement so that the LED switches on permanently when taken into the dark room.

--- **[1]**

5 A potential divider circuit is shown below.



The resistance of the variable resistor is R. The potential difference across the variable resistor is V.

Which graph shows the correct variation with R of V?

A

B

C

D

Your answer [1]

6 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.

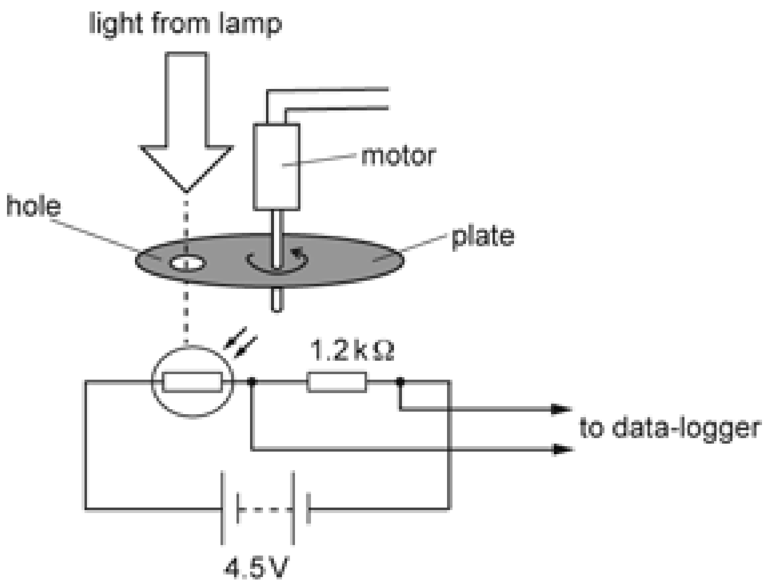


Fig. 17.1

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*.

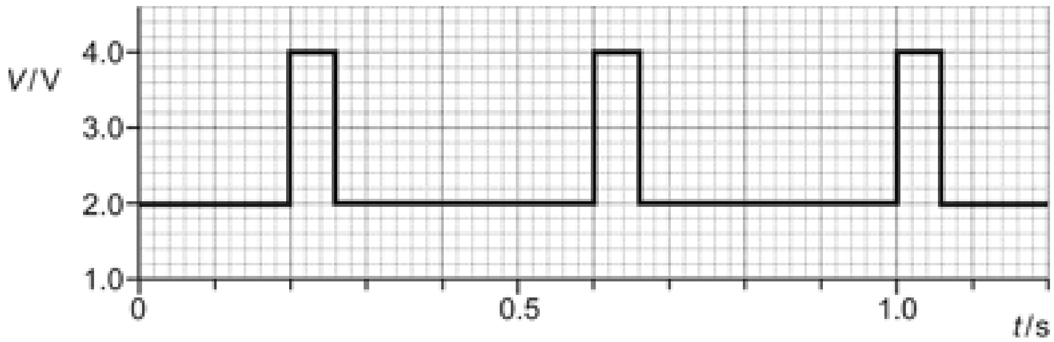


Fig. 17.2

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]

7 A filament lamp X is part of an electrical circuit. The circuit has a battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance. The potential difference across the lamp can be increased **continuously** from 0 to 6.0 V. This potential difference is measured using a voltmeter.
The lamp glows brightly at 6.0 V.

i. Draw a circuit diagram for this electrical arrangement.

[2]

ii. Describe and explain the variation of the resistance of this lamp as the potential difference across it is changed from 0 to 6.0 V.

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____

____

____ **[4]**

iii. The filament lamp X is now connected in a different circuit as shown in Fig. 16.

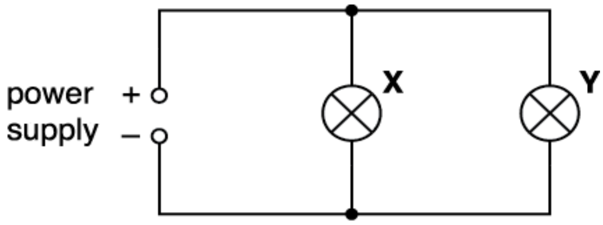


Fig. 16

The power dissipated in X is three times more than the power dissipated in the filamentlamp Y. The filament wire of lamp X has a diameter half that of lamp Y.
The filament wires of X and Y are made of the same material and are at the same temperature.

