1 **(a)** The following electrical quantities are often used when analysing circuits. Draw a straight line from each quantity on the left-hand side to its correct units on the right-hand side.

potential difference	$C\,s^{-1}$
resistance	$J\,C^{-1}$
power	$V\,A^{-1}$
current	$J\,s^{-1}$

[3]

(b) Fig. 3.1 shows a battery of e.m.f. 6.0V and negligible internal resistance connected in series with a thermistor and a 560Ω resistor.

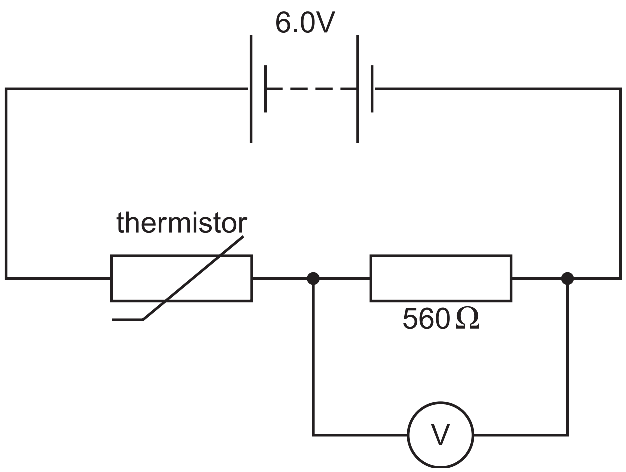


Fig. 3.1

The voltmeter across the resistor has infinite resistance.

(i) The reading on the voltmeter is 2.4V. Calculate the resistance R_T of the thermistor.

R_T = ... Ω **[3]**

(ii) Calculate the current in the circuit.

current = ... A **[1]**

(c) The variation of resistance with temperature for this thermistor is shown in the graph of Fig. 3.2.

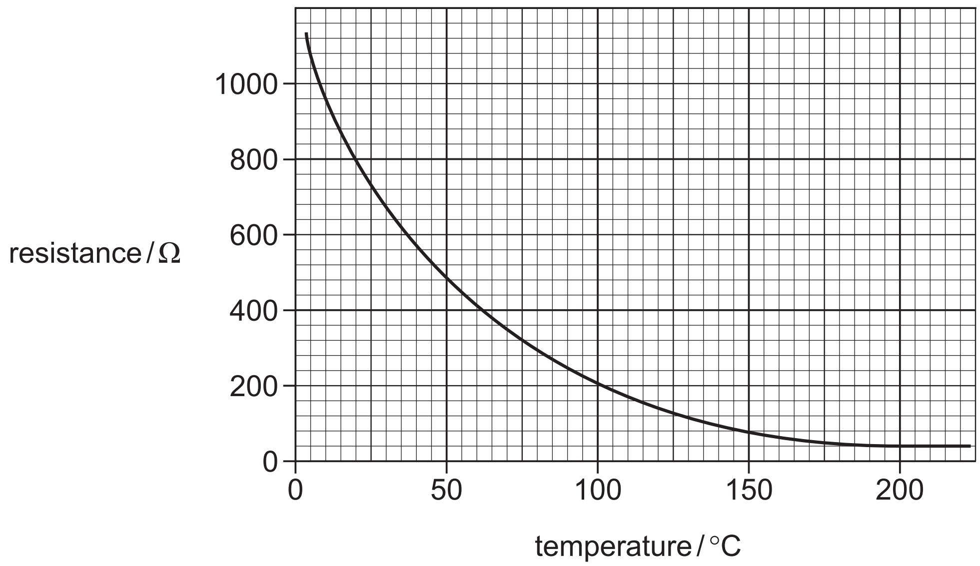


Fig. 3.2

(i) Use the graph to determine the temperature of the thermistor when its resistance is 800 Ω.

temperature = ... °C **[1]**

(ii) State and explain, without calculation, how the reading of the voltmeter in Fig. 3.1 will change as the temperature of the thermistor increases to 80 °C.

....

....

....

....

