Chapter 2: Electricity

Lesson 2.1 Static Electricity

1 e.g. a polythene rod

1b e.g. a metal wire

2 If static charge begins to build up on a conductor when you are rubbing it with a cloth, charge will flow through the conductor through you to the ground.

3a attract

3b repel

3c attract

3d repel

4 Her hair builds up static charge. Since the type of charge is the same on each strand of hair (either all positive or all negative) then the strands of hair repel each other.

5 Electrons move from the duster to the polythene so the duster loses negative charge. Therefore, it builds up positive charge.

Lesson 2.2 Electric fields

1 The direction of the arrows is the direction that the force acts on a positive charge. A positive charge placed in the field in Figure 2.5 would feel a force of repulsion, so it would always be acting away from the centre.

2 Positive charges would feel a force of attraction towards the negative charge in the middle. Therefore, the lines should all be pointing inwards to the centre.

3 The size of the force remains the same because the electron is always at the same distance from the charged sphere.

4a Anywhere close to the central charge.

4b Anywhere far away from the central charge.

5 The arrows show the direction that the electric field acts on a positive charge – which is useful. This could be misleading, however, if you are considering a negative charge in the field as the force would act the opposite way.

6 No – because a spark occurs when particles break apart due to an electric field and a vacuum doesn't have any particles in it.

7 The electric field between two charged objects is stronger if the objects are closer together. Sparks are more likely to occur in stronger electric fields.

8 The rate that lightning strikes should increase. When the cloud passes over a hill, the distance between it and the ground becomes smaller – this creates a stronger electric field.

Lesson 2.3 Electric current

1 $I = Q / t = 80 / 16 = 5$ A

2 $t = Q / I = 96 / 6 = 16$ s

3 There needs to be a source of potential difference within a complete loop in a circuit.

4 6V battery transfers 6J of energy per coulomb of charge. Number of coulombs of charge, $Q = It = 1 \times 60 = 60$ C.

Therefore total energy transferred = 6 × 60 = 360 J

5 Electrons transfer energy to the kinetic energy stored in the metal ions. This makes them move faster and therefore become hot.

6 If you increase the resistance of the variable resistor, the current decreases. The lamp will get dimmer if the current decreases.

7 $R = V / I = 12 / 3 = 4\ \Omega$

8 $V = IR = 1.5 \times 6 = 9$ V

Lesson 2.4 Series and parallel circuits

1 Close the switches

2 They both get dimmer and they are the same brightness as each other (and the third lamp)

3 In the series circuit both light bulbs would not be shining; in the parallel circuit the unscrewed bulb would not be shining but the other bulb would continue to shine.

4a 0.4 A – the current through components in series is the same

4b 10 Ω + 20 Ω = 30 Ω

4c 8 V – the potential difference of the power supply (12 V) is shared between the components (4 V and 8 V)

4d The current would be half as big because the total resistance has doubled from 30Ω to 60Ω.

5a 0.6 A – the current from the supply (1.8A) is the sum of the currents through the motor (1.2A) and the lamp. So the current through the lamp = 1.8 – 0.6 = 1.2 A.

5b 12 V – the potential difference across each component in a parallel circuit is the same and is equal to the p.d. of the power supply.

5c It must be smaller than 10 Ω. Connecting resistors in parallel decreases the total resistance, so connecting the lamp to the motor in parallel would make the resistance less than the resistance of the motor.

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5d Adding the resistor decreases the total resistance, therefore the battery will be providing a bigger current.

Lesson 2.5 Investigating circuits

1 If the component or the cable is able to conduct electricity, then a current flows in the circuit when it is connected between the terminals. This makes the buzzer sound.

2a $R = V / I = 12 / 2 = 6\Omega$

2b You can adjust the variable resistor (either by moving a slider or by rotating a dial) so that its resistance increases.

3 The voltmeter needs to be connected in parallel to the resistor. Its high resistance means that no measurable current flows when it is connected in series.

4 $R = V / I = 12 / 0.6 = 20\ \Omega$

5 Total resistance, $R = 5 + 7 = 12\ \Omega$

$I = V / R = 6 / 12 = 0.5$ A

6 Total resistance, $R = 3 + 6 = 9\ \Omega$

Current, $I = V / R = 12 / 9 = 1.33$ A

Therefore p.d. across 3 Ω resistor = $IR = 1.33 \times 3 = 4$V

7 The potential difference across the 3Ω resistor = $I \times R = 3$ V.

The current through the 6 Ω resistor is also 1 A so the p.d. across the 6 Ω resistor = 1 × 6 = 6 V.

Therefore, the p.d. of the battery = 3V + 6V = 9V.