Calculate the ratio

$$\frac{\text{mean drift velocity of charge carriers in lamp } \mathbf{X}}{\text{mean drift velocity of charge carriers in lamp } \mathbf{Y}}.$$

ratio = ______________________________ **[3]**

8(a) Fig. 17 shows a potential divider circuit consisting of a fixed resistor of resistance R and a negative temperature coefficient (NTC) thermistor.

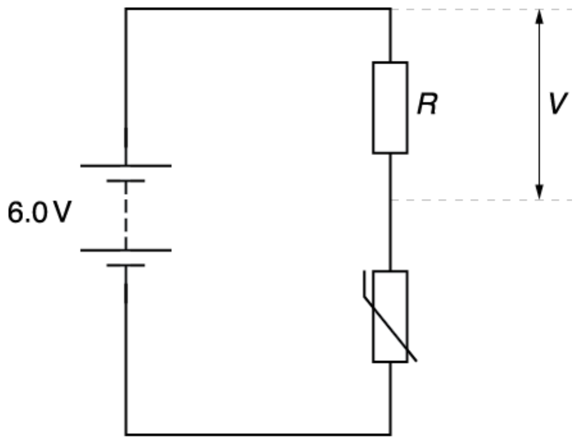


Fig. 17

The battery has electromotive force (e.m.f.) of 6.0 V and negligible internal resistance.
The thermistor is at room temperature. The resistance of the thermistor is 0.25 R.

Calculate the potential difference V across the resistor.

V = ______________________________ V **[2]**

(b) A voltmeter whose resistance is 5 R is connected across the fixed resistor.

The voltmeter reading is **less** than your answer in the previous question.

Explain why the voltmeter reading is less and suggest an alternative measuring device.

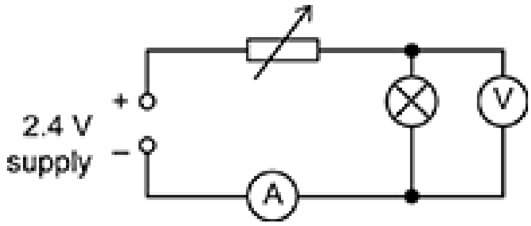
[2]

(c) The circuit shown in Fig. 17 is now placed in a cold fridge. The temperature of the thermistor slowly decreases to a constant value.

Describe and explain, in terms of current in the circuit, the variation of the potential difference V across the fixed resistor with time.

[4]

9 A student connects the circuit shown to plot the *I*-*V* characteristic of the filament lamp.



The current in the lamp is *I* and the potential difference across it is *V*. The supply has e.m.f. 2.4 V and negligible internal resistance. The maximum resistance of the variable resistor is about 60 Ω.

i. Explain why this circuit will provide data for large *V* values but not for small *V* values.

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[2]

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ii. Complete Fig. 16 to design a circuit so that data may be obtained for *V* from zero to 2.4 V for the lamp.

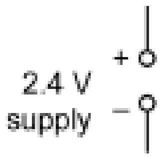

Fig. 16

[2]

10(a) A student designs a circuit to vary the brightness of a filament lamp. The circuit is shown in **Fig. 17.2**.

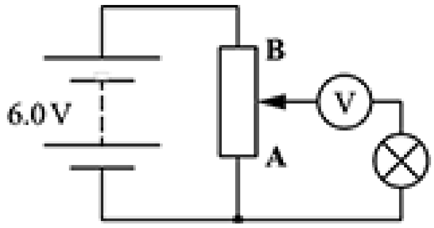

Fig. 17.2

The circuit is set up. Moving the slider from **A** to **B** changes the voltmeter reading from 0 V to 6.0 V but the lamp stays off. The lamp is not faulty.

Explain the observations above and refine the circuit design so that the brightness of the lamp can be varied as the slider is moved from **A** to **B**.

-- [3]

(b) * **Fig. 17.3** shows how the resistance of a thermistor varies with temperature.

