COE. DC

Challenging **MCQ** questions by The Physics Cafe

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1 In Fig 5.1. below, an electrical device (load) is connected in series with a cell of e.m.f. **2.5 V** and internal resistance *r*. The current *I* in the circuit is **0.10 A**. The power dissipated in the load is **0.23 W**.

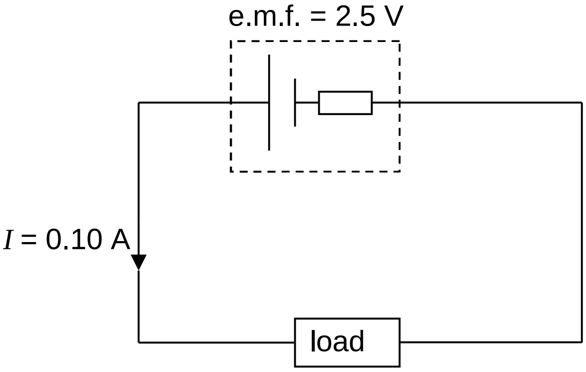

Fig 5.1

(a) S.I. unit for resistance is defined as the Ohm (Ω).

Define the Ohm.

……..

……………………………………………………………………………………………………[1]

(b) Show that the internal resistance *r* of the cell is **2.0 Ω.**

[1]

(c) A second identical cell is connected into the circuit in **(a)** as shown below in Fig.5.2.

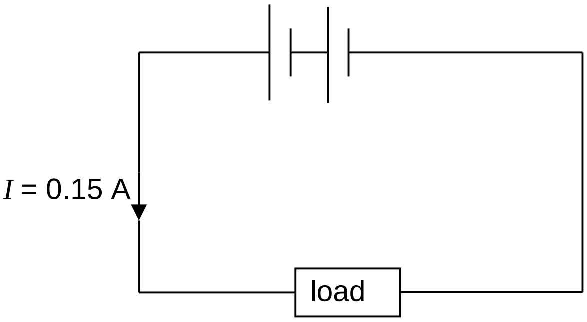

Fig. 5.2

The current in this circuit is **0.15 A**. Deduce that the load is a non-ohmic device.

……………………………………………………………………………………………

…………………………………………………………………………………………… [3]

Ans **(a)** <u>One ohm</u> is the <u>resistance of a conductor</u> in which <u>the current is 1 ampere</u> <u>when a potential difference of 1 volt is applied across it</u>.

OR

One ohm is the <u>resistance of a conductor</u> in which the <u>ratio of potential difference across it</u> <u>to</u> the <u>current flowing through</u> it is <u>1 volt</u> <u>per</u> <u>ampere</u>.

(b) Power dissipated in r = Total Power – Power dissipated in Load

$I^2 r = \varepsilon I - P_L$

$(0.10)^2 r = (2.5)(0.10) - 0.23$

$r = 2.0\ \Omega$

(c) <u>Single cell</u>

Resistance of Load, $R_1 = \frac{0.23}{0.10^2} = 23\Omega$

<u>Two cells</u>

$5.0 = 0.15R + 0.15 \times 4.0$

Resistance of Load, $R_2 = 29\ \Omega$

As <u>an ohmic device has constant resistance</u>, since the <u>load's resistance has changed/ increased</u>, the load can be deduced as a non-ohmic device.

2 **(a)** Define *potential difference* between two points on an electric circuit.

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....

