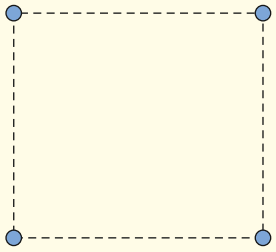
Additional Topic 5 questions

Test yourself

5.1 Electric fields

1 Four equal charges $q = -5.0\,\mu C$ are placed at the vertices of a square of side 12 cm, as in the diagram. Determine the force on the charge at the top right vertex.



2 A small plastic sphere is suspended from a fine insulating thread near, but not touching, a large sphere that is being charged. As the charge on the big sphere increases it is observed that **i** the plastic sphere is slowly attracted toward the large sphere, **ii** eventually touching it, **iii** at which point it is violently repelled. Carefully explain these observations.

3 The electric field at a point in space has magnitude $100\,N\,C^{-1}$ and is directed to the right. An electron is placed at that point. For this electron, calculate **a** the force and **b** the acceleration.

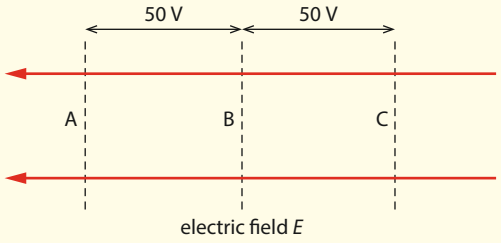
4 The number of electrons per second moving through the cross-sectional area of a copper wire is 4.0×10^{19}.

a Determine the current in the wire.

b The diameter of the wire is 1.5 mm and the number of free electrons per unit volume for copper is $8.5 \times 10^{28}\,m^{-3}$. Estimate the drift speed for the electrons.

5 Give an estimate for the number of free electrons per unit volume for gold (density $19\,390\,kg\,m^{-3}$; molar mass $197\,g\,mol^{-1}$). Assume that each atom contributes just one electron to the set of free electrons.

6 The potential difference between consecutive dotted lines in the diagram is 50 V. The red arrows indicate the electric field.



a Calculate the work that must be done by an external agent in moving a charge of $+5.0\,\mu C$ from A to B.

b Repeat the calculation in **a** when the same charge is moved from A to C.

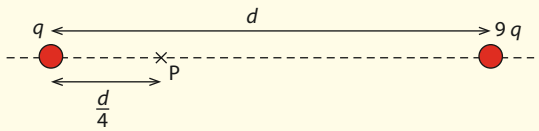
c The $+5.0\,\mu C$ charge is moved from A to C and then from C to B. Calculate how much work would be required then. Compare your answer to that in part **a** and comment.

d An electron is released from rest from a point on line B. State whether the electron will reach line A or line C and calculate its speed there.

7 a An electron is accelerated by a potential difference of 100.0 V. Determine the speed of the electron after acceleration.

b Determine the speed a proton would attain if accelerated by the same potential difference as the electron.

8 Two positive point charges of magnitude q and $9q$ are a distance d apart, as shown in the diagram.



a Calculate the electric field strength at point P, a distance $\frac{d}{4}$ from q.

b Sketch a graph of the electric field as a function of the distance x from the charge q. (Take the field to be positive if it is directed to the right.)

c How do the answers to **a** and **b** change if the charges are both negative?

5.2 Heating effect of electric currents

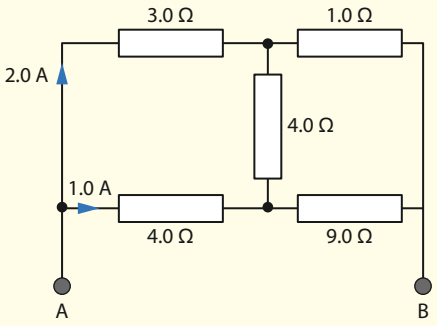
9 Explain why a light bulb is most likely to burn out when it is first turned on rather than later.

10 State the factors that affect the resistance of a metal wire.

11 Determine the factor by which the resistance of a wire changes when its radius is doubled.

12 The resistance of a fixed length of wire of circular cross-section is 10.0 Ω. Predict the resistance of a wire of the same length made of the same material but with only half the radius.

13 Look at the arrangement of resistors shown in the diagram.



a Find the current in, and potential difference across, each resistor. The potential at A is 12 V.

b What is the potential difference between A and B?

