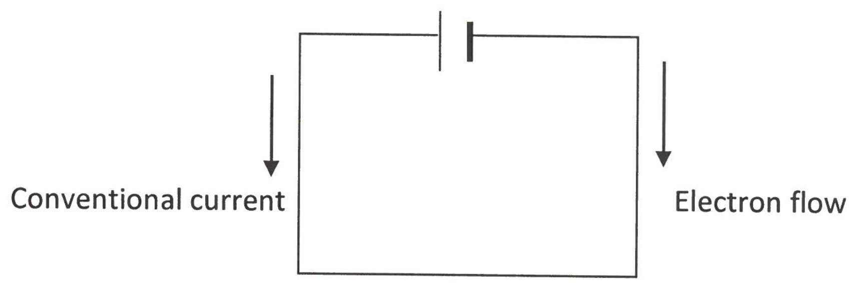
4.1 Charge and Current

Pages 152–163 (Pearson), 118–133 (Oxford)

4.1.1 Charge

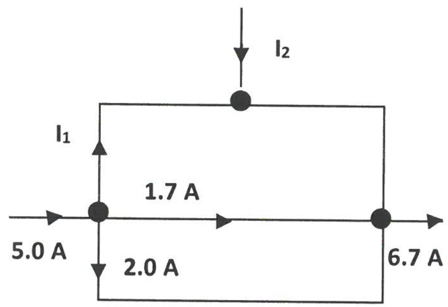
Question	Answer	
4.1.1: Oxford 118-126, Pearson 152-156		
Define 1 coulomb.	The amount of charge that passes in 1 second when the current is 1 ampere.	
Define the elementary charge.	$e = 1.6 \times 10^{-19}$ C	
State the charge of: **(a) An electron** **(b) A proton**	**(a)** $-e$ (-1.6×10^{-19} C)	**(b)** $+e$ (1.6×10^{-19} C)
Define current.	The rate of flow of charge.	
Explain the difference between the direction of the conventional current and electron flow.	The direction of conventional current flows from the positive terminal to the negative terminal. The direction of electron flow is from the negative terminal to positive terminal.	
State what causes a current in: **(a) A metal** **(b) An electrolyte**	**(a)** The movement of electrons	**(b)** The movement of ions
Define Kirchoff's first law.	The sum of the current into a junction is equal to the sum of the current out of the junction.	
State which conservation law is obeyed by Kirchoff's first law.	The conservation of charge.	
State the law of conservation of charge.	The charge entering a junction is equal to the charge leaving a junction. Charge is neither lost nor used up.	

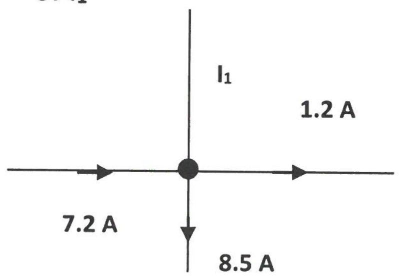
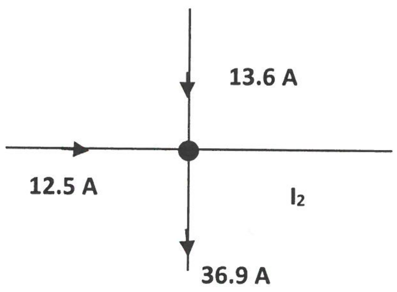
4.1.1 Charge	Question	Answer
	Which of the following is an alternative unit for the ampere? **Js^{-1}** **Cs^{-1}** **VA^{-1}**	Cs^{-1}
	Draw labeled arrows on the circuit diagram below the directions of: **(a) Conventional current** **(b) Electron flow**	
	A component has a current of 220 A flowing through it for 20 minutes. **Calculate the charge that flowed through the component during these 20 minutes.**	$I = \frac{Q}{t}$ $Q = It$ Convert minutes into seconds: $t = 20 \times 60 = 1200\ s$ $Q = 220 \times 1200 = 264000\ C$

