Module 6 Section 2: Electric Fields

Electric Field Strength

Electric field strength, E, is defined as the force per unit positive charge. It's the force that a charge of +1 C would experience if it was placed in an electric field.

$$E = \frac{F}{Q}$$

E = electric field strength in NC^{-1}

F = force on the charged object in N

Q = charge of the object in C

Electrical field strength, E, is defined as the **force per unit charge** on a positive test charge at that point.

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

Both F and E, can be repulsive (positive) or attractive (negative).

Radial Fields

Point charges have a **radial electric field** (see Figure 1). Remember, the field lines show the direction in which a positive charge (shown by $+q$ in Figure 1) would feel a force when placed in the electric field. So for a positive point charge, $+Q$, the field lines point away from the point charge, and for a negative point charge, $-Q$, they point towards it.

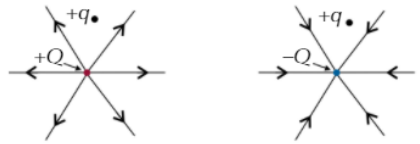


Figure 1: *Electric field lines for a positive point charge and a negative point charge.*

Coulomb's Law

Coulomb's law states that the force between two point charges is directly proportional to the product of the charges and inversely proportional to the separation squared.

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$$

Where $\frac{1}{4\pi\varepsilon_0}$ is a constant ≈ $9 \times 10^9\, F\, m^{-1}$

Uniform Electric Fields

A **uniform electric field** is one with the same electric field strength everywhere. It can be produced by connecting two parallel plates to the opposite poles of a battery — see Figure 1. This is a parallel plate capacitor. The field lines point from the plate with the more positive potential to the plate with the less positive potential.

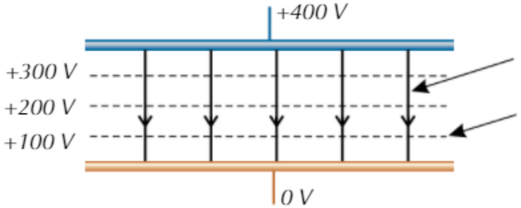


Figure 1: *Electric field lines between parallel plates.*

The field strength E is the same at all points between the two plates and is given by:

$$E = \frac{V}{d}$$

E = electric field strength in Vm^{-1}

V = potential difference between the plates in V

d = distance between the plates in m

Electric Potential

All points in an electric field have an **electric potential**, V. This is equal to the work done bringing a unit positive charge (+1 C) from a point infinitely far away to that point in the electric field. This means that at infinity, the electric potential will be zero.

So electric potential is the potential energy per unit charge. In a radial field around a point charge, electric potential is given by:

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

V = electric potential in V

Q = point charge creating the electric field in C

r = distance from the point charge in m

$$E = Vq = \frac{Qq}{4\pi\varepsilon_0 r}$$

Q = point charge creating the electric field in C

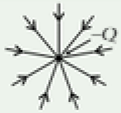
q = point charge in the electric field in C

E = electric potential energy in J

r = distance between Q and q in m

ε_0 = permittivity of free space in Fm^{-1}

Key points

Electric field strength, E, is force per unit positive charge.
Coulomb's law for the electric force between two point charges is also an inverse square law. $F \propto \frac{1}{r^2}$
The electric field lines for a negative point charge... 
Electric potential, V, is potential energy per unit positive charge and is zero at infinity.

Electric field strength: $E = \frac{F}{Q}$

Coulomb's law: $F