8 The current through the 4 Ω resistor = $V / R = 8 / 4 = 2$ A.

Therefore, the current through the other resistor = 2 A.

The potential difference across the other resistor = 12 – 8 = 4 V.

So the resistance = $V / I = 4 / 2 = 2\ \Omega$.

9 The total p.d. stays the same (12 V) and the current increases. Since $R = V / I$ this means that the equivalent resistance of the circuit gets less.

10 The same current will pass through a 9 V battery connected to a 9 Ω resistor.

Therefore, the current = $V / R = 9 / 9 = 1$ A.

Lesson 2.6 Circuit components

1 They are directly proportional to each other.

2 The voltmeter is connected in parallel.

3 The I-V graph is not a straight line through the origin.

4 Tungsten obeys Ohm's law when the temperature remains constant. In a filament lamp the temperature increases as more current flows through it (to thousands of degrees), so the lamp does not obey Ohm's law.

5a At 1 V: $R = V / I = 1 / 0.2 = 5\ \Omega$

At 6 V: $R = V / I = 6 / 0.4 = 15\ \Omega$

5b Graph should show the resistance starting at a low value (not 0 Ω) and then rapidly rising to a higher, steady value as the filament lamp heats up to a constant temperature.

Lesson 2.7 Required Practical: Investigate, using circuit diagrams to construct circuits, the *I-V* characteristics of a filament lamp, a diode and a resistor at constant temperature

1 The meters only work properly if the ammeter is in connected in series and the voltmeter is connected in parallel.

2 The independent variable is the current and the dependent variable is the potential difference.

3 To stop the temperature increasing.

4 The current is directly proportional to the potential difference.

5 The lamp is not an ohmic conductor. Its resistance increases as the current and potential difference become higher positive and negative values.

6 The diode has a very high resistance when the potential difference is negative and it has a very low resistance when the potential difference is positive.

Lesson 2.8 Required Practical: Use circuit diagrams to set up and check appropriate circuits to investigate the factors affecting the resistance of electrical circuits, including the length of a wire at constant temperature and combinations of resistors in series and parallel

1 You would expect the current to increase as the p.d. across it is increased. This is because $I = V / R$.

2 You could either vary the setting on the power supply between 0 V and 12 V or you could alter the resistance of the variable resistor (usually by moving a slider or by rotating a dial).

3 The temperature is also likely to increase.

4 In order to measure the resistance of the wire you would need to measure the p.d. across the wire by

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using a voltmeter connected in parallel and you would need to measure the current flowing though the wire by connecting an ammeter in series. You would then calculate the resistance by dividing the p.d. by the current. The wire would also need to be in a series circuit with a power supply and a variable resistor.

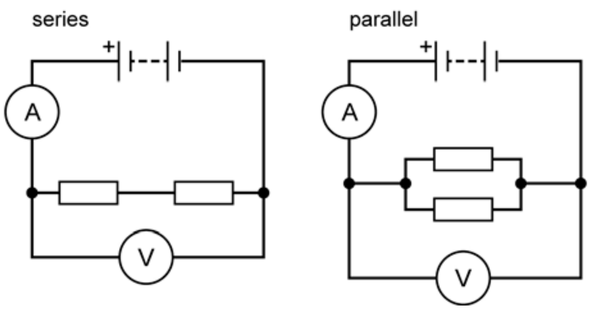
Calculate the resistance for different lengths of wire, which you can measure with a ruler.

5a The resistance should be directly proportional to the length.

5b A graph of resistance on the y-axis against length on the x-axis should be a straight line (with a positive gradient) through the origin.

6 To keep the temperature constant, you could measure the temperature of the wire using a thermometer and adjust the p.d until the temperature is the same each time.

7a



7b In series, the combined resistance should be the sum of the individual resistances. In parallel the combined resistance should be less than the smallest individual resistance.

8a First resistance = V / I = 6 / 0.1 = 60 Ω

Second resistance = 3 / 0.2 = 15 Ω.

Therefore the expected value of the total resistance = 60 + 15 = 75 Ω.

The student obtained a value of 3.9 / 0.05 = 78 Ω which is higher than expected.

8b Higher resistance is unlikely to be due to a gain in temperature since the current is actually lower than before. Extra resistance is likely to be from the contact between the resistors. Another possible reason is from inaccurate measurements such as rounding error in the current reading.)

Lesson 2.9 Control circuits

1 The resistance of the LDR.

2 When the temperature increases, the resistance decreases.

3 The I-V graph is not a straight line through the origin.

4 The temperature increases when the current increases. You can work out the resistance by reading off the graph and dividing the p.d. by the current. At higher values of current (and therefore higher temperatures) the resistance is a lower value.

