AS Level Physics

Chapter 7 – Electricity

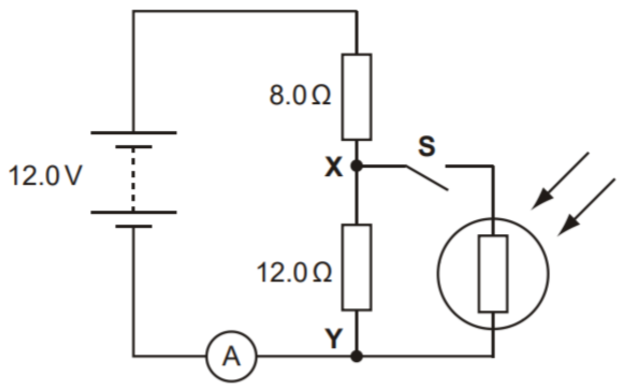
7.7.2 Potential Dividers

Worked Examples

Potential Dividers

Exam Style Question 1

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



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

(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

(ii) the potential difference across XY.

Potential Dividers

Exam Style Question 1

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

Step 1: Calculate the current through the circuit using $V = IR$

The two resistors are in series so add them together to give:

$$R_{total} = 12.0\ \Omega + 8.0\ \Omega = 20.0\ \Omega$$

Step 2: Rearrange $V = IR$ to find I:

$$I = \frac{V}{R} = \frac{12.0\ V}{20.0\ \Omega} = 0.60\ A$$

Step 3: Use $V = IR$ but $R = 12.0\ \Omega$ and $I = 0.60\ A$ to calculate the voltage through points X and Y:

$$V = (0.60\ A)(12.0\ \Omega) = 7.2\ V$$

(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

The resistance of the LDR decreases so the total resistance in the circuit decreases and the current increases.

(ii) the potential difference across XY.

The total resistance across XY decreases because of the LDR and the $12\ \Omega$ resistor are in parallel. This means the p.d. across XY has a smaller share of the supply p.d. and the p.d. across XY decreases.

Potential Dividers

Exam Style Question 2

Fig. 1 shows a thermistor and fixed resistor of $200\ \Omega$ connected through a switch S to a $24\ V$ d.c. supply of negligible internal resistance. The voltmeter across the fixed resistor has a very high resistance.

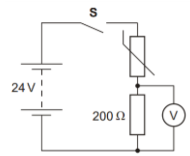


Fig. 1

(a) When the switch S is closed the voltmeter initially measures $8.0\ V$.

Calculate

(i) the current I in the circuit

(ii) the potential difference V_T across the thermistor

(iii) the resistance R_T of the thermistor

(iv) the power P_T dissipated in the thermistor.

(b) A few minutes after closing the switch S the voltmeter reading has risen to a steady value of $12\ V$. The value of the fixed resistor remains at $200\ \Omega$.

Explain why

(i) the potential difference across the fixed resistor has increased

(ii) the resistance of the thermistor must now be $200\ \Omega$.

(c) Sketch, on the labelled axes of Fig. 2 below, a possible I-V characteristic for:

(i) the fixed resistor. Label it R.

(ii) the thermistor. Label it T.

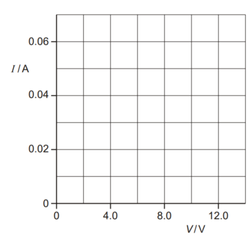


Fig. 2

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Potential Dividers

Exam Style Question 2

(a) Calculate

(i) the current I in the circuit

Use $V = IR$ and rearrange for I:

$$I = \frac{V}{R} = \frac{8.0\ V}{200\ \Omega} = 0.04\ A$$

(ii) the potential difference V_T across the thermistor

We know there are $24\ V$ supplied from the battery and $8\ V$ is used by the resistor therefore the voltage across the thermistor is:

$$V_T = 24\ V - 8\ V = 16\ V$$

(iii) the resistance R_T of the thermistor

Use $V = IR$ and rearrange for R:

$$R = \frac{V}{I} = \frac{16\ V}{0.04\ A} = 400\ \Omega$$

(iv) the power P_T dissipated in the thermistor.

