SP10a Electric circuits

Student Book

7th **1**

Name of particle	Charge	Mass (relative to the proton)	Location
electron	−1	$\frac{1}{1835}$ (negligible)	shells around nucleus
proton	+1	1	nucleus
neutron	0	1	nucleus

8th **2** diagram of carbon 14 atom with 6 protons and 8 neutrons in the nucleus and 6 orbiting electrons, 2 in inner shell, 4 in outer shell

4th **3** **a** circuit diagram of a series circuit with 2 lamps; cell or battery, may have a switch open or closed, any order of components

4th **b** circuit diagram of a series circuit with 4 lamps; cell or battery, may have a switch open or closed, any order of components

5th **4** circuit diagram of a parallel circuit with 2 lamps; cell or battery, may have a switch open or closed, any order of components

6th **5** circuit diagram of any circuit with 2 lamps and 3 switches (open or closed); cell or battery, any order of components

S1 circuit diagram with a cell, two lamps in parallel and two switches one in each branch so that each lamp can be turned off separately

S2 Arrow showing current from + terminal to − terminal of cell, labelled 'current'. Arrow showing current from − terminal to + terminal of cell, labelled 'electron flow'.

E1 Protons and neutrons are close together in the centre/nucleus. Electrons are in orbits called shells. They are widely spaced, 2 in first shell, then 8 in the second. In metal atoms the electrons in the outer shells are not tightly held. They can become separated/delocalised and carry a current.

E2 Series circuits have one route for current, parallel circuits have more than one route. Current is the same everywhere in a series circuit but can be different in different branches of parallel circuits, though the total current is the same. Potential difference adds up across components in series to give the same potential difference as the cell or battery. Potential difference is the same across components in parallel. This means lamps in series will all go out if one blows but others will stay lit in parallel. In parallel, components can be switched independently.

Exam-style question

In the LH circuit the lamps will all go out (1) because the circuit is broken and no current can flow (1). In the RH circuit the other 2 lamps will stay on (1) because the current can flow in the other two branches of the circuit (1).

Activity and Assessment Pack

SP10a.1 Series and parallel circuits

1 Table showing series circuits have dimmer lamps but those with parallel lamps are unchanged.

2 **a** series with three lamps
b three

3 **a** one
b It is the same.

4 In a series circuit, the electric current has to pass through more lamps than in a parallel circuit.

5 Use ammeters to measure the current, and compare.

SP10a.2 Circuit symbols

From top to bottom, left to right:

1 – lamp
2 – battery
3 – cell
4 – switch
5 – voltmeter
6 – ammeter
7 – resistor
8 – motor
9 – diode
10 – thermistor
11 – variable resistor
12 – light-dependent resistor (LDR)
13 – light-emitting diode (LED)

SP10a.3 Electric circuits – Strengthen

1 **a** lamp
b switch
c cell

2 circuit diagram with a cell switch and lamp

3 missing words filled in the following order: current, electron, negative, conventional

4

Particle	Relative charge	Relative mass	Location in atom
proton	+1	1	nucleus
neutron	0	1	nucleus
electron	–1	$\frac{1}{1835}$ (negligible)	around nucleus

SP10a.4 Atoms and circuits Homework 1

1 pairs: 1c, 2d, 3e, 4b, 5f, 6a

2 a f

b d

3 circuit diagram of series circuit with two cells; positive terminal connected to lamp then switch, lamp, switch

4 nucleus, proton, neutron and electron labelled in correct positions

SP10a.5 Series circuits, parallel circuits and atoms – Homework 2

1 a protons

b neutrons

c Neutrons have no charge.

2 diagram labelled 'nitrogen-14 atom'; seven protons and seven neutrons labelled in nucleus; seven electrons labelled around nucleus

3 circuit diagrams:

a series circuit; two cells, positive terminal to lamp then switch, lamp, switch, lamp

b parallel circuit; two cells, positive terminal to switch branch to two lamps in parallel, then rejoin to one lamp in series and back to negative terminal

4

Series circuits
If one lamp breaks, they all go out.
Lamps cannot be switched on and off independently.
As more lamps are added, the brightness of each one is dimmer.
Parallel circuits
If one lamp breaks, the others stay on.
A lamp in a branch of the circuit can be switched on and off independently from the other branches.
As more lamps are added, the brightness of each one stays the same.