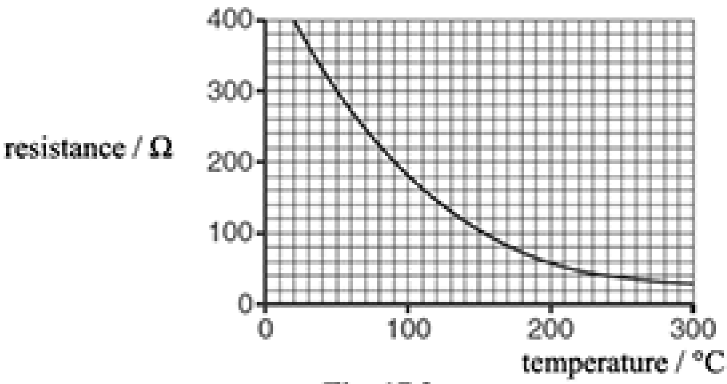

Fig. 17.3

Fig. 17.4 shows a potential divider circuit which uses this thermistor. The circuit is designed to monitor the changes in the temperature of an oven in the range 200 °C to 300 °C.

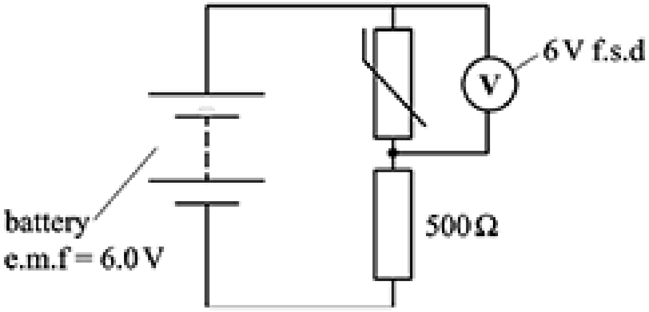

Fig. 17.4

The voltmeter has very high resistance and has a full scale deflection (f.s.d.) of 6.0 V.

Explain how the circuit works and use calculations to discuss a significant limitation of this design.

[6]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1		i	(100 / 5100) x 5 (= 0.098) (V) OR (8000 / 13000) x 5 (= 3.077) (V) **0.098 to 3.077** OR **2.98** (V)	C1 A1	**ALLOW** rounding of either or both of these values to 2sf **ALLOW** final answer of range of 0.1 to 3 OR 3 (1sf answer) if more than 1sf seen previously <u>Examiner's Comments</u> This was correctly done by around three quarters of the candidates. Most used a version of the potential divider formula twice and then either gave these two values as the extremities or the difference between them. There were some clear calculational errors despite the equation being used correctly. Some candidates had a value of the maximum voltage above the supply voltage which should have alerted them to a problem.
		ii	Any two from: Increase the input voltage Decrease (the resistance of) R_1 / (fixed) resistor Extend range of thickness of jelly used	2 x B1	**ALLOW** emf for input voltage but not just potential difference **IGNORE** current **NOT** decrease the resistance alone **NOT** just make jelly thinner/thicker. Must be clear that values below 1mm or above 5mm are to be used. <u>Examiner's Comments</u> Candidates should make sure that they only give the required number of responses when prompted, as any incorrect responses may invalidate correct ones. It is important to make sure that the sense of change of any quantity is given, rather than simply a change. Over three quarters of candidates were able to achieve at least 1 mark on this question.

Question			Answer/Indicative content	Marks	Guidance
		iii	As the light intensity increases the resistance of the LDR/ R_2 decreases the PD measured (across R_2) decreases OR As the light intensity increases the total resistance of the circuit decreases the current increases	B1	**ALLOW** reverse argument Must be clear that the resistance is that of the LDR **ALLOW** output voltage/voltmeter reading for PD across R2 <u>Examiner's Comments</u> Although many candidates had a good understanding of this response, only around a third were able to give a complete and structured response. Three points needed to be made: how the light intensity varies, its effect on the resistance of the LDR and the effect on the output p.d.. Many candidates mentioned just changes rather than the sense of change, and also missed out some detail making the explanation incomplete.
			Total	5	
2			B	1	<u>Examiner's Comments</u> This proved to be a challenging question with only around a quarter of the candidates able to obtain the correct response. It was likely that written working was helpful here and many candidates set out some form of a potential divider calculation. Some did this in ratios and others made up a value for the two resistances (e.g. 10 Ω) which they then decreased to 8.0 Ω for the thermistor. The incorrect responses were spread fairly evenly across the distractors, which is maybe surprising as it would be expected that candidates should have appreciated that the p.d. across the thermistor would now be less than the initial 4.5 V.
			Total	1	