14 A light bulb is rated as 60 W at 220 V.

a Calculate the current flows in the light bulb when it is connected in series to a 220 V source of voltage.

b The lamp is connected in series to a 110 V source of voltage. Calculate the current flows in the lamp. (Assume the resistance stays the same.)

c Determine the power output of the light bulb when it is connected to the 110 V source.

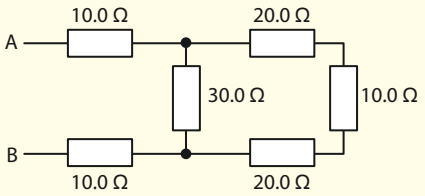
15 Determine the energy used when a 1500 W kettle is used for four minutes:

a in kW h

b in joules.

16 In country X the voltage supplied by the electricity companies is 110 V and in country Y it is 220 V. Consider a light bulb rated as 60 W at 110 V in X and a light bulb rated as 60 W at 220 V in Y. Take the cost of electricity per kW h to be the same. Suggest where it costs more to operate a light bulb for one hour.

17 Determine the resistance between A and B in the diagram.



18 Six light bulbs, each of constant resistance 3.0 Ω, are connected in parallel to a battery of emf = 9.0 V and negligible internal resistance. The brightness of a light bulb is proportional to the power dissipated in it. Compare the brightness of one light bulb when all six are on, to that when only five are on, the sixth having burnt out.

19 One light bulb is rated as 60 W at 220 V and another as 75 W at 220 V.

a Both of these are connected in parallel to a 110 V source. Determine the current in each light bulb. (Assume that the resistances of the light bulbs are constant.)

b Would it cost more or less (and by how much) to run these two light bulbs connected in parallel to a 110 V or a 220 V source?

20 Three appliances are connected (in parallel) to the same outlet, which provides a voltage of 220 V. A fuse connected to the outlet will blow if the current drawn from the outlet exceeds 10 A. The three appliances are rated as 60 W, 500 W and 1200 W at 220 V. Suggest whether the fuse blows.

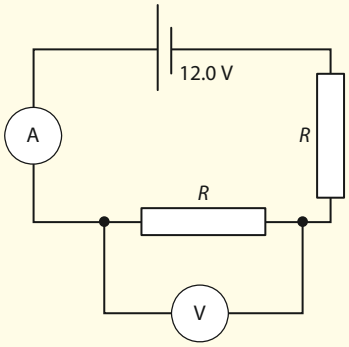
21 An electric kettle rated as 1200 W at 220 V and a toaster rated at 1000 W at 220 V are both connected in parallel to a source of 220 V. The fuse connected to the source blows when the current exceeds 9.0 A. Determine whether both appliances can be used at the same time.

22 At a given time a home is supplied with 100.0 A at 220 V. How many 75 W (rated at 220 V) light bulbs could be on in the house at that time, assuming they are all connected in parallel?

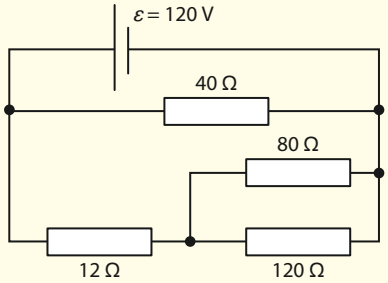
23 **a** Determine the reading of the voltmeter in the circuit shown in the diagram if both resistances are 200 Ω and the voltmeter also has a resistance of 200 Ω.

b Determine the reading of the ammeter.

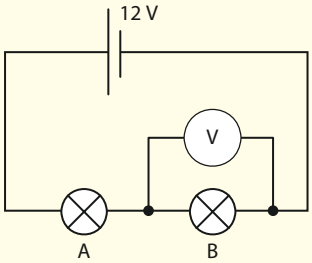
c The voltmeter is replaced by an ideal voltmeter. Determine the readings of the voltmeter and ammeter.



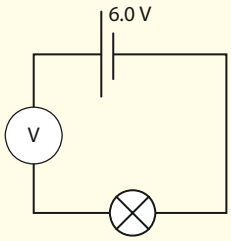
24 For the circuit shown in the diagram, calculate the current taken from the supply.