.... **[3]**

(iii) The circuit of Fig. 3.1 can be used as a temperature sensor. Temperature sensors are used in the kitchen to control the internal temperatures of ovens (typically 200 °C) and refrigerators (typically 4 °C). Use the graph of Fig. 3.2 to suggest in which device this sensor would be more suitable.

In your answer you should link the information from the graph to the working of the sensor.

....

....

....

....

.... **[3]**

[Total: 14]

2 **(a)** Define the *resistivity* ρ of a metal wire.

....

....

.... **[2]**

(b) In the UK the National Grid is used to transmit electric power. Each pylon supports 24 cables. See Fig. 2.1. Each cable consists of 38 strands of aluminium. See Fig. 2.2.

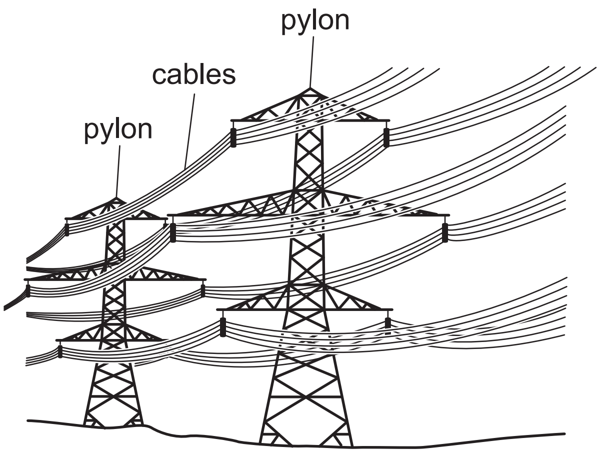


Fig. 2.1

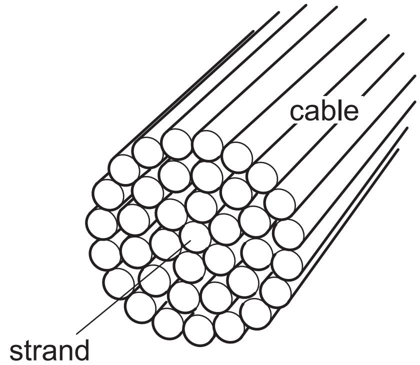


Fig. 2.2

(i) The resistance per km of a cable is 0.052 Ω km^{-1}. Explain why the resistance per km of a single strand is approximately 2.0 Ω km^{-1}.

....

....

.... **[2]**

(ii) The resistivity of aluminium is 2.6 x 10^{-8} Ω m. Calculate the cross-sectional area *A* of a single strand of the cable.

A = ………………..m^2 **[2]**

(c) The input voltage to each cable in Fig. 2.1 is 400 kV. The cable carries a current of 440 A. Calculate

(i) the input power to one cable

input power = ...W **[2]**

(ii) the number of cables required to transmit the power from a 2000 MW power station

number of cables = ...**[1]**

(iii) the power lost as heat per km of cable

lost power = ...**[3]**

(iv) the percentage of the input power that is available at a distance of 100 km from the power station.

percentage of power =..............................% **[2]**

[Total: 14]

3 Fig. 3.1 shows a circuit containing a battery of e.m.f. 12V, two resistors, a light-dependent resistor (LDR), an ammeter and a switch **S**. The battery has negligible internal resistance.

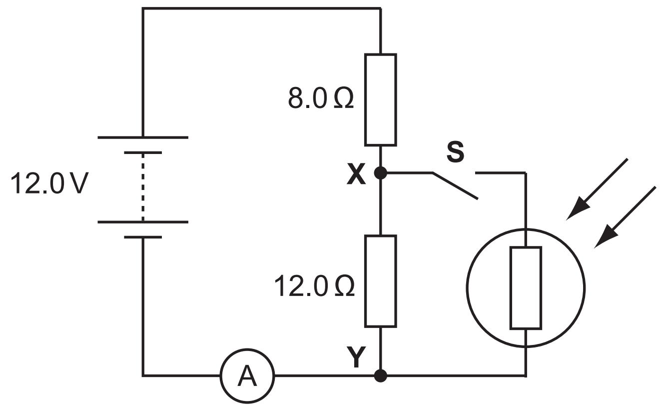


Fig. 3.1

(a) When the switch **S** is open, show that the potential difference between the points **X** and **Y** is 7.2V.

