8.3.2 ELECTRIC FIELDS AND CIRCUITS

One of the main advantages of electricity is that it can be moved with comparative ease from one place to another through electric circuits

2.1 Describe the **behaviour of electrostatic charges** and the **properties of the fields** associated with them

- **Electrostatic charge** – charge due to **excess or deficiency of electrons**
  - **Electrons > protons**, negatively charged (excess electrons)
  - **Protons > electrons**, positively charged (lack of electrons)
  - **Electrons = protons**, neutral
  - **like charges repel, unlike charges attract**
- Electrostatic charges can be created by **'friction'** and **contact**
  - Friction increases contact between bodies, **electrons are transferred** between objects

2.2 Define the **unit of electric charge** as the coulomb

- SI unit of electric charge – **coulomb (C)**
  - **1 Coulomb =** charge on $\mathbf{6.25 \times 10^{18}}$ electrons/protons
  - Charge of one electron/proton = $\frac{1}{6.25 \times 10^{18}} = \mathbf{-/+ 1.60 \times 10^{-19}}\, C$
- **Q and q used** to represent electric charge

2.3 Define the **electric field** as a field of force with a **field strength** equal to the force per unit charge at that point: $E = \frac{F}{q}$

- **Electric field** – region where electric charge **experiences a force**
  - Q exerts a force F onto another charge, q
  - No change in **charge** from the force
- Electric field **direction** – **direction acting on a positive charge**
  - **Positive charge** placed in electric field will go **same direction**
  - **Negative charge** placed in electric field will go **opposite direction**
  - Force and electric fields have a **direction**
- Electric field **strength/magnitude** (E) – force (F) exerted on a charge (q) when placed at a point
  - Measured by $E = \frac{F}{q}$ (strength equal to force per unit of charge) where:
    - E is **electric field strength** measured in **newtons/coulomb (N/C)**
    - F is **force** measured in newtons
   - q is the charge measured in coulombs
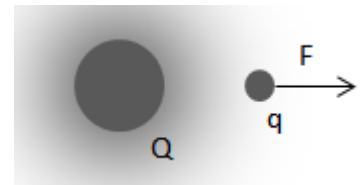
Define **electric current** as the **rates at which charge flows** (coulombs/second or amperes) under the influence of an electric field

- Electric current (I) – **rate at which net charge flows under influence of an electric field**
  - When a neutral body moves (protons and electrons moving same direction/speed), no current
- Measured in **amperes** (A, amp) – amount of current when **one coulomb** flows in **one second**

2.5 Identify that current can be either **direct** with the net flow of charge carriers **moving in one direction** or **alternating** with the charge carriers **moving backwards and forwards**

- **Charge carriers** – moving charges in an electric field
  - **Direct current** (DC) moves in **one direction**
  - **Alternating current** (AC) alternates **back and forth**
    - Terminals alternate by **changing polarities**
- Negative charges move from **negative to positive terminal** to form electricity
- Positive charges move from **positive to negative terminal** – conventional current
 - Normally use **conventional current** (from + to -)

Negative charge flow
Electron Current

Positive charge flow
Conventional Current
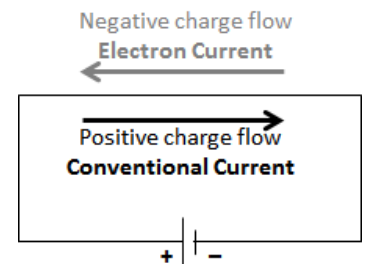
Further explanation of current: http://web.engr.oregonstate.edu/~traylor/ece112/lectures/elect_flow_vs_conv_I.pdf

2.6 Describe **electric potential difference (voltage)** between two points as the **change in potential energy** per unit charge moving from one point to the other **(joules/coulomb or volts)**

- Electric **potential difference** – change in **potential energy/work per coulomb** of charge between two points
  - E.g. a 6V battery gives 6 joules of energy per coulomb of charge
- Also known as **voltage (V)**, measured in **volts**

2.7 Discuss how **potential difference changes between different points** around a DC circuit

- A **voltmeter** can measure **potential difference** between points:
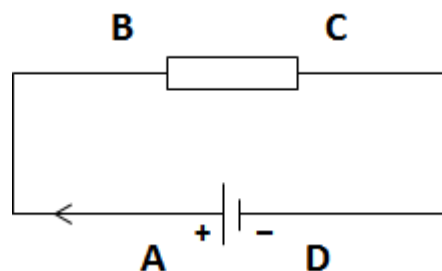
- **A to B (and C to D)**: no change, as there is little loss of electric potential energy through the wire (conductor)
- **B to C**: falls, as electric potential energy is **dissipated** in resistor – potential/voltage drop
- **D to A**: increases (potential/voltage rise) as electric potential energy **generated** by power supply
- **B to C and D to A** should be the same – as energy is generated, it is dissipated by the resistor

2.8 Identify the difference between **conductors and insulators**

- **Conductor** – material that **contains charge carriers**, e.g. metals, salt solutiosn
- **Insulator** – material that **does not contain charge carriers**, e.g. plastic, glass, rubber
    - If charge has enough energy (high voltage), insulator may be forced to conduct, e.g. lightning in air