Question			Answer/Indicative content	Marks	Guidance
3			B	1	<u>Examiner's Comments</u> The correct response is **B**. This question was correctly answered by around two thirds of candidates. There appeared to be various routes to the correct solution; many opted to work out a current in terms of *R*, but the more elegant working was in terms of simple ratios which demonstrated a good understanding of p.d. in a series circuit. Encouragingly, very few candidates opted for response **A**, which was a p.d. below that of the thermistor alone. It should be noted that a couple of candidates put a '7' in the answer box – as correct working had been shown by them, and leading to the correct numerical value this was credited by examiners. However, this cannot be guaranteed to occur in other cases and candidates are to be encouraged to put only the correct letter.
			Total	1	
4		i	In darkness LDR has more resistance / p.d. across LDR is large **or** In light LDR has less resistance / p.d. across LDR is small Clear idea that when the LED is on, this will force the p.d. across LED / LDR to decrease, forcing the LED to switch off (ORA) (The cycle of LED switching on and off is repeated)	B1 B1	 Note the explanation must be in terms of p.d. / potential divider. **Ignore** current
		ii	A sensible suggestion, e.g. Point the LED away from the LDR / increase distance (between LED and LDR) / insert a card between (LED and LDR)	B1	
			Total	3	

Question			Answer/Indicative content	Marks	Guidance
5			A	1	<u>Examiner's Comments</u> This is a question on a potential divider circuit and a sketch of the correct *V*-*R* graph. Unfortunately, the distractor **B** was a bit too strong. **A** is the correct sketch. When $R = 0$, *V* had to be zero too. Most candidates did write down the correct potential divider expression for *V*, but then did not acknowledge that *V* cannot be directly proportional to *R* – the straight-line graph through the origin could not be the correct answer. It was a choice between **A** or **B**, and by the brief reasoning above, the answer had to be **A**.
			Total	1	

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>6</td><td></td><td></td><td>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)
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</td><td>B1 × 6</td><td>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

• 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

<u>Examiner’s Comments</u>

This was one of the two LoR questions. It required understanding of potential dividers, light-dependent resistor and rotation frequency of a spinning plate.

Examiners expect varied responses, and two very dissimilar answers can score comparable marks as long as the criteria set out in the answers’ section of the marking scheme are met. Level 3 answers had the correct maximum and minimum resistance values of the LDR, a decent description and explanation of the trace</td></tr>
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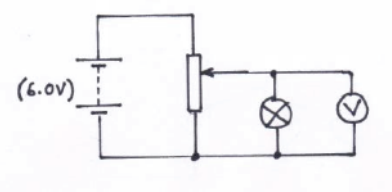
Question				Answer/Indicative content	Marks	Guidance
						shown in Fig. 17.2, and an outline of how the frequency of the spinning plate was determined. As mentioned earlier, eclectic answers are inevitable – verbose and concise answers can be at Level 3. In Level 2 answers there were generally missed opportunities. Half-done calculation and descriptions either with some errors or lacking in depth. Level 1 answers had some elements of calculations or descriptions. The two exemplars below, illustrate a Level 3 response and a Level 1 response. **Exemplar 7** When the hole in the metal plate is directly above the LDR, light shines the LDR. This causes the resistance on the LDR to decrease. This means that the total resistance of the circuit decreases, so the current flowing in the circuit increases. As the resistance of the fixed resistor is constant and current increases, the p.d. across it (V) must increase, by $V = IR$. This can also be shown using the potential divider equation: $V_{out} = \frac{R_2}{R_1 + R_2} \times V_{in}$, where V_{out} is the p.d. across the fixed resistor (V). We can rearrange this equation to find the resistance of the LDR both when light is and isn't shining on it. For when light isn't shining on it: $(2.0) = \frac{(1.2\times10^3)}{R_{max} + (1.2\times10^3)} \times (4.5) \Rightarrow R_{max} = 1500\,\Omega$ For when light is shining on it: $(4.0) = \frac{(1.2\times10^3)}{R_{min} + (1.2\times10^3)} \times (4.5)$, $R_{min} = 150\,\Omega$ The frequency can be found by first finding the period, T. This is the time taken for the voltage p.d. (V) to return to the same value. This is $T = 0.4$ s. Finding the inverse of this will give the frequency $f = 1/T = \frac{1}{0.4} = 2.5$ Hz. This is a Level 3 response from a top-end candidate who scored 6 marks. The description of the variation of the resistance of the LDR, the circuit current and the potential difference across the fixed resistor is perfect. The calculations of the LDR resistances are nicely embedded into the general explanation. The calculation of the frequency is all correct. This is a model answer for 6 marks. Compare and contrast this with the Level 1 response below. **Exemplar 8**