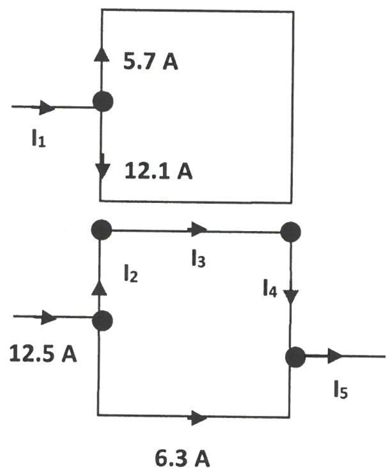
	Question	Answer
4.1.1 Charge	**A charge of 35 μC flowed through a lamp when a current of 5 A was flowing through the lamp.** **Calculate the amount of time the lamp was switched on for.**	$I = \frac{Q}{t}$ $t = \frac{Q}{I}$ $t = \frac{35 \times 10^{-6}}{5}$ $t = 7 \times 10^{-6}\ s$
	Calculate the current in a component that has a charge of 15 mC passing through it in 6 μs.	$I = \frac{Q}{t}$ $I = \frac{15 \times 10^{-3}}{6 \times 10^{-6}}$ $I = 2500\ A$

	Question	Answer
4.1.1 Charge	**Calculate the number of electrons that flowed through a component with a current of 70 A over 1 hour and 5 minutes.**	First calculate charge: $I = \frac{Q}{t}$ $Q = It$ Convert the time into seconds: $t = 65 \times 60 = 3900\ s$ $Q = 70 \times 3900 = 273000\ C$ The charge of 1 electron is 1.6×10^{-19} C. $\text{Number of electrons} = \frac{\text{Total charge}}{\text{Charge of one electron}}$ $\text{Number of electrons} = \frac{273000}{1.6 \times 10^{-19}}$ $\text{Number of electrons} = 1.71 \times 10^{24}$

4.1.1 Charge

Question	Answer	
Over 30 seconds a lamp had a charge of 2.4 mC flowing through it. (a) Calculate the rate of flow of charge. (b) Calculate the number of electrons flowing per second.	(a) The rate of flow of charge is the current. $I = \frac{Q}{t}$ $I = \frac{2.4 \times 10^{-3}}{30}$ $I = 8 \times 10^{-5} A$	(b) The charge of 1 electron is 1.6×10^{-19} C. Number of electrons = $\frac{\text{Total charge}}{\text{Charge of one electron}}$ Number of electrons = $\frac{2.4 \times 10^{-3}}{1.6 \times 10^{-19}}$ Number of electrons = 1.5×10^{16}
Using Kirchhoff's first law identify the missing currents.  	$I_1 = 1.3$ A	$I_2 = 1.7$ A

	Question	Answer	
4.1.1 Charge	**(a) State the size and direction of I_1**  **(b) State the size and directions of I_2** 	(a) 2.5 A down	(b) 10.8 A left

	Question	Answer
4.1.1 Charge	 **Complete the table.**	I_1: 17.8 A I_2: 6.2 A I_3: 18.3 A I_4: 24.0 A I_5: 30.3 A
4.1.2 Mean drift velocity	**4.1.2: Oxford 127-133; Pearson 157-161**	
	Define 'mean drift velocity'.	The average velocity of a charged particle (e.g. an electron) as it moves through a wire.
	Write down an equation for mean drift velocity and explain what each of the terms means.	$v = \frac{I}{nAq}$ v - mean drift velocity I - current n - number of charge carriers per m^3 q - charge of each charge carrier

4.1.2 Mean drift velocity

Question	Answer
Describe the effect on the size of the current if: **(a) Area is halved** **(b) Charge carrier speed triples** **(c) A helium nucleus is used instead of a proton** **(d) The number of charge carriers is doubled**	(a) The current would halve. (b) The current would triple. (c) The current would double. (d) The current would double.
Describe what happens to the current if the radius of the wire is doubled.	The current would increase by a factor of four.
Describe what would happen to the current if both the charge of the charge carriers and the cross-sectional area is doubled.	The current would increase by a factor of four.
In terms of the number of charge carriers, explain the difference between metals, semiconductors and perfect insulators.	Metals have a large number of charge carriers, semiconductors have fewer charge carriers and perfect insulators have no charge carriers.
In terms of the number of charge carriers explain the difference between perfect insulators and real insulators.	Perfect insulators have no charge carriers and real insulators have a very small number of charge carriers.