[2]

(b) The switch **S** is now closed. Describe and explain the change to each of the following when the intensity of light falling on the LDR is increased:

(i) the ammeter reading

....

....

.... **[2]**

(ii) the potential difference across **XY**.

....

....

.... **[2]**

[Total: 6]

4 This question is about the use of a thermistor fitted inside a domestic oven as a temperature sensor in a potential divider circuit.

Fig. 2.1 shows the potential divider circuit in which the component $\mathbf{R_2}$ is connected in parallel to the input of an electronic circuit that switches the mains supply to the heating element in the oven on or off.

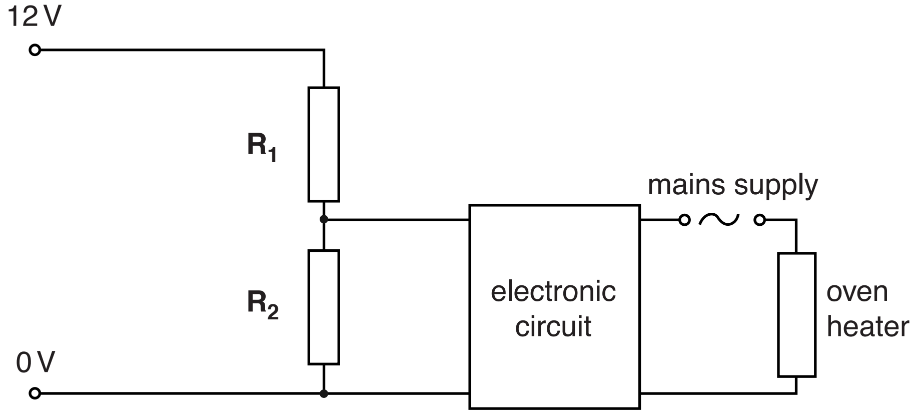


Fig. 2.1

(a) $\mathbf{R_1}$ is a variable resistor and $\mathbf{R_2}$ is the thermistor. The circuit symbols for $\mathbf{R_1}$ and $\mathbf{R_2}$ are incomplete. Complete these circuit symbols on Fig. 2.1. **[2]**

(b) It is required that the p.d. across the thermistor $\mathbf{R_2}$ is 7.0 V when at a temperature of 180 °C. The variation of resistance with temperature for $\mathbf{R_2}$ is shown in Fig. 2.2.

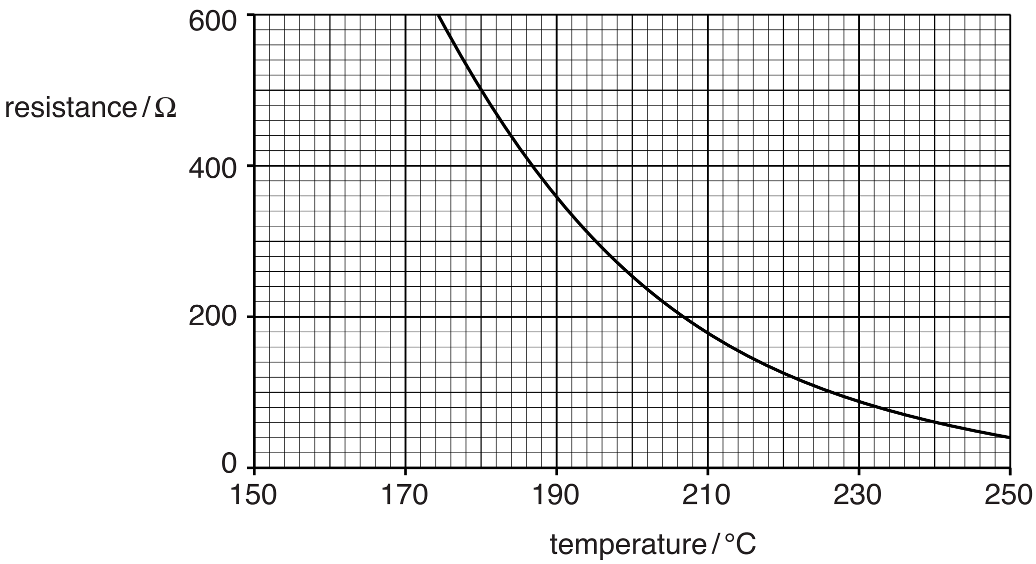


Fig. 2.2

(i) Use Fig. 2.2 to determine the resistance of $\mathbf{R_2}$ at a temperature of 180 °C.