5 When you cover the LDR, the resistance increases so the current decreases. When you uncover the LDR the opposite happens so the current increases.

6 The current passing through the diode is very small when the p.d. is negative. Therefore, a diode has a very high resistance when the p.d. is negative.

7 The resistance of a diode is very small when the current goes through it in the allowed direction. This might allow the current to become dangerously high and damage the diode. An extra resistor prevents the current from becoming too high.

Lesson 2.10 Electricity in the home

1 In a direct potential difference, the current is always pushed in the same direction. In an alternating potential difference, the power supply pushes the current so that it keeps on changing direction.

2 The peaks and the troughs would be about half as big (since the potential difference is about half as much) and there would be less time between them (since the frequency is higher).

3 Plastic is a good insulator of electricity. So this prevents people from receiving an electric shock.

4 It would be very dangerous to wire up a plug the wrong way round. Therefore, you need to be able to identify which wire is which very easily – even if you are colour blind.

5 A battery powered torch only uses a small p.d. and it probably doesn't have a metal case. Therefore there is a much smaller risk of harm if the user receives an electric shock – so it doesn't need an earth wire. A mains lamp, however often has a metal casing and has a high risk of harm if the user receives an electric shock – so it often has an earth wire.

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6 The earth wire prevents electric shocks if the metal casing becomes live due to a fault. The earth wire provides a path of low resistance so the current will be very high. This makes sure that the fuse melts and switches off the circuit

Lesson 2.11 Transmitting electricity

1 If the local power station breaks down or it has to be switched off for maintenance then your house can still receive electrical power from other power stations.

2 “National” means that the electrical connections cover the whole country; “Grid” means that consumers are connected to many power stations rather than just one and that electrical power can be delivered by many routes.

3 A p.d. as high as this would be too dangerous. It would produce a lethal current through you if you touched it (or even if you got close to it, as it would pass through the air).

4 We are using resources to produce electricity which are running out so we need to make sure we aren’t wasting them. If lots of energy is wasted then our electricity bills would be higher as we would have to pay for the wasted energy as well.

5 This reduces the current passing through the power cables. A smaller current does not heat up the cables as much so less energy is wasted.

6 They are connected between the power cables and factories or homes.

7 When there are moving parts, the device heats up and wastes energy by transferring it to thermal energy stores. There is no friction in transformers so energy is not wasted in this way.

8 So there is only a small amount of energy wasted between the power station and the transformer.

9 There is not a complete circuit between the birds and the ground, so no current flows.

Lesson 2.12 Power and energy transfers

1 A kettle transfers energy from the mains electricity store into the thermal energy stored in the water by heating.

2a The electric current turns the motor in the drill. This means that it transfers energy from the mains electricity store into the kinetic energy stored in the drill. Energy is also transferred to the thermal energy stored in the surroundings.

2b The power of the drill = 400 W.

3 $E = Pt = 2500 \times (45 \times 60) = 6\,750\,000$ J (or 6.75 MJ)

4 $P = E / t = 10\,000 / 5 = 2000$ W (or 2 kW)

5 $E = QV = 30 \times 230 = 6900$ J

6 $V = E / Q = 1800 / 75 = 24$ V

7a Energy transferred in 5 minutes, $E = 1150 \times 5 \times 60 = 345\,000$ J

$Q = E/V = 345\,000 / 230 = 1500$C.

7b $Q = E / V = 345\,000 / 33\,000 = 10.5$ C

Lesson 2.13 Calculating power

1a $P = VI = 230 \times 4 = 920$ W

1b $R = P / I^2 = 920 / 4^2 = 57.5\ \Omega$

(You could also calculate this by using $R = V / I = 230 / 4 = 57.5\ \Omega$)

2a $I = P / V = 36 / 12 = 3$ A

2b $R = P / I^2 = 36 / 3^2 = 4\ \Omega$

(Again, you could calculate this by using $R = V / I = 12 / 3 = 4\ \Omega$)

3 It could be transferred to the thermal energy stores in the kettle and the surroundings.

4a Volume = $15 \times 10 \times 2 = 300$ m^3

Mass = density × volume = 1000 × 300 = 300 000 kg

4b Energy transferred = $mc\Delta\theta = 300\,000 \times 4200 \times (22 - 17) = 6\,300\,000\,000$ J (or 6300 MJ)

4c $t = E / P = 6\,300\,000\,000 / 2000 = 3\,150\,000$ s = 875 hours (over 36 days!)

5a The microwave oven transfers 800 J to the thermal energy stored in the food every second.

5b A vacuum cleaner transfers 1600 J to the kinetic energy stored by the dust, and the thermal energy stored in the surroundings every second.

Lesson 2.14 Key Concept: What’s the difference between potential difference and current?