4.1.2 Mean drift velocity

Question	Answer
Describe and explain the difference in the ability to conduct electricity of solid sodium chloride and molten sodium chloride.	In solid sodium chloride the ions are unable to move freely; therefore, it is unable to conduct electricity. However, in molten sodium chloride, the charge carriers can move freely and it is a good conductor of electricity.
Gases are usually insulators of electricity. **In what case may a gas become a conductor of electricity?**	When a high voltage is applied to a gas it ionises the atoms in the gas – this allows electricity to flow.
How do the charge carriers of liquids and gases differ to the charge carriers in solids?	The charge carriers in liquids and gases are ions, whereas the charge carriers in solids are delocalised electrons.
What is an electrolyte?	An electrolyte is a solution of positive and negative ions. These ions are charge carriers.
Calculate the mean drift velocity of the electrons of a wire with a current of 6.2 A flowing through it, a cross-sectional area of 5 mm^2 and $5.2x\ 10^{28}$ electrons per m^2.	$v = \frac{I}{nAq}$ Convert the cross-sectional area from mm^2 to m^2: $A = 5 \times 10^{-6} m^2$ $v = \frac{6.2}{5.2 \times 10^{28} \times 5 \times 10^{-6} \times 1.6 \times 10^{-19}}$ $v = 1.49 \times 10^{-4} ms^{-1}$

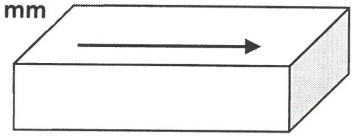
4.1.2 Mean drift velocity

Question	Answer
A wire has an electron density of 6.1 x 10^{28} electrons per m^3. The wire has a diameter of 2.3 mm and its electrons have a mean drift velocity of 0.11 mms^{-1}. **Calculate the current flowing through the wire.**	Calculate the cross-sectional area of the wire: $A = \pi r^2$ $A = \pi \times (\frac{1}{2} \times 2.3 \times 10^{-3})^2$ $A = 4.15 \times 10^{-6}\ m^2$ Convert the units of mean drift velocity from mms-1 to ms-1. $v = 0.11 \times 10^{-3} ms^{-1}$ $I = Anev$ $I = 4.15 \times 10^{-6} \times 6.1 \times 10^{28} \times 1.6 \times 10^{-19} \times 0.11 \times 10^{-3}$ $I = 4.46A\ (2\ dp)$
Calculate the electron density of 76 kg of a metal given that 1 m^3 of this metal has a mass of 4,500 kg and 76 kg of the metal contains 7.8 x 10^{29} free electrons.	$\text{electron density} = \frac{\text{number of electrons}}{\text{volume}}$ $4500kg = 1\ m^3$ $76kg = 0.0169\ m^3$ $\text{electron density} = \frac{7.8 \times 10^{29}}{0.0169}$ $\text{electron density} = 4.62 \times 10^{31}$ electrons per m^3 $(2\ dp)$

4.1.2 Mean drift velocity

Question

1.1 mm



0.9 mm

1.2 mm

A strip of metal has a current of 1.67 mA flowing through it.

The dimensions of the metal strip are 1.2 mm x 0.9 mm x 1.1 mm.

The metal strip contains 8.75 x 10^{16} electrons.

Calculate the mean drift velocity of the electrons in this metal strip.