5 The third and fourth will have the same brightness.

6 a a flow of charge

b Conventional current goes from the positive terminal of the cell around the circuit to the negative terminal; the flow of electrons is in the opposite direction, from negative to positive.

7 A metal has free electrons that can move through the metal and carry a charge. Wood does not.

SP10b Current and potential difference

Student Book

5th 1 a X = 0.2 A

5th b Y = 0.4 A

5th c Z = 0.6 A

5th 2 0.4 A

5th 3 The marbles will roll down the ramp and reach a higher speed at the bottom, because they have more gravitational potential energy at the top, which is transferred to kinetic energy.

5th 4 a To transfer energy to the electrons or so that there is a force on the electrons to make them move.

5th b So that there is a complete path for the electrons.

6th 5 A = 3 V, B = 1.5 V, C = 4.5 V

S1 voltmeter, ammeter, lamp, switch and cell

S2 A = 20 mA, B = 0.75 V

E1 A = 20 mA because that is the current in the circuit; B = 0.75 V because there are two lamps in series so the voltage is halved across both of them; C = 20 mA because the current is 40 mA in the whole circuit but halved in one of the branches; D = 40 mA because the current is 40 mA in the whole circuit; E = 3 V because there is a voltage of 3 V in the circuit as a whole; F = 0 V because that part of the circuit is not closed so no current will flow.

Exam-style question

Connect an ammeter in series with the lamp to measure current (1) and a voltmeter in parallel with the lamp to measure potential difference (1). (Can be shown on a circuit diagram.)

Activity and Assessment Pack

SP10b.1 Measuring current and potential difference in circuits

2 The current decreased.

3 The potential difference across each lamp decreased.

4 Current for two lamps = half current for one lamp. Current for three lamps = one third current for one lamp.

5 (If lamps are identical) potential difference for two lamps = half potential difference for one lamp. Potential difference for three lamps = one-third potential difference for one lamp.

6 Total current increased.

7 The potential difference stayed the same across each lamp.

8 Current for two lamps = twice current for one lamp. Current for three lamps = three times current for one lamp.

9 Potential difference stays the same.

10 **a** student's own answer

b If yes, then we can assume that lamps were the same; if no, this could be because the lamps were different (although it could also be due to differences in the batteries or poor connections).

SP10b.2 Using models

1 **a** electrons

b conductors

c cell

d lamp

2 They will continue to roll down the slope.

3 The current stops everywhere when the cell is disconnected.

4 Make the lift higher. The marbles would roll faster.

5 **b** The cell pushes the electrons around the wires in the circuit.

c The electrons do not get used up, they just go around and around the circuit.

d The lamp transfers energy by heating and radiating.

e This increases the thermal store of energy in the room.

6 B

7 C

SP10b.3 Current and potential difference – Strengthen

1 correct match of symbol and label

2 **a** ammeter

b voltmeter

c series

d series

e potential difference

3 3 V

4 **a** decrease

b decrease

c decrease

SP10b.4 Circuits – Homework 1

1 **a** current

b potential difference (voltage)

c ammeter in series, voltmeter in parallel

2 A = 1 A, B = 4.0 A

3 A = 2 V, B = 4.5 V

4 the same as, half, half, half

SP10b.5 More about circuits Homework 2

1 **a** circuit with battery, lamp and switch; ammeter in series and voltmeter in parallel

b ammeter

c voltmeter

2 a potential difference (provided by a cell/battery) across the circuit and a complete unbroken circuit

3 The potential difference between two points is the difference in potential energy that a charge would have after moving from one point to the other. (The potential difference between two points is 1 V if 1 J of energy is transferred to or from a charge of 1 C when it moves from one point to the other.)