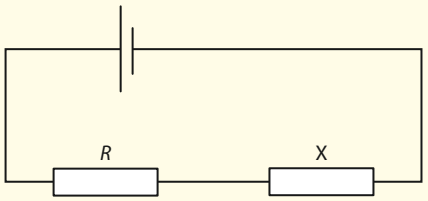
25 Two identical lamps are connected to a cell of emf 12 V and negligible internal resistance, as shown in the diagram. Calculate the reading of the (ideal) voltmeter when lamp B burns out.



26 State the reading of the ideal voltmeter in the circuit in the diagram.



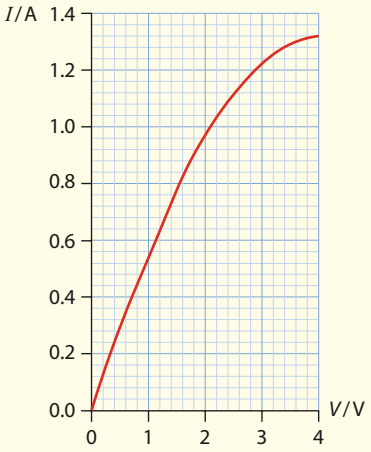
27 Two resistors are connected in series as shown in the diagram. The cell has negligible internal resistance. Resistor *R* has a constant resistance of 1.5 Ω.



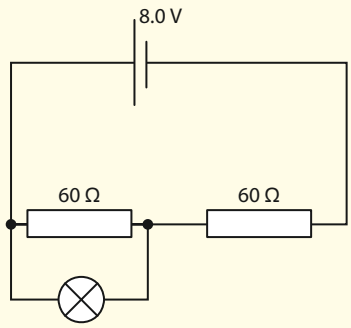
The current–voltage (*I*–*V*) characteristic of resistance X is shown in the diagram.

The potential difference across resistor *R* is 1.2 V.

Calculate the emf of the cell.

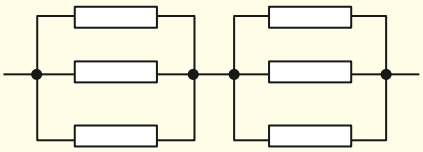


28 A lamp of constant resistance operates at normal brightness when the potential difference across it is 4.0 V and the current through it is 0.20 A. To light up the lamp, a student uses the circuit shown in the diagram.



a Calculate the resistance of the light bulb at normal brightness.
b Calculate the potential difference across the light bulb in the circuit in the diagram.
c Calculate the current through the light bulb.
d Hence explain why the light bulb will not light.

24 Each resistor in the diagram has a value of 6.0 Ω. Calculate the resistance of the combination.



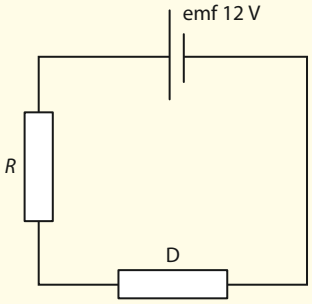
25 You are given one hundred 1.0 Ω resistors. Determine the smallest and largest resistance you can make in a circuit using these resistors.

26 A wire that has resistance R is cut into two equal pieces. The two parts are joined in parallel. What is the resistance of the combination?

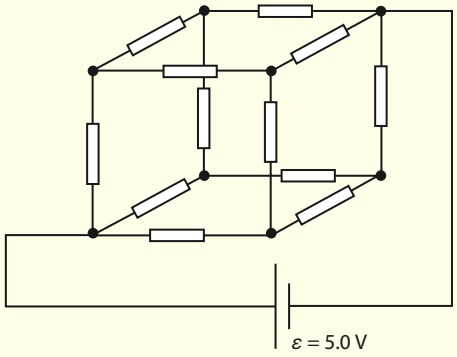
27 A toaster is rated as 1200 W and a mixer as 500 W, both at 220 V.
a Both appliances are connected (in parallel) to a 220 V source. Determine the current in each appliance.
b How much energy do these appliances use if both work for 1 hour?

28 Two light bulbs are rated as 60 W and 75 W at 220 V. If these are connected in series to a source of 220 V, what will the power in each be? Assume a constant resistance for the light bulbs.

29 A device D, of constant resistance, operates properly when the potential difference across it is 8.0 V and the current through it is 2.0 A. The device is connected in the circuit shown, in series with an unknown resistance R. Calculate the value of the resistance R. (The cell has negligible internal resistance.)