Answer

Calculate the cross-sectional area of the metal strip:

$$A = 1.1 \times 10^{-3} \times 0.9 \times 10^{-3}$$

$$A = 9.9 \times 10^{-7}\, m^2$$

Calculate the electron density:

$$\text{electron density n} = \frac{\text{number of electrons}}{\text{volume}}$$

$$\text{electron density n} = \frac{8.75 \times 10^{16}}{1.2 \times 10^{-3} \times 0.9 \times 10^{-3} \times 1.1 \times 10^{-3}}$$

$$\text{electron density n} = 7.37 \times 10^{25} \text{ electrons per m}^3$$

$$v = \frac{I}{nAq}$$

$$v = \frac{1.67 \times 10^{-3}}{7.37 \times 10^{25} \times 9.9 \times 10^{-7} \times 1.6 \times 10^{-19}}$$

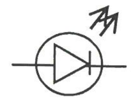
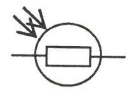
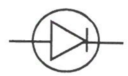
$$v = 1.43 \times 10^{-4}\, ms^{-1}$$

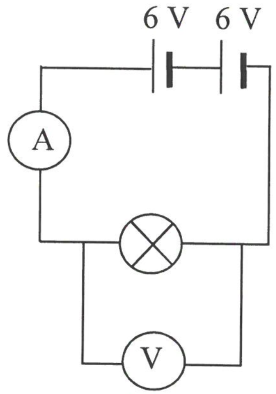
4.2 Energy, Power and Resistance

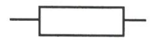
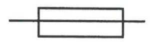
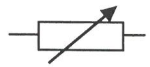
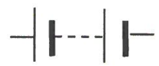
Pages 166–185 (Pearson), 134–165 (Oxford)

4.2.1 Circuit symbols

Question	Answer
4.2.1: Oxford 134-135; Pearson 152-153	
Draw circuit symbols for the components in the table.	See table below
Draw a circuit diagram showing a lamp connected to two 6 V cells. Include a voltmeter and an ammeter to measure the potential difference and current across the lamp.	See circuit diagram below

Component	Symbol
LED	
LDR	
Thermistor	
Diode	



<table>
<tr><th></th><th>Question</th><th>Answer</th></tr>
<tr><td>4.2.1 Circuit symbols</td><td>Complete the table.</td><td>
<table>
<tr><th>Component</th><th>Symbol</th></tr>
<tr><td>Resistor</td><td></td></tr>
<tr><td>Fuse</td><td></td></tr>
<tr><td>Variable resistor</td><td></td></tr>
<tr><td>Battery</td><td></td></tr>
</table>
</td></tr>
<tr><td rowspan="4">4.2.2 Emf and pd</td><td>Define potential difference.</td><td>Energy transferred from electrical energy to other forms per unit charge.</td></tr>
<tr><td>Define the volt.</td><td>The potential difference across a component when 1 joule of energy is used to move 1 coulomb of charge through the component.</td></tr>
<tr><td>State an alternative unit for the volt.</td><td>JC^{-1}</td></tr>
<tr><td>Define the electromotive force.</td><td>Energy transferred from chemical energy to electrical energy per unit charge.</td></tr>
</table>

4.2.2 Emf and pd

Question	Answer
Distinguish between pd and emf in terms of energy transfer.	The pd is the energy transferred from electrical energy to other forms per unit charge, whereas emf is the energy transferred from chemical energy to electrical energy per unit charge. OR The pd is the work done BY charge carriers, whereas the emf is the work done ON charge carriers.
An electron is accelerated through a potential difference of 12 V. **Calculate:** **(a) The kinetic energy of the electron.** **(b) The velocity of the electron.** $e = 1.6 \times 10^{-19}$ C $m_e = 9.11 \times 10^{-31}$ kg	**(a)** $eV = \frac{1}{2}mv^2$ $eV = 1.6 \times 10^{-19} \times 12 = 1.92 \times 10^{-18} J$ **(b)** $v = \sqrt{\frac{2eV}{m}}$ $v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 12}{9.11 \times 10^{-31}}}$ $v = 2.05 \times 10^{6}\ ms^{-1}$
A helium nucleus was accelerated through a potential difference of 50 V. **Given that the mass of a nucleon is 1.67×10^{-27} kg, calculate the velocity of the helium nucleus.** $e = 1.6 \times 10^{-19}\ C$	$v = \sqrt{\frac{2eV}{m}}$ $v = \sqrt{\frac{2 \times 2 \times 1.6 \times 10^{-19} \times 50}{4 \times 1.67 \times 10^{-27}}}$ $v = 6.92 \times 10^{4}\ ms^{-1}$