4 **a** single lamp (F) = 4.8 A, two lamps in parallel = 2.4 A (i.e. half through each), three lamps in parallel = 1.6 A (i.e. one-third through each)

b potential difference = sum of series potential differences = (6.6 + 3.3 + 2.2) V = 12.1 V

5 Cells in series have a higher total potential difference than one cell, but will last for the same time as one cell. Cells in parallel will have the same potential difference as one cell but will last for a longer time than one cell.

6 a a = b = c = 0.1 A, d = 3 × a (or b or c) = 0.3 A, e = d + a (or b or c) = 0.4 A

b V across a = V across b = V across c = 0.6 V

c V across d = V across a + V across b + V across c = 1.8 V

V across E = 2.4 V

Battery potential difference = 1.8 V + 2.4 V = 4.2 V

SP10c Current, charge and energy

Student Book

1 A current is the rate of flow of charge. In metals the current is caused by electrons moving.

2 2 A × 8 s = 16 C

3 $\frac{10\text{ C}}{0.5\text{ A}}$ = 20 s

4 8 C × 3 V = 24 J

5 $\frac{150\text{ J}}{50\text{ C}}$ = 3 V

S1 Doubling the current doubles the rate at which charge flows, so there is twice as much in the same time. Switching on for 3 times as long means 3 times as much charge will flow. So 2 × 3 = 6 times as much charge flows in the circuit.

S2 A cell with double the potential difference will transfer double the energy to each coulomb of charge passing through it.

E1 charge = 44 × 60 × 60 = 158 400 C

potential energy = 158 400 × 12 = 1 900 800 J or 1.9 × 10^6 J (2 significant figures)

Exam-style question

A potential difference of 4 V means that 4 J of potential energy (1) is transferred to (or from) each coulomb of charge (1).

Activity and Assessment Pack

SP10c.1 Measuring energy transferred in a circuit

(page 1)

3 The values calculated and measured should be similar but, owing to the small size of the unit, there is likely to be quite a large difference in the actual numbers.

4 Doubling the time should double the energy transfer.

(page 2)

4 Doubling the time will double the energy transferred.

5 Energy will be transferred by heating to the wires in the circuit and to the meters.

6 No, because the joulemeter is measuring the energy transferred in more connecting wires and in the ammeter and voltmeter.

7 The meters will probably give slightly different values depending on exactly where they are placed in the circuit. This is because they are not connected across exactly the same circuit.

SP10c.2 Rope model of an electric circuit

1 boxes on diagram, clockwise from top left:

a cell; a current; a component, e.g. lamp; a component, e.g. lamp; a transfer of energy by heating; the electrons in the wire; a switch

2 added to table:

good – Current is the same everywhere in a circuit.

poor – A complete circuit is needed for current to flow.

good – Current stops everywhere when there is a break in the circuit.

SP10c.3 Current, charge and energy Strengthen

1 coulomb, C

2 $t = \frac{Q}{I}$

3 a doubled

b halved

c doubled

4 $V = \frac{E}{Q}$

5 It will double.

6 a 60 C

b 0.5 C

7 18 J

8 a 1 J

b joule, coulomb

SP10c.4 Calculating charge and energy 1 – Homework 1

1 a charge

b electrons, charge, potential difference, current

c potential difference
d energy, coulomb, volt

2 a charge = current × time
b The total amount of charge doubles.
c 72 C
d 900 C
e 40 s

3 a The energy transferred doubled.
b 7200 J
c 270 J
d 400 C

4 a 360 C
b 1620 J

SP10c.5 Calculating charge and energy 2 – Homework 2

1 rate of flow of charge

2 A metal contains electrons that are free to move. When there is a potential difference across the metal the electrons all move in the same direction. They have a negative charge. This flow of charge forms a current.

3 540 C

4 900 C

5 7 A

6 600 s = 10 minutes

7 the energy transferred to a unit charge which passes through the cell

8 1 volt = 1 joule ÷ 1 coulomb

9 8100 J

10 5200 C

11 a 2970 C
b 59 400 J
c Some energy transferred by heating, dissipated, increasing the thermal energy store of the surroundings.

