Current Electricity

Name _____ Date _____

By the end of this topic I can...

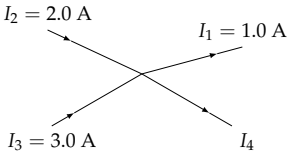
- state and use Kirchhoff's two laws
- combine resistors in series and parallel
- use e.m.f., internal resistance, terminal p.d. and lost volts
- use potential dividers, a potentiometer and bridge circuits

Kirchhoff's laws

Kirchhoff's first law: at any point in a circuit the sum of currents _____ the point equals the sum of currents _____ it:

- a consequence of conservation of _____

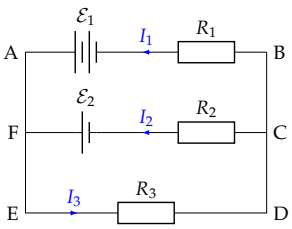
Example 12.1 The diagram shows part of an electric circuit. The values of I_1, I_2 and I_3 are labelled. Calculate the current I_4.



Kirchhoff's second law: around any closed loop the sum of the e.m.f.s equals the sum of the p.d.s:

- a consequence of conservation of _____; choose a loop direction and be consistent with signs

Example 12.2 The diagram shows a circuit where e.m.f. of the batteries and the values of resistance are all known. Write down the equations for the currents I_1, I_2 and I_3 using Kirchhoff's laws.



Resistor networks

Series

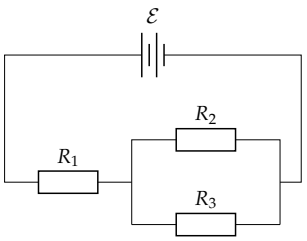
- same _____ through each; p.d.s _____

Parallel

- same _____ across each; currents _____

- adding a resistor in series _____ R_{total}; adding one in parallel _____ it
- n identical resistors R_0 in parallel: $R_{\text{total}} =$ _____

Example 12.3 In the circuit shown, the battery has an e.m.f. $\mathcal{E} = 18$ V, and the resistors have $R_1 = 6.0\ \Omega$, $R_2 = 4.0\ \Omega$ and $R_3 = 12\ \Omega$. (a) Find the total resistance of all external resistors. (b) Find the current through the battery. (c) Find the p.d. across R_1, R_2 and R_3. (d) Find the total power dissipated in R_2 and R_3.



Internal resistance

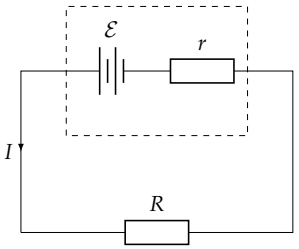
• a real source has **internal resistance** r: it behaves as an ideal cell of e.m.f. $\mathcal{E}$ in series with r

• $V_R = IR$ is the **terminal p.d.**; $V_r = Ir$ is the **lost volts**, so $V_R = \mathcal{E} - Ir$ is _____ the e.m.f. when current flows

• maximum current (short circuit, $R = 0$): $I_{\max}$ = _____; open circuit: $I = 0$ and terminal p.d. = _____

• powers: total = _____; to external circuit = _____; lost in the cell = _____

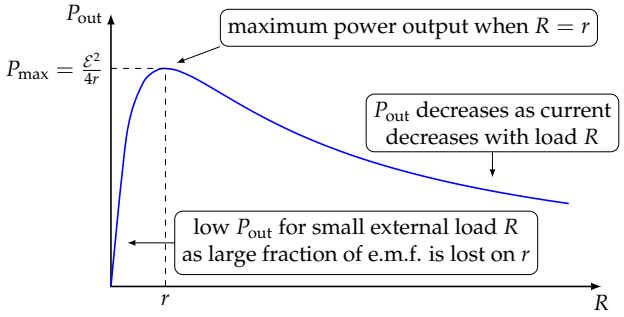
Example 12.4 A car battery has an e.m.f. of 20 V and an internal resistance of 0.50 Ω. When a starter motor of resistance of 3.50 Ω is connected to the battery, find (a) the current supplied to the motor, (b) the p.d. across the battery terminals, (c) the power at which the motor operates.



Example 12.5 A battery of e.m.f. 12 V is connected to a network of total resistance of 22 Ω. The current through the battery is 0.50 A. Find (a) the internal resistance of the battery, (b) the total power produced by battery, (c) the power dissipated in battery.

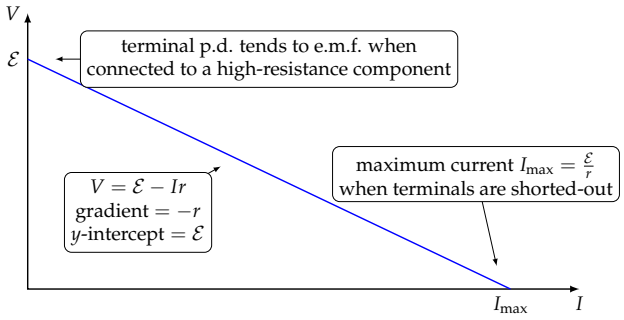
Example 12.6 An electric heater is operating at a working p.d. of 200 V. A current of 5.0 A is driven by a voltage source of 230 V. The source has an internal resistance of 4.0 Ω and the resistance of the connecting wires is not negligible. Find (a) the lost volts in the source, (b) the resistance of the wires, (c) the useful power from the source, (d) the efficiency of this circuit.