Use $P = IV$

$$P = (0.04\ A)(16\ V) = 0.64\ W$$

(b) Explain why

(i) the potential difference across the fixed resistor has increased

The thermistor has heated up and so its resistance has dropped. However, the resistance across the fixed resistor is the same so the fixed resistor gets a larger share of the voltage.

(ii) the resistance of the thermistor must now be $200\ \Omega$.

The voltages are equal, so resistances are equal.

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Potential Dividers

Exam Style Question 2

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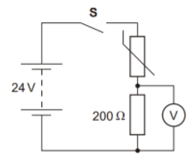

Fig. 1

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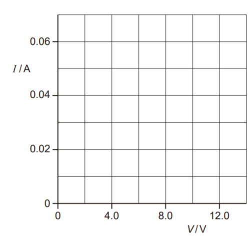

Fig. 2

Potential Dividers

Exam Style Question 2

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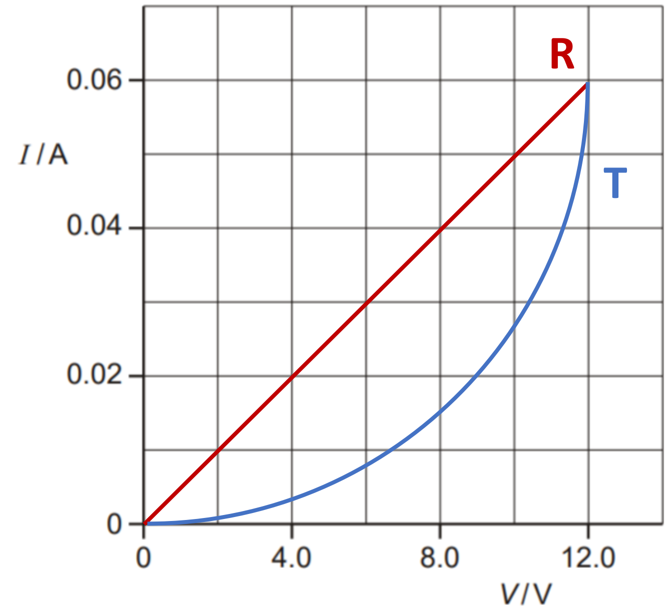


Fig. 2

Potential Dividers

Exam Style Question 3

Fig. 3.1 shows a circuit consisting of a battery of electromotive force $16.0\ V$ and negligible internal resistance, two resistors and a thermistor.

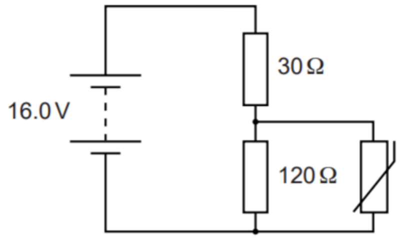


Fig. 3.1

(a) (i) Define the term electromotive force (e.m.f.).

(ii) Explain the meaning of the term internal resistance.

(b) The thermistor has a resistance of $360\ \Omega$ at $20\ °C$. Calculate

(i) the total resistance R of the thermistor and the resistor of resistance $120\ \Omega$ at $20\ °C$

(ii) the potential difference V across the thermistor.

(iii) It is suggested that the thermistor in the circuit of Fig. 3.1 is used to monitor temperatures between $20\ °C$ and $200\ °C$. Describe how the potential difference across the thermistor and the current in it will vary as the temperature increases above $20\ °C$.

(c) The battery in Fig. 3.1 is rechargeable.

(i) Calculate the charge stored in the battery when it is charged for $8.0\ hours$ at a constant current of $1.2\ A$.

(ii) After charging, the battery loses energy at a constant rate of $1.4\ J\ s^{-1}$. The e.m.f. of the battery remains constant at $16.0\ V$. Calculate how many hours it takes for the battery to discharge.

Potential Dividers

Exam Style Question 3

(a) (i) Define the term electromotive force (e.m.f.).
Energy transferred from source and changed from some form to electrical energy per unit charge.