12 a $t = 6 \times 60 \times 60 = 21\,600$
$Q = 0.9 \times 21\,600 = 19\,440$
$E = 19\,440 \times 5 = 97\,200$ J
b The electric current transfers energy to the battery, where it increases the chemical store of energy in the battery. Some energy is transferred by heating the charger, the wires, the battery and the surroundings, or some energy is transferred by heating and dissipated in the surroundings.

SP10c.6 Equation practice

1 a 180 C
b 12.5 A
c 720 s
d 0.5 A
e 3600 s (or 1 hour)

2 a 180 C
b 3000 s or 50 minutes

3 a 220 C
b 15 840 C

4 a 11 400
b 3
c 300
d 2000
e 12

5 a i $Q = I \times t = 0.001 \times 1 \times 60 \times 60 = 3.6$ C
ii 6000 mA = 6A
$Q = I \times t = 6 \times 1 \times 60 \times 60 = 21\,600$ C
iii $t = Q \div I = 21\,600 \div 2 = 10\,800$ s or 3 hours
b i $E = Q \times V = 21\,600 \times 5 = 108\,000$ J
ii $E = Q \times V = 1000 \times 5 = 5000$ J

SP10d Resistance

Student Book

1 $\frac{9\text{ V}}{600\ \Omega} = 0.015$ A or 15 mA

2 Current increases because resistance has decreased and more current can flow.

3 a $\frac{6\text{ V}}{30\ \Omega} = 0.2$ A
b $\frac{12\text{ V}}{0.2\text{ A}} = 60\ \Omega$ (or 30 + 30 = 60)

4 Total R is 120 Ω so $I = \frac{12}{120} = 0.1$ A, i.e. half of previous current.
Potential difference across X is 0.1 A × 20 Ω = 2 V and across Y is 0.1 A × 100 Ω = 10 V (or 12 – 2 = 10 V) so V across X is less than it was but it has increased across Y.

5 It is smaller because there are two pathways for the current to pass through.

S1 Voltage = current × resistance. If you increase the resistance but not the voltage then the current will drop. To get the same current at a higher resistance, you need to increase the voltage.

S2 Diagram of three 100 Ω in series which gives maximum resistance. This is because the current has to pass through all three (or because the total of the potential differences across each resistor gives the total potential difference so there is less p.d. across each resistor, so current will be less). Three resistors in parallel give minimum resistance because there are three routes for current to pass.

E1 Potential difference across each resistor is equally shared, i.e. 6 V.

current = $\frac{6\text{ V}}{200\ \Omega}$ = 0.03 A so total resistance is

$\frac{12\text{ V}}{0.03\text{ A}}$ = 400 Ω

E2 total $I = \frac{12\text{ V}}{200\ \Omega} + \frac{12\text{ V}}{200\ \Omega}$

= 0.06 A + 0.06 A = 0.12 A

total $R = \frac{12\text{ V}}{0.12\text{ A}}$ = 100 Ω

Exam-style question

V across resistor Z = 9 V – 3 V = 6 V (1)

For Z $R = \frac{6\text{ V}}{0.05\text{ A}}$ (1) = 120 Ω (1) ecf value of 6 V

Activity and Assessment Pack

SP10d.1 Investigating resistors

(page 2)

2 **c** larger
d the current doubled
e doubles

3 **b** should be a straight line through the origin
d should be a straight line through the origin but steeper

SP10d.2 Resistors in series

(page 2)

2 **b** They are the same.
c The calculated value is the sum of the two resistances.

3 total resistance in series = sum of all the resistances

4 1 kΩ + 1 kΩ = 2 kΩ

SP10d.3 Resistance – Strengthen

1 ohm Ω

2 difficulty, current

3 **a** $I = \frac{V}{R}$
b $I = \frac{12}{3}$ = 4 A
c $I = \frac{12}{6}$ = 2 A
d When the resistance increased the current decreased.