Example 12.7 A cell of e.m.f. $\mathcal{E}$ and internal resistance r is connected in series with a variable resistor R. R is gradually increased from zero. (a) Suggest how the p.d. across the battery terminals change when R is increased. (b) For larger values of R, power delivered to R decreases. Suggest the advantage, despite the low power output, of using this cell in a circuit of larger resistance.



• output power to the load is greatest when $R =$ ____: $P_{max} =$ _____

Measuring e.m.f. and internal resistance



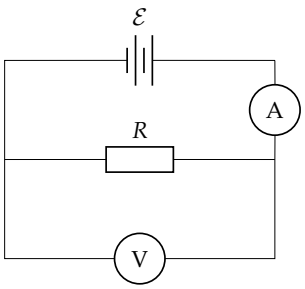
• vary R and record V and I; since $V = \mathcal{E} - Ir$, a graph of V against I is a _____ with y-intercept = ____ and gradient = _____

Meters

• an ideal ammeter has _____ resistance; an ideal voltmeter has _____ resistance

• real meters have a resistance: treat them as ordinary resistors in the circuit

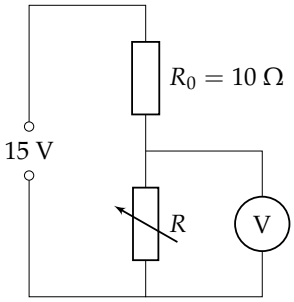
Example 12.8 The diagram shows a simple circuit. The battery has a negligible internal resistance and an e.m.f. of 8.0 V. The resistor has a fixed resistance of 20 Ω. (a) Find the readings shown on the ammeter and the voltmeter if both meters are ideal. (b) Instead, the ammeter has a non-zero resistance of 1.0 Ω and the voltmeter has a resistance of 60 Ω, what are the true readings displayed on the two meters?



Potential dividers

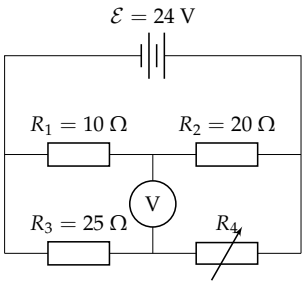
Two resistors in series share the supply p.d. in proportion to their resistances:

Example 12.9 The diagram shows an electric circuit incorporating a power supply of negligible internal resistance and a high-resistance voltmeter. Determine the range of voltage reading on the voltmeter as the variable resistor R is adjusted over its full range from 0 Ω to 50 Ω.



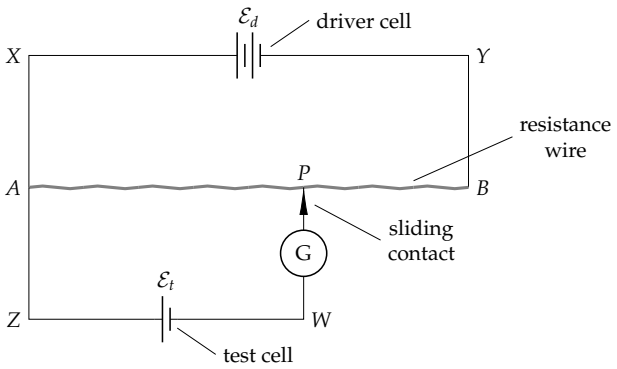
Bridge circuit

• the bridge is _____ (no current in the galvanometer) when $\frac{R_1}{R_2} =$ _____

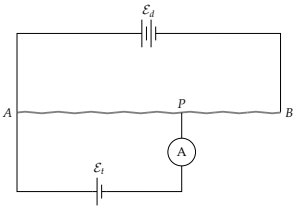


Example 12.10 Four resistors are connected to a battery as shown. (a) If the variable resistor R_4 is adjusted to have a resistance of 35 Ω, what is the reading on the voltmeter? (b) If the voltmeter reads zero, what is the resistance for R_4?

Potentiometer



• at balance no current flows through the _____, so its internal resistance causes _____; $\mathcal{E}_t = \dfrac{AP}{AB} \times \mathcal{E}_d$



Example 12.11 The driver cell has e.m.f. 17 V and internal resistance 5.0 Ω. Wire AB has resistance 80 Ω and length 80 cm. The galvanometer reads zero when $AP = 50$ cm. Find (a) the current in the wire, (b) the p.d. across AP, (c) the e.m.f. of the test cell.

Practice questions

Question 12.1 Explain, using resistors in series or parallel, (a) why a long wire has more resistance than a short wire, (b) why a thick wire has less resistance than a thin one.

Question 12.2 A 12 V battery of negligible internal resistance is connected to a 4.0 Ω resistor in series with a parallel pair of 6.0 Ω and 3.0 Ω resistors. Find (a) the total resistance, (b) the battery current, (c) the current in the 3.0 Ω resistor.

Question 12.3 A cell of e.m.f. 1.5 V and internal resistance 0.50 Ω is connected to a 2.5 Ω resistor. Find the current and the terminal p.d.

Question 12.4 A student measures a terminal p.d. of 1.50 V with no current and 1.20 V when the current is 0.50 A. Find the e.m.f. and internal resistance.

Question 12.5 A 12 V supply of negligible internal resistance is connected across a 4.0 kΩ resistor in series with an 8.0 kΩ resistor. What is the p.d. across the 8.0 kΩ resistor?

Question 12.6 A cell has e.m.f. 6.0 V and internal resistance 2.0 Ω. For what external resistance is the output power greatest, and what is that power?