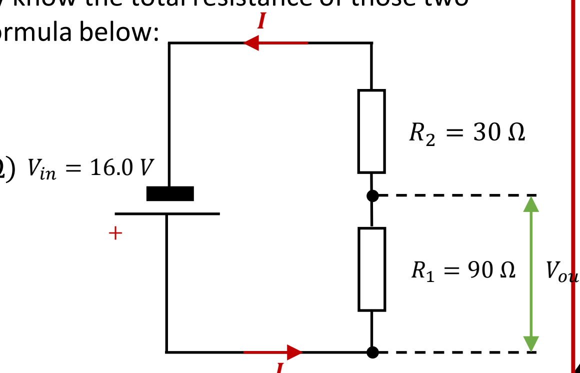
(a) (ii) Explain the meaning of the term internal resistance.
This is when some energy is transferred into thermal energy (or lost as heat) in the battery. The battery behaves as if it has an internal resistance and develops lost volts.

(b) (i) Calculate the total resistance R of the thermistor and the resistor of resistance $120\ \Omega$ at $20\ °C$.

$$\frac{1}{R_T} = \frac{1}{120\ \Omega} + \frac{1}{360\ \Omega}$$
$$\frac{1}{R_T} = \frac{1}{90}$$
$$R_T = 90\ \Omega$$

(b) (ii) the potential difference V across the thermistor.
Remember the thermistor and the $120\ \Omega$ are in parallel so they share the same voltage, and we already know the total resistance of those two resistors so we can use the formula below:

$$V_{out} = \left(\frac{V_{in}}{R_1 + R_2}\right) R_1$$
$$V_{out} = \left(\frac{16\ V}{30\ \Omega + 90\ \Omega}\right)(90\ \Omega)$$
$$V_{out} = 12\ V$$



Potential Dividers

Exam Style Question 3

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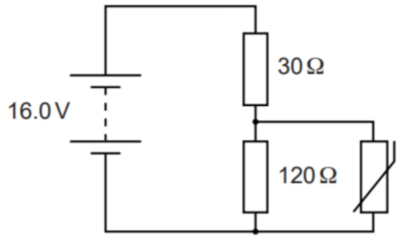

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(i) the total resistance R of the thermistor and the resistor of resistance $120\ \Omega$ at $20\ °C$

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(c) The battery in Fig. 3.1 is rechargeable.

(i) Calculate the charge stored in the battery when it is charged for $8.0\ hours$ at a constant current of $1.2\ A$.

(ii) After charging, the battery loses energy at a constant rate of $1.4\ J\ s^{-1}$. The e.m.f. of the battery remains constant at $16.0\ V$. Calculate how many hours it takes for the battery to discharge.

Potential Dividers

Exam Style Question 3

(b) (iii) Describe how the potential difference across the thermistor and the current in it will vary as the temperature increases above $20\ °C$.

Resistance of the thermistor decreases with temperature increase.
Therefore, current in the circuit increases.
The resistance decreases for the combination ($120\ \Omega$ resistor and thermistor) and the resistance across the $30\ \Omega$ resistor stays the same. This means the combination gets a lower share of the total voltage and so the voltage across the thermistor falls.

(c) (i) Calculate the charge stored in the battery when it is charged for $8.0\ hours$ at a constant current of $1.2\ A$.

Use $Q = It$

$$t = 8.0\ hours \times 3600\ seconds = 28800\ seconds$$
$$Q = (1.2\ A)(28800\ seconds) = 34560\ C$$

(c) (ii) Calculate how many hours it takes for the battery to discharge.

Use $energy = QV$

$$energy = 34560\ C \times 16\ V = 552960\ J$$

And we know the battery loses energy at a constant rate of $1.4\ J\ s^{-1}$ therefore the time taken to discharge the battery is:

$$time = \frac{552960\ J}{1.4\ J\ s^{-1}} = 394971.4286\ s$$

Now convert the value from seconds to hours:

$$time = \frac{394971.4286\ s}{3600\ s} = 109.7\ hours = 110\ hours$$

Please see '7.7.1 Potential Dividers notes' pack for revision notes.

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