resistance = ... Ω **[1]**

(ii) When the temperature is 180 °C the p.d. across $\mathbf{R_2}$ is 7.0 V. Calculate the current in $\mathbf{R_2}$.

current = ... A **[1]**

(iii) The electronic circuit draws a negligible current. Show that the resistance of the variable resistor $\mathbf{R_1}$ must be about 350 Ω.

[2]

(iv) $\mathbf{R_2}$ is heated slowly. Show that the p.d. across $\mathbf{R_2}$ must fall to about 5.0 V when the temperature of $\mathbf{R_2}$ reaches 200 °C.

[2]

(c) The thermistor $\mathbf{R_2}$ is fitted inside the oven. When the p.d. across $\mathbf{R_2}$ falls to 5.0 V the oven heater switches off. The oven cools until the p.d. across $\mathbf{R_2}$ rises to 7.0 V when the heater switches on again.

$\mathbf{R_1}$ is adjusted to 250 Ω. Calculate the temperatures at which the oven heater is switched on and off.

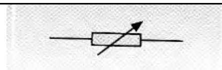
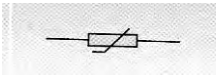
temperature on .... °C

temperature off .... °C **[4]**

Question			Expected Answers	M	Additional Guidance
1					
	a	i	V J $^{-1}$ R V $^{-1}$ P J $^{-1}$ I C $^{-1}$.	B1 B1 B1	4 correct 3 marks; 2 correct 2 marks 1 correct 1 mark
	b	i	using $V_{out} = R_2/(R_1 + R_2)\ V_{in}$: **alt:** 2.4 = I x 560 V_{out} = 3.6 V so I = 4.3 mA 3.6 = R_2/(560 + R_2) 6 3.6 = I R_2 R_2 = 840 (Ω)	C1 C1 A1	 **accept** R_2 = (3.6/2.4) x 560 or .2.4 = 560/(560 + R_2) 6
		ii	I = 4.3 x 10^{-3} (A)	B1	**accept** 4.3 m(A) or 3/700 (A) **ecf (b)(i)** i.e. I = 6/(560 + R_2)
	c	i	20 ± 2 (^{o}C)	B1	
		ii	R_{Th} will fall/ resistance will fall giving greater share of supply V across fixed R/AW causing the voltage across (fixed) R/voltmeter reading to rise	B1 B1 B1	 **accept** explanation in terms of potential divider equation **or** current increases **or** current same in both resistors/resistors in series
		iii	ΔR is large for small ΔT at low temperatures/AW in terms of gradient so thermistor is better in circuit to control low temp, refrigerator	M2 A1	**accept** sensitivity greater at low temperature **or** vice versa **or** ΔR is small for small ΔT at high temperatures scores 1 out of 2
			Total question 3	**14**	