4.2.2 Emf and pd

Question	Answer
An electron was accelerated through a potential difference of X volts to a speed of 50,000 ms^{-1}. **Calculate the size of the potential difference X.** $e = 1.6 \times 10^{-19}$C $m_e = 9.11 \times 10^{-31}$kg	$eV = \frac{1}{2}mv^2$ Rearranging: $V = \frac{mv^2}{2e}$ $V = \frac{9.1 \times 10^{-31} \times 50000^2}{2 \times 1.6 \times 10^{-19}}$ $V = 7.11 \times 10^{-3} V \ (2\ dp)$
Complete the table.	(see table below)

Potential difference (mV)	Charge (μC)	Work done (μJ)
2.2	**8.7**	0.019
208333	**1.2**	**250**
5.7	350877	**2000**
5.4	**8.9**	0.048

4.2.2 Emf and pd

Question	Answer
Calculate the potential difference across a component if 50 J of work is done when 7 C of charge passes across the component.	$W = VQ$ $V = \frac{W}{Q}$ $V = \frac{50}{7}$ $V = 7.14\,V\ (2\,dp)$
For a battery with an emf of 24 V, calculate the work done per coulomb.	$\varepsilon = \frac{W}{Q}$ For 1 coulomb of charge: $\varepsilon = W$ Therefore: Work done per coulomb $= 24\,JC^{-1}$
For two minutes a current of 3.2 A flows through a component with a potential difference across it of 18 V. **(a) Calculate the charge that flows through the component in two minutes.** **(b) Calculate the work done on the charges.**	**(a)** $Q = It$ $Q = 3.2 \times 2 \times 60$ $Q = 384\,C$ **(b)** $W = VQ$ $W = 18 \times 384$ $W = 6912\,J$

	Question	Answer
4.2.2 Emf and pd	**A current of 14 A is measured across a component. The potential difference across the component is measured as 18 V. The circuit was switched on for 30 minutes.** **(a) Calculate the charge that flows through the component in the 30 minutes.** **(b) Calculate the number of electrons that flow through the circuit in this time.** **(c) Calculate the work done on the electrons in the circuit.**	**(a)** $Q = It$ $Q = 14 \times 30 \times 60$ $Q = 25200\ C$
		(b) $\text{Number of electrons} = \dfrac{\text{Total charge}}{\text{Charge of one electron}}$ $\text{Number of electrons} = \dfrac{25200}{1.6 \times 10^{-19}}$ $\text{Number of electrons} = 1.575 \times 10^{23}$
		(c) $W = VQ$ $W = 18 \times 25200$ $W = 453600\ J$
4.2.3 Resistance	**4.2.3: Oxford 141-148, 153-157; Pearson 168-172**	
	Define resistance.	$\text{resistance} = \dfrac{\text{potential difference}}{\text{current}}$
	Define the ohm.	1 ohm is the resistance of a component if a 1 volt potential difference makes a current of 1 ampere flow through the component.

4.2.3 Resistance

Question	Answer
State Ohm's law.	At constant temperatures, in an ohmic conductor the current flowing through it is directly proportional to the potential difference across it.
Explain how an I-V characteristic graph can be determined for an LED. **Sketch the LED's I-V characteristic graph.**	• Connect a power supply to an LED. • Connect a voltmeter in parallel with the LED and an ammeter and a variable resistor in series with the LED. • Change the resistance using the variable resistor and record the current and voltage. • Repeat for a range of different resistances. • Reverse the terminals of the power supply, change the resistance and record the current and voltage. Repeat for a range of different resistances. • Plot the results on an I-V graph.