



Essentials of Electricity 1:

Point Charges & Electrostatics

Atom-sized particles (atoms, subatomic particles, ions, molecules) have a property called **charge** that causes them to be attracted to each other or repelled from each other. Particles that have an excess of **electrons** have a **negative** charge, and particles that have a shortage of electrons have a **positive** charge. Particles that have opposite charges are attracted to each other, and particles that have similar charges are repelled from each other. The variable used to represent charge is **q**.

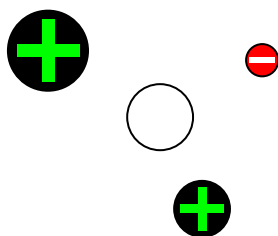
Every electron has the same amount of charge as every other electron, and this is also the smallest amount of charge you can have. It's called the **elementary charge**, and its symbol is **e**. A **proton** has a charge of **e**, and an electron has a charge of **-e**. Because elementary charges are small and hard to count in real-world measurements, we have another unit for charge called the **coulomb (C)**. A coulomb is equal to 6.24×10^{18} elementary charges; an elementary charge is equal to 1.602×10^{-19} C.

The degree to which particles attract or repel each other is called the **electric force (F_E)**. Electric force is determined by the magnitude of each charge (**q₁** and **q₂**) and the distance (**r**) between them. Greater charges mean stronger electric force and greater distances mean weaker electric force. Electric force, measured in **newtons (N)**, can be calculated with **Coulomb's Law**:

$$F_E = \frac{kq_1q_2}{r^2}, \text{ where } k = 8.988 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2.$$

ELECTRICAL FIELDS

We can also measure the influence of a charged particle on its surrounding space regardless of whether another charged particle is near enough to feel it. Think in terms of the gravity around a moon. If you're far enough away from the moon, you don't feel its pull, but the moon still has a gravitational field around it. Like the moon and its



gravitational field, a charged particle has an **electrical field** around it. The strength of the electrical field at a particular point some distance, **r**, away from a source of charge, **q**, can be calculated by

$$E = \frac{kq}{r^2}$$

The total field strength in the centre of the white circle is the sum of the field strengths from each of the surrounding three charges.

Electrical field strength can be positive or negative, depending on the source of the charge. It's also cumulative: if there are multiple sources of charge near a point, the total electrical field strength at the point is the sum of the individual field strengths of the charge sources.



ELECTRICAL POTENTIAL

Recall that an object has gravitational potential energy when it is held away from a source of a gravitational field (for example, by placing it on a high shelf where it could fall). In the same way, a charged object has **electrical potential energy** when it is held away from another charged object that it's attracted to, or when it's forced to be close to another charged object that it's being repelled from. The charged object's electrical potential energy is converted into kinetic energy when the object is released, just like an object's potential energy is converted when it falls.

To raise an object some vertical distance takes work, and the amount of work depends on the mass of the object being moved and the difference in height above the source of the gravitational field. The same is true in electrostatics: a charged particle that moves from one location to another in the presence of an electrical field gains or loses electrical potential energy, depending on the distance travelled and the charges' strengths. Like any form of energy, electrical potential energy (PE_E or E_E) is measured in joules (J).

The difference in energy between two locations, independent of the charge on the particle being moved, is called the **electrical potential** or **potential difference**. It's analogous to height in gravitational potential energy: it's a measure of the difference in the strengths of attractions a charge would experience between one location and another. Electrical potential is measured in **volts (V)** and so it's also called **voltage (V)**. In a uniform electrical field (E), the voltage across a distance (d) can be calculated as follows:

$$V = E \cdot d$$

It is important to remember that voltage, unlike other concepts in the electricity units of your course, is measured across a distance, not just at a point.

The work required to move a charge, q , through a potential difference is calculated by:

$$W = q \cdot V$$

Remember that work can also be defined as difference in energy, so the work is the difference in electrical potential energy a particular charged particle experiences in moving from one location to another.

The concept of voltage will be important when working with circuits, which is covered in the Learning Centre review worksheet *Essentials of Electricity 2*.