.... [1]

(b) A cell of e.m.f. **4.5 V** and internal resistance of **0.70 Ω** is connected in series with a resistor R, as shown in Fig. 3.1. Resistor R is made of metal wire and the ammeter reads **200 mA.**

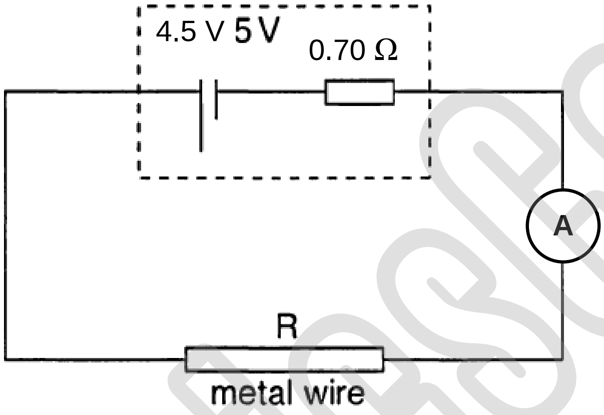

Fig. 3.1

Determine the resistance of R.

resistance of R = ………………… Ω [2]

(c) A second similar cell is now connected in series with the cell in **(b)** and the resistor R. The current in the circuit is **350 mA** and the resistance of R changes.

Calculate the new resistance of R.

new resistance of R = ………………… Ω [2]

(d) The cells in **(c)** are now connected in series with a fixed resistor of resistance **2500 Ω** and a thermistor, as shown in Fig. 3.2.

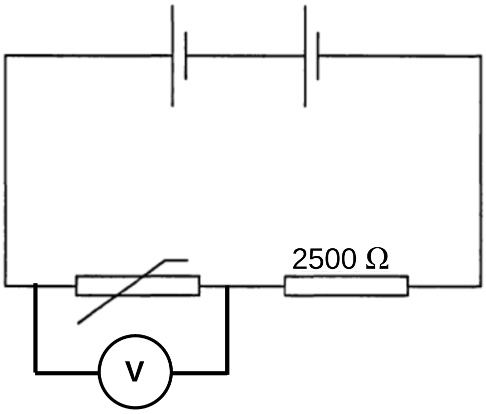

Fig. 3.2

The thermistor has resistance **5000 Ω** at **0 °C** and **2250 Ω** at **20 °C**.

(i) Determine the maximum and the minimum values of the readings of the voltmeter as the temperature of the thermistor is varied from 0 °C to 20 °C.

The internal resistance of the cells can be assumed to be negligible and the voltmeter has a very high resistance.

maximum reading = ……….. V

minimum reading = ……… V [2]

(ii) In one particular application of the circuit shown in Fig. 3.2, it is desired that the potential difference across the **fixed** resistor should range from **3.6 V** at 0 °C to **7.2 V** at 20 °C.

Determine whether, by substituting a different fixed resistor in the circuit of Fig. 3.2, it is possible to achieve this range of potential.

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…………………………………………………………………………………………………… [3]

Ans **(a)** Potential difference between two points on a circuit is the amount of **energy** converted **per unit charge** from **electrical** to **non electrical** between the two points.

(b) $\varepsilon = IR + Ir$

$IR = \varepsilon - Ir$

$(0.20)R = 4.5 - (0.70 \times 0.20)$

$R = 21.8\ \Omega$

(c) Note that the total internal resistance is sum of the individual internal resistance (1.40 Ω).

$\varepsilon = IR + Ir$

$IR = \varepsilon - Ir$

$(0.35)R = (4.5+4.5) - (1.40 \times 0.35)$

$R = 24.3\ \Omega$

(d) (i) By using potential divider,

maximum reading is obtained when the resistance of the thermistor is 5000 Ω.

maximum reading = $\frac{5000}{5000+2500} \times 9.0 = 6.0$ V (2 s.f.)

minimum reading is obtained when the resistance of the thermistor is 2250 Ω.

minimum reading = $\frac{2250}{2250+2500} \times 9.0 = 4.3$ V

(ii) At 0 °C, resistance of thermistor is 5000 Ω. let R be the resistance of the fixed resistor

$3.6 = \frac{R}{R+5000} \times 9.0$

Solving, $R = 3330\ \Omega$.

At 20 °C,

$7.2 = \frac{R}{R+2250} \times 9.0$

Solving, $R = 9000\ \Omega$.

The values of resistance of the fixed resistor for the two conditions are not the same. Hence, it is **not possible** to substitute **a single** fixed resistor to meet the requirements.