Question			Expected Answers	Marks	Additional Guidance
2					
	a		ρ = RA/l with terms defined	M1 A1	full word definition gains both marks **allow** *A is area* as adequate; no unit cubes
	b	i	**either** the cable consists of (38) strands in parallel; **or** the area of the cable is 38 times the area of a strand or vice versa; so the resistance of 1 strand is 38 times bigger, (i.e. 1.98 Ω km^{-1}) **or** the resistance is inversely proportional to the area	B1 B1	max 1 mark for 38 x 0.052 = 1.98 with no further explanation **allow** with **either** and **or** **allow only** with **or**
		ii	A = ρ l/R = 2.6 x 10^{-8} x 1000/2.0 = 1.3 x 10^{-5} (m^2)	C1 A1	**allow** 1 mark max. for R = 0.052 giving A = 5.0 x 10^{-4} (m^2) **give** 1 mark max. for 1.3 x 10^{-8} (m^2)
	c	i	P = VI = 400x 10^3 x 440 = 1.8 x 10^8 (W) or 180 M(W)	C1 A1	P = VI **not** adequate for first mark **expect** 176
		ii	2000/176 = 11.4 so 12 required	B1	**ecf(c)(i);** using 180 gives 11.1
		iii	P = I^2R = 440^2 x 0.052 = 1.0 x 10^4 W (km^{-1}) or 10 kW (km^{-1})	C1 C1 A1	**accept** power/cable = 2000/12 = 167 MW I = 167M/400k = 417 A P = 417^2 x 0.052 = 9.0(3) kW (km^{-1}) **N.B.** answer mark includes consistent unit
		iv	power lost per cable = 10 k x 100 x 12 = 12.0 MW fraction remaining = (2000 – 12)/2000 = 0.994 x 100 = 0.994 so 99.4% or power lost per strand = 10 k x100 = 1.0 MW fraction remaining = (176 – 1)/176 = 0.994 so 99.4%	C1 A1	**ecf(c)(ii)(iii)** **allow** second mark for 'correct' answer as fraction not percentage with BOD sign **allow** 1 mark max. if give correct % lost given rather than % remaining **allow** 1 mark max. for 100 x (2000 – 1)/2000 = 99.95%
			Total question 2	**14**	

Question			Expected Answers	Marks	Additional Guidance
3					
	a		resistors in series add to 20 Ω and current is 0.60 A so p.d. across XY is 0.60 x 12 (= 7.2 V)	B1 B1	**accept** potential divider stated **or** formula gives (12 /20) x 12 V (= 7.2)V
	b	**i**	the resistance of the LDR decreases (so total resistance in circuit decreases) and current increases	M1 A1	
		ii	resistance of LDR and 12 Ω (in parallel)/across **XY** decreases so has smaller share of supply p.d. (and p.d. across XY falls)	B1 B1	**alternative** I increases so p.d. across 8.0 Ω increases; so p.d. across **XY** falls
			Total question 3	**6**	

Question			Answer	M	Guidance
4					
	a		 for R_1  for R_2	B1 B1	
	b	i	500 Ω	B1	**accept** ± 20 Ω
		ii	7.0 = I x 500; I 0.014 (A)	B1	**ecf b(i)**
		iii	5.0 = 0.014 x R or 12 = 0.014(500 + R) R = 360 Ω	M1 A1	**ecf b(i)(ii)** **allow** R = 500 x 5/7 = 360 Ω
		iv	(at 200°C) R_{th} = 250 Ω V across thermistor =12 x 250/(250 + 350) = 5.0 V **alt** 5.0 = 12 x R/(R + 350) **or** I = 7.0/350 = 0.02 A; V_h = 5.0 = 0.02 x R R = 250 Ω which occurs at 200°C	B1 B1	**allow** R_{th} = 250 ± 10 giving 4.8 to 5.1 V **expect** 350 or 360; **allow** 1 SF where answer is 5.0 **NOT** 250 x 0.02 = 5.0 V; 0.02 A must be justified **allow** 7.0 = 12 x 350/(350 + R)
	c		**switch on** 5.0 = 12 x 250/(250 + R) or 7.0 = 12 x R/(250 + R) giving R = 350 Ω which is 190°C **switch off** 7.0 = 12 x 250/(250 + R) or 5.0 = 12 x R/(250 + R) giving R = 180 Ω which is 210°C **or** Switch on, R2 / R1 = 7/5 giving R2 - 250 x 7/5 = 350 ohm Switch off, R2 / R1 = 5/7 giving R2 = 250 x 5/7 = 179 ohm	M1 A1 M1 A1	**accept** solution in 2 stages first calculating currents on I = 0.02 and R = 7/0.02 off I = 0.028 and R = 5/0.028 **allow** ± 5°C in reading from graph **N.B.** zero marks for correct temperatures quoted without some correct working/justification
			Total question 2	**12**	