2.9 Define **resistance** as the **ratio of voltage to current** for a particular conductor: $R = \frac{V}{I}$

- Resistance – potential difference across a resistor due to **collisions of between electrons and lattice**
- Resistance (R) measured in **ohms (Ω) –** Ohm's Law, $R = \frac{V}{I}$ (or $V = IR$)
    - If there is no change in voltage, then V = 0, so R = 0 (low resistance)
- Resistors can be **ohmic** or **non-ohmic**
    - Ohmic resistors have **V proportional to I** – so resistance stays the same
    - Non-ohmic resistors do not obey Ohm's law (V ∝ R)

2.10 Define qualitatively how each of the following **affects the movement of electricity** through a conductor: length, cross sectional area, temperature, material

- As **length** of conductor increases, **movement of electricity decreases** (resistance increases)
    - Greater chance of collision between electrons and positive lattice
- As **area of cross section** increases, **movement of electricity increases** (resistance decreases)
    - Lower chance of collision as there is more space for electrons to travel
- As **temperature** increases, **movement of electricity decreases** (resistance increases)
    - Lattice vibrates more, increasing chance of collision
- Depends on what **material** is used
    - **Metals** conduct more easily: Ag, Cu, Al, Fe high conductivity, **movement of electricity high**
    - Steel and Nichrome less conductive
    - Insulators such as glass used as insulators – **movement of electricity low**

2.P1 Present **diagrammatic information** to describe the **electric field strength and direction**

- Lines always go from **positive to negative**, never cross
- Strength measured by **number of arrows** (so equal charges have **same number of arrows**)

BETWEEN **CHARGED PARALLEL PLATES**

- Uniform electric field between parallel plates – **equal magnitude and direction**

not for KC Notes
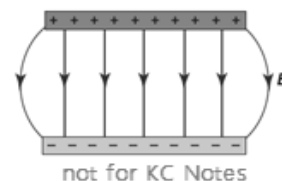
ABOUT AND BETWEEN A **POSITIVE AND NEGATIVE POINT CHARGE**

- Fields combine to produce **one resultant electric field**
- Points can form a **null point** where electric field strength is zero (n)

not for KC Notes
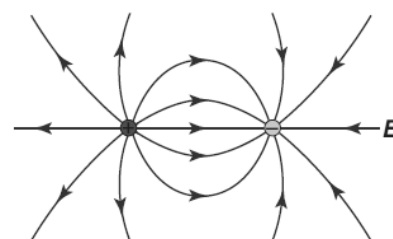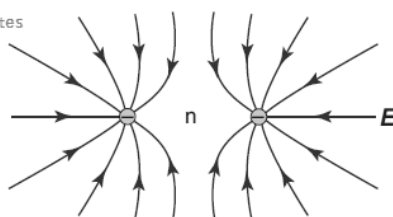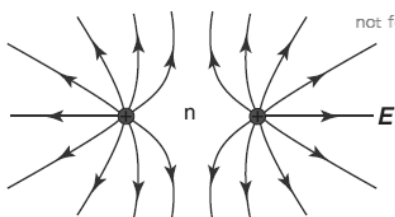
2.P2 Solve **problems** and analyse information using: $E = \frac{F}{q}$

A charge of -8 μC experiences a force of 0.5×10^{-4} *N west in an electric field. Calculate the strength, E, of the field at the point.*

A negative charge experiences a force in the **opposite direction – east**
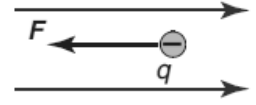
$$E = \frac{F}{q} = \frac{0.5 \times 10^{-4}\ N}{8\ \mu C} = \frac{0.5 \times 10^{-4}\ N}{8 \times 10^{-6}\ C} = \boldsymbol{6.25\ N/C}$$

Note: 1 Coulomb = 1×10^{-6} Coulombs

2.P3 Plan, choose equipment for and perform a first-hand investigation to gather data and use the available evidence to show the **relationship between voltage across and current in a DC circuit**

- See **Experiment 2.P3** in 8.3 Experiment Booklet

2.P4 Solve **problems** and analyse information applying: $R = \frac{V}{I}$

*A current of **5 A** flows through a **10 Ω** resistor. Calculate the potential drop across the resistor.*

$$V = IR = 5 \times 10 = 50\ V$$

*Calculate the current flowing if the voltage across a **4 Ω** resistor is **10 V**.*

$$I = \frac{V}{R} = \frac{4}{10} = 0.4\ A$$

2.P5 Plan, choose equipment for and perform a first-hand investigation to gather data and use the available evidence to show the **variations in potential difference** between **different points around a DC circuit**

- See **Experiment 2.P5** in 8.3 Experiment Booklet

2.P6 Gather and process secondary information to identify **materials** that are commonly **used as conductors** to provide **household electricity**

- **Copper** wiring is used
- **Aluminium and steel** used for **transmission lines** (copper too expensive, not strong enough)