Question			Answer/Indicative content	Marks	Guidance
					When the light shines through the hole onto the LDR, the resistance decreases, causing the pd across the fixed resistor to increase, and vice versa when the ~~[illegible]~~ light is blocked again. Determine the frequency by seeing how long the plate takes to rotate, so from pd increase to pd increase, 0.4 seconds frequency $= \frac{1}{T}$ frequency $= 2.5$ This is a Level 1 response from an E-grade candidate. The description of the variation of the resistance of the LDR is correct. However, there are no calculations of the resistance of the LDR, as required in the question. Hence, a significant part of the question has been omitted. According to the marking criteria, this could only score Level 1. The examiner credited 2 marks for this response.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
7		i	Correct circuit with a battery, potential divider, lamp and voltmeter.  	B1	
		i	Correct symbols used for all components.	B1	**Allow**: A cell symbol for a battery
		ii	Description: The temperature of the filament increases. (AW)	B1	
		ii	The resistance of the lamp increases	M1	
		ii	from a non-zero value of resistance.	A1	**Allow** 'when cold the resistance is small'
		ii	Explanation: Resistance increases because electrons/charge carriers make frequent collisions with ions. (AW)	B1	
		iii	($P = VI$) current in **X** is 3 times the current in **Y** Or area of **X** is 4 times smaller than area of **Y**	C1	**Allow** other correct methods.
		iii	$I = Anev$ and ratio = $\frac{3}{0.25}$	C1	
		iii	ratio = 12	A1	
			Total	**9**	

Question			Answer/Indicative content	Marks	Guidance
8	a		$V = \frac{R}{R + 0.25R} \times 6.0$	C1	**Allow** other correct methods.
			V = 4.8 (V)	A1	
	b		The total resistance of the voltmeter and resistor in parallel is less than R. (AW)	B1	
			A suitable alternative device stated, e.g. digital voltmeter, oscilloscope or data-logger (connected to a laptop).	B1	
	c		The resistance of the thermistor increases.	B1	
			The current in the circuit decreases.	B1	
			The p.d. across the resistor decreases because of $V = IR$ or $V \propto R$.	B1	
			The p.d. becomes constant. (AW)	B1	
			Total	8	
9		i	With the variable resistor set at zero / close to zero, the p.d. across the resistor is zero / small, so p.d. across lamp is 2.4 V / large.	B1	
		i	With the variable resistor set at its maximum value, there is a p.d. across the variable resistor, so p.d. across the lamp is not small.	B1	
		ii	The lamp is connected to the slider contact of a potentiometer arrangement.	B1	
		ii	Ammeter and voltmeter connected correctly.	B1	
			Total	4	

Question			Answer/Indicative content	Marks	Guidance
10	a		The voltmeter has large or infinite resistance. Hence the p.d. across the lamp or current in the lamp is small or zero (and the lamp is not lit). Refining design: remove voltmeter from the circuit or place the voltmeter across the lamp.	B1 B1 B1	
	b		* **Level 3 (5–6 marks)** Explanation is complete with E1, 2 and 3 For calculation expect C3 At least two limitations mentioned. *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)** Expect two points from E1, 2 and 3 Expect either C1 or C2 for the calculations Expect at least one limitation Limitation identified but calculations are inappropriate. *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)** Expect at least one point from explanation Expect C1 and an attempt at C2 Limitations given are inappropriate. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	B1	**Explanation (E)** 1. Total resistance decreases as temperature increases (allow reverse argument) 2. Current in circuit increases as temperature increases or p.d. is in the ratio of the resistance values 3. Therefore, the p.d. across resistor increases or p.d. across thermistor decreases **Calculations (C)** 1. $I = V / R$ used to show current increases as temperature increases 2. Potential divider equation (or $I = V / R$ and $R = R_1 + R_2$) used to calculate the voltmeter reading at either 200 °C or 300 °C • V_{300} = 6.0 × 25/(25 + 500) = 0.29 V • V_{200} = 6.0 × 60 /(60 + 500) = 0.64 V) 3. Potential divider equation used to calculate the voltmeter reading at **both** 200°C and 300 °C **Limitation (L)** 1. The change in resistance is small when resistance of thermistor changes from 200 °C to 300 °C 2. Change in voltmeter reading is too small over this range 3. Non-linear change of resistance with temperature
			Total	9	