3 The variation of electrical resistance of a thermistor with temperature is shown in Fig. 5.1.

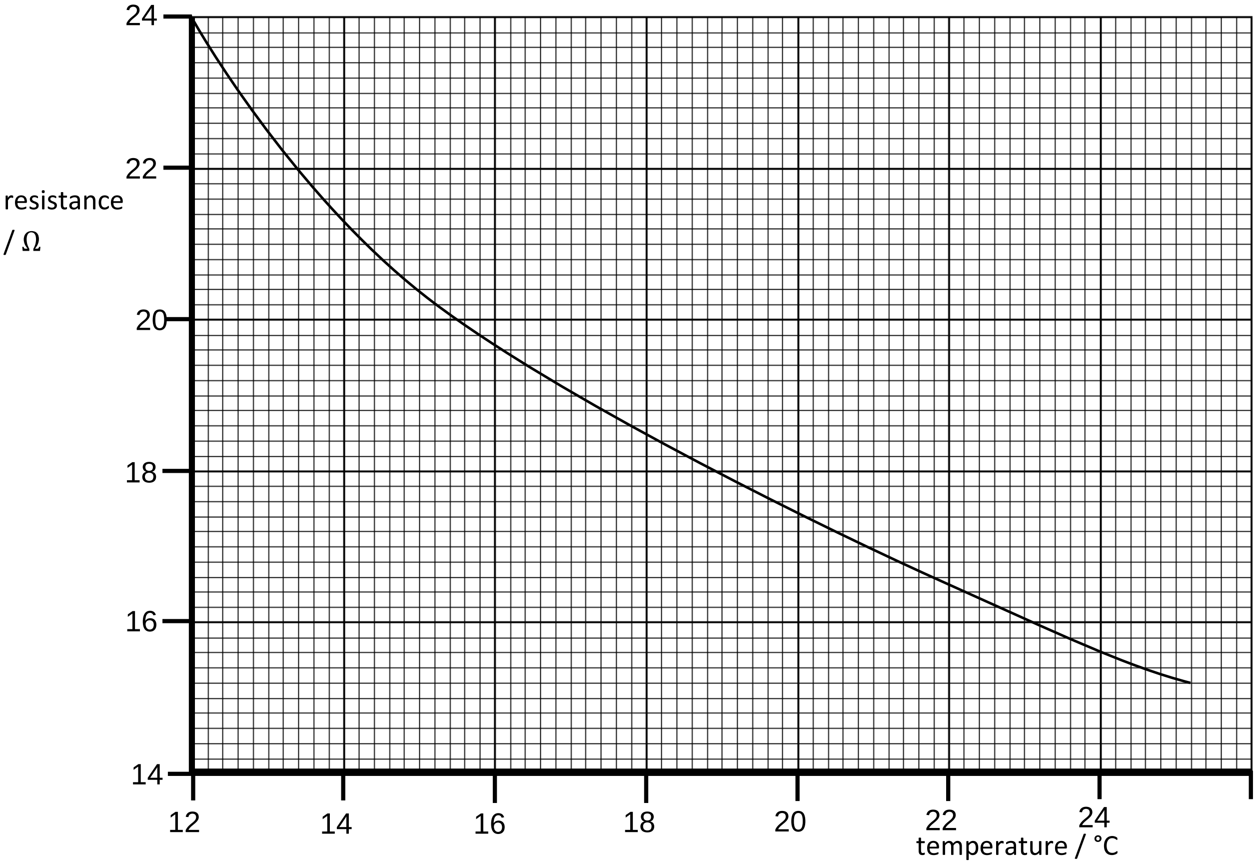

Fig. 5.1

(a) Thermistors can be made with intrinsic semiconductor materials.

Describe how band theory is used to explain the trend of the graph shown in Fig. 5.1.

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(b) Fig. 5.2 shows a circuit which can be used to determine the temperature of the thermistor with the help of Fig. 5.1. A uniform metre wire AB is connected between the terminals of a driver cell of e.m.f. **3.0 V** and of negligible internal resistance.