4 **a** smaller, larger
b larger, smaller

SP10d.4 Resistors and resistance Homework 1

1 A = cell, B = resistor, C = variable resistor

2 **a** increases, easier
b ohm, Ω

3 $V = I \times R$

4 9 × 3 = 27 V

5 100 ÷ 4 = 25 Ω

6 **a** 200 + 180 = 380 Ω
b (1.5 × 1000) + 500 = 2000 Ω (or 2 kΩ)

7 **a** increases
b decreases

8 **a** current and potential difference
b ammeter added in series – anywhere in the circuit
voltmeter added in parallel with the resistor – not with the variable resistor or the cell
c by decreasing the resistance of the variable resistor (Changing is worth some credit – but decreasing is correct.)
d Decreasing the resistance makes it easier for the current to pass around the circuit. ('Increases the potential difference across the resistor' is also an acceptable answer.)

SP10d.5 Resistance and resistors Homework 2

1 **a** ohm Ω
b $V = I \times R$

2 **a** Current decreases.
b Increased resistance means it is more difficult for current to flow, so for the same potential difference current is less.

3 $\frac{9}{36}$ = 0.25 A

4 $\frac{230}{12}$ = 19 Ω (or 19.2 Ω to 3 sf)

5 **a** The total resistance is increased because the current has to pass through both resistors so it is more difficult. (or Because the potential difference is shared between the resistors.)

b The total resistance is less because there are two paths for current to pass so it is easier.

6 **a** $\frac{24}{3 \times 1000}$ = 0.008 A (or 8 mA)

b 3 kΩ + 5 kΩ = 8 kΩ

c $I = \frac{V}{R} = \frac{24}{8}$ kΩ = 0.003 A or 3 mA

d **i** 3 kΩ × 3 mA = 9 V

ii 5 kΩ × 3 mA = 15 V

7 **a** Series circuit: cell or battery, variable resistor, fixed resistor, ammeter (switch optional). A voltmeter connected in parallel with the resistor – not with the variable resistor or the cell.

b **i** Measure current and potential difference.

ii Use $V = I \times R$ to calculate resistance.

iii Adjust the variable resistor so that the resistance is lower to give a higher current.

8 **a** Connect each wire in turn in series with a battery and an ammeter. There will be no current through the broken wire.

b Series circuit: battery, ammeter, yellow wire, 47 Ω resistor, blue wire, 10 Ω resistor, red wire, 3 Ω resistor, green wire, battery.

c resistors in series:
total resistance = 47 Ω + 3 Ω + 10 Ω
= 60 Ω

d $\frac{12\text{ V}}{60\ \Omega}$ = 0.2 A (or 200 mA)

e $\frac{12\text{ V}}{0.16\text{ A}}$ = 75 Ω

f all 4 wires: 75 Ω − 60 Ω = 15 Ω
1 wire = 15 ÷ 4 = 3.75 Ω (3.8 Ω to 2 sf)

SP10d.6 Equation practice

1 230, 4, 1800, 12, 0.1, 18 (17.7 to 3 sf)

2 $\frac{5}{1000} \times (1 \times 1000)$ = 5 V

3 **a** $\frac{9}{3}$ = 3 Ω

b $\frac{3}{12}$ = 4 A

4 **a** A = $\frac{12}{0.030}$ = 400 Ω

B = $\frac{6}{0.012}$ = 500 Ω

C = $\frac{12}{0.015}$ = 800 Ω

b C

SP10e More about resistance

Student Book

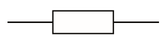
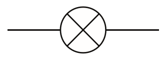
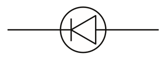
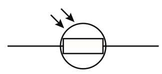
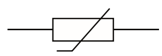
(5th) **1** **a** A fixed resistor is an electrical component which has the same resistance for all values of the potential difference across it.

(5th) **b** The current is doubled.

(6th) **2** Because it is not a straight line.

(6th) **3** As the light intensity increases, the resistance of the LDR decreases.

(4th) **4**

Component	Symbol
Fixed resistor	
Filament lamp	
Diode	
Light-dependent resistor	
Thermistor	

(6th) **5** As the temperature increases, resistance in a thermistor decreases, so more current flows.

(7th) **6** **a** Measure the current and potential difference in the circuit at the lowest possible resistance. Then increase the resistance and measure potential difference and current for each resistance increase.

(7th) **b** As the potential difference increases the current will increase, but they will not be in direct proportion because the resistance increases.

(7th) **7** **a** thermistor, beaker, ice, kettle, thermometer

(7th) **b** circuit diagram which is similar to figure D in the Student Book, but with a thermistor in place of the lamp

7th

c Measurements of current and potential difference should be taken at a variety of temperatures, i.e. close to freezing and then in roughly five-degree intervals to about 40 degrees (the equipment will be damaged above this temperature).

S1 a Fixed resistor is a straight line, lamp is an S shape/curved/non-linear.

or

For the fixed resistor resistance does not change as potential difference is changed. This means that the current is in direct proportion to the potential difference and there is a straight line on the graph. For the filament lamp the current also increases as the potential difference increases but the resistance is not constant. The resistance increases as the potential difference increases.

b The resistance does not change in the fixed resistor and there is a straight line on the graph, which means that current is in direct proportion to potential difference. The resistance in the diode is very high when the potential difference is in one direction, in fact no current flows at all. When the direction of the potential difference swaps direction the current does flow and the diode behaves more like a fixed resistor.

S2 Heater – use a thermistor: when the temperature falls the resistance will rise and this can be used to turn on a heater.

Light – light dependent resistor: when it gets dark the resistance in the LDR will rise and this can be used to turn on a light.

E1 between 0 °C and 1 °C (i.e. low temperature)

Exam-style question

As light intensity increases, the current increases (1) because the resistance of the LDR decreases (1).

SP10e Core practical – Investigating resistance

Student Book

1 ohms (or Ω) (1)

2 a An ammeter has to measure the current through a component (1), so the same current must flow through the ammeter (1).

b It has to measure the potential difference across the component (1), and not transfer energy itself, so it has to be connected in parallel (1).

3 Graph with sensible scales on axes (1) and axes labelled (1).

All points correctly plotted to ± half a square (2). Only one mark if 1 point plotted in error, 0 marks if more than one error.

Smooth curve passing through all the points for each line (1), suitable key (1).

4 a R (at 1 V) = $\frac{1\text{ V}}{0.2\text{ A}}$ (1) = 5 Ω (1)

R (at 6 V) = $\frac{6\text{ V}}{1.2\text{ A}}$ = 5 Ω (1)

b R (at 1 V) = $\frac{1\text{ V}}{0.12\text{ A}}$ = 8.3 Ω (1),

R (at 6 V) = $\frac{6\text{ V}}{0.53\text{ A}}$ = 11.3 Ω (1)

5 a The graph for the resistor shows that the current is directly proportional to the potential difference (1), which means that the resistance is constant even when the voltage changes (1). This is supported by the calculations, which show the same resistance at 1 V and 6 V (1).

b Any three points from: the graph for the filament lamp shows that there is no linear/proportional relationship between potential difference and current (1). The line shows that for each 1 V increase in potential difference, the increase in current gets less and less (1). This means that the resistance increases with increasing potential difference (1). This conclusion is supported by the calculations which show that the resistance is higher at 6 V than at 1 V (1).

c Repeat the investigation with other resistors and filament lamps (1). If the same results were obtained it would support the conclusion (1) but would not prove that the conclusion held for *all* resistors/lamps (1).

6 a Both should be 0.23 A (1) because the current is the same everywhere in a series circuit (1).

b 0.82 A (1) because the current through the power pack/cell is the sum of the currents in the branches of the circuit (1).

7 a i $R = \frac{4\text{ V}}{0.23\text{ A}}$ (1) = 17.4 Ω (1)

ii $R = \frac{4\text{ V}}{0.82\text{ A}}$ (1) = 4.9 Ω (1)

b Connect them in parallel. (1)