35 Twelve 1.0 Ω resistors are placed on the edges of a cube and connected to a 5.0 V battery, as shown in the diagram. Determine the current leaving the battery.



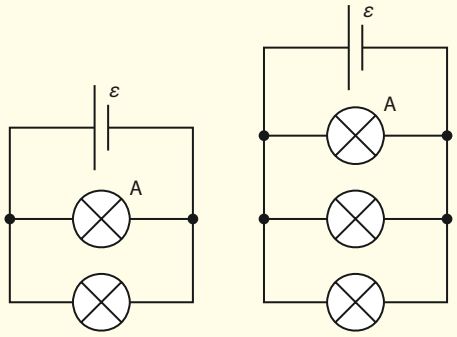
5.3 Electric cells

36 A direct current supply of constant emf 12.0 V and internal resistance 0.50 Ω is connected to a load of constant resistance 8.0 Ω. Find:

a the power dissipated in the load resistance

b the energy lost in the internal resistance in 10 min.

37 Two identical lamps, each of constant resistance R, are connected as shown in the circuit on the left. A third identical lamp is connected in parallel to the other two.

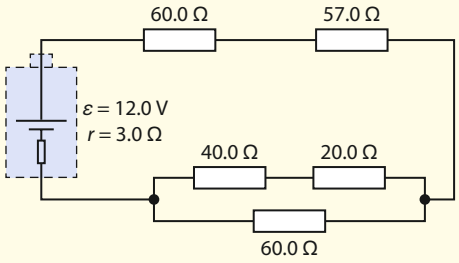


Compare the brightness of lamp A in the original circuit (left) with its brightness in the circuit with three lamps (right), when:

a the battery has no internal resistance

b the battery has an internal resistance equal to R.

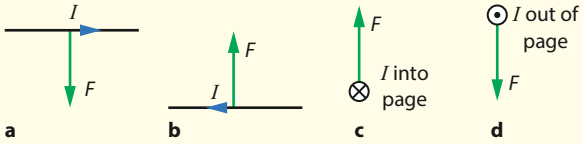
38 Find the current in each of the resistors in the circuit in the diagram. What is the total power dissipated in the circuit?



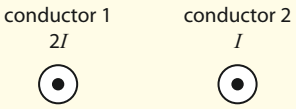
5.4 Magnetic fields

39 An electron is shot along the axis of a solenoid that carries current. Suggest whether it will experience a magnetic force.

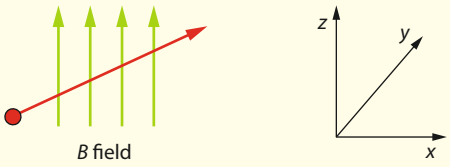
40 The diagram shows four different wires carrying current and the magnetic force on each. Determine the direction of the magnetic field in each case.



41 The diagram shows two parallel conductors carrying current out of the page. Conductor 1 carries double the current of conductor 2. On a copy of the diagram, draw to scale the magnetic fields created by each conductor at the position of the other and the forces on each conductor.



42 A proton of velocity $1.5 \times 10^6\,\text{m s}^{-1}$ enters a region of uniform magnetic field $B = 0.50\text{T}$. The magnetic field is directed vertically up (along the positive z-direction) and the proton's velocity is initially on the z–x plane, making an angle of 30° with the positive x-axis.



a Show that the proton will follow a helical path around the magnetic field lines.

b Calculate the radius of the helix.

c Determine the number of revolutions per second the proton makes.

d Determine the velocity of the proton along the field lines.

e Calculate the vertical separation of the coils of the helix.

43 An electron enters a region of uniform magnetic field $B = 0.50\text{T}$. Its velocity is normal to the magnetic field direction. The electron is deflected into a circular path and leaves the region of magnetic field after being deflected by an angle of 30° with respect to its original direction. Determine the time for which the electron was in the region of magnetic field.

44 Two identical charged particles move in circular paths at right angles to a uniform magnetic field as shown in the diagram. The radius of particle 2 is twice that of particle 1.
Determine the following ratios:

a $\dfrac{\text{period of particle 2}}{\text{period of particle 1}}$

b $\dfrac{E_\text{K} \text{ of particle 2}}{E_\text{K} \text{ of particle 1}}$