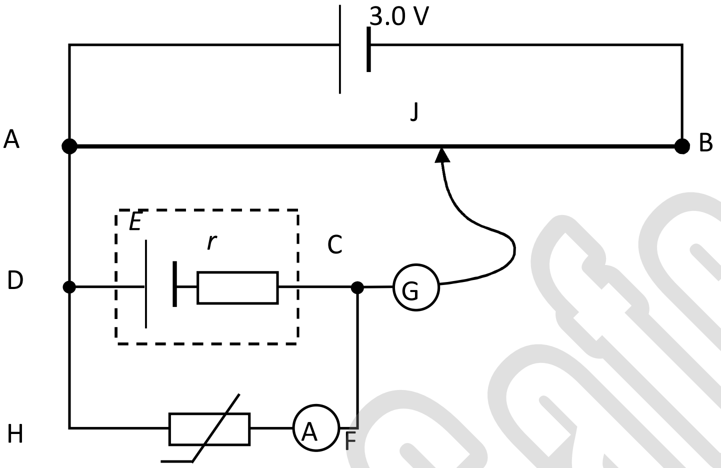

Fig. 5.2

(i) State the ratio of the potential differences across AJ and HF at balance length.

ratio = ………………………………. [1]

(ii) Explain whether the temperature measurement is more or less accurate when the internal resistance of battery *E* is large.

………………………………………………………………………………………

……………………………………………………………………………………… [2]

(iii) The galvanometer shows zero deflection when length AJ is **0.40 m**.
Determine the potential difference across HF.

potential difference = ………………………………. V [1]

(iv) Given that the temperature of the thermistor is 24.0°C at balance length conditions,

1. state the resistance of the thermistor,

resistance = ………………………………. Ω [1]

2. determine the current flowing through battery *E.*

current = ………………………………. A [1]

3. Circuit DCHF is at a situation where there is maximum power being transferred from the battery to the thermistor.
Calculate the e.m.f. of battery.

e.m.f. = ………………………………. V [2]

(v) Determine the balance length when the semiconductor-based thermistor is at 0K. Explain your working.

balance length = ………………………………. m [2]

Ans **(a)** resistance decreases with temperature B0

At higher temperatures, greater availability of thermal energy
Electrons from valence band can be promoted to conduction band,
leaving behind holes in the valence band. B1

negative-charged electrons in the conduction band and
positively-charged holes in the valence band
serve as mobile charge carriers B1

effect of having more free mobile charge carriers,
outweigh that of the increased lattice vibration
which disrupting smooth slow of the mobile charge carriers B1 [3]

(b) (i) 1 B1 [1]

(b) (ii) larger total resistance in circuit → smaller current in DCHF M1

less resistive heating effect in thermistor, more accurate A1 [2]

OR

p.d. across HF decreases → balance length decreases M1

percentage uncertainty in length increases, less accurate A1

(b) (iii) $\frac{0.40}{1} = \frac{V_{HF}}{emf} \rightarrow V_{HF} = (0.40)(emf) = 1.2\text{ V}$ B1 [1]

(b) (iv) 1. 15.6 Ω (read to nearest 0.1 Ω) B1 [1]

(b) (iv) 2. $V_{HF} = R_{thermistor}I \rightarrow I = \frac{1.2}{15.6} = 0.0769\text{ A}$ B1 [1]

(b) (iv) 3. maximum power theorem: $r = R_{\text{thermistor}}$ M1

$V_{DC} = E - V_r \rightarrow E = V_{DC} + V_{thermistor} = 2V_{thermistor} = 2.4\text{ V}$ A1 [2]

(b) (v) no thermal energy available
electrons cannot be promoted valence to conduction band
no conduction of electricity possible, infinite resistance M1

$V_{AJ} = emf \rightarrow L_{AJ} = \frac{2.4}{3.0}(1) = 0.80\text{ m}$ A1 [2]