1 Your head is rubbing against the nylon jumper and electrons pass from one object to another. This means your head becomes oppositely charged to the jumper and there is an electric field between them. If the electric field is strong enough, the charges in the air particles get pulled apart – which creates the spark.

2 Connect two 12 V car batteries in series.

3 No – it also depends on the current that the device is able to provide.

4 The higher the p.d. (the volts) the larger the electric shock. However, the energy deposited to your body also depends on the current. So a large p.d. is safe if the current through you is very small.

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However, a current as large as about 0.1 A can kill you.

5 $P = VI = 230 \times 0.05 = 11.5$ W

6 $R = P / I^2 = 11.5 / 0.05^2 = 4600\ \Omega$

Lesson 2.15 Maths Skills: Using formulae and understanding graphs

1a $V = IR = 10$ A × 100 Ω = 1000 V

1b $V = IR = 5$ A × 3000 Ω = 15 000 V

2 $V = IR$

Divide both sides by I

$R = V / I$

3 $P = VI = 230 \times 5 = 1150$ W

4 $P = I^2R$

Divide both sides by r

$I^2 = P / R$

Square-root both sides

$I = \sqrt{(P / R)}$

5 $P = I^2R = 5^2 \times 1000 = 25\ 000$ W

6 If the straight line goes through the origin, then the slope indicates the **constant of proportionality** or (**1/constant of proportionality**) depending on which way round the axes are plotted.

7 The relationship is not proportional because the graph is not a straight line through the origin.

End of Chapter Questions

1 Green and yellow [1 mark]

2

[1 mark]

3 Series [1 mark]

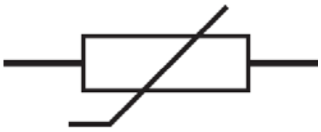
4 A network of power cables [1 mark] and transformers [1 mark] that connect power stations to consumers.

5 $I = Q / t$ [1 mark] = 100 / 20 = 5 A [1 mark]

6 You could rub the balloon against your hair. [1 mark]

7 The neutral wire and the earth wire are the wrong way round [1 mark]. The cable grip needs to be covering the outer insulation [1 mark].

8



[1 mark]

9 Frequency = 50 Hz [1 mark]

Potential difference / Voltage = 230 V [1 mark]

10 A region of space where a force acts [1 mark] on an electric charge [1 mark].

11 The balloons will repel each other.

12 The brightness of all of the lamps decreases [1 mark]. The current decreases [1 mark].

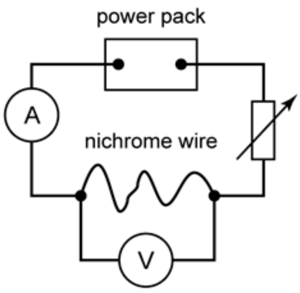
13 $I = P / V$ [1 mark] = 2000 / 230 = 8.7 A [1 mark]

14 The resistance increases. [1 mark]

15 The charge flows from them to the ground. This creates an electric current. [1 mark]

16 If the current becomes too large [1 mark] then the current becomes high enough to melt the wire in the fuse which breaks the circuit and stops the current flowing [1 mark].

17



[1 mark for the ammeter connected in series and the voltmeter connected in parallel. 1 mark for power supply/battery/cell and variable resistor included in series with the wire]

18 $I = V / R$ [1 mark] = 12 / 8 = 1.5 A [1 mark]

19 C was the filament lamp [1 mark]

D was the high-valued resistor [1 mark]

20 Power = current^2 × resistance (or $P = I^2R$) [1 mark]

21 Adding resistors in series increases the total resistance of the circuit as this makes it harder for the charge to flow through [1 mark]. Adding resistors in parallel decreases the total resistance of the circuit as this makes it easier for the charge to flow through due to the extra path they can follow [1 mark].

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22 $E = P \times t$ [1 mark] = 60 × (1 × 60) = 3600 J [1 mark]

23 Power rating of torch = IV = 5 × 12 = 60 W

Power rating of food mixer = IV = 6 × 230 = 1380 W [1 mark]

$E = Pt$

Energy transferred by kettle = 3000 × 20 = 60 000 J

Energy transferred by microwave = 920 × 60 = 55 200 J

Energy transferred by torch = 60 × 200 = 12 000 J

Energy transferred by food mixer = 1380 × 50 = 69 000 J

So the food mixer transferred the most amount of energy and it transferred 69 000 J [1 mark]

24 Any **two** from: Higher potential difference supply needs a smaller current (for the same power); a current heats the wire and wastes energy; a smaller current means the system is more efficient. [2 marks]

Any **one** from: Transformers are needed to change the pd which makes the system more complicated and prone to faults; a high pd is very dangerous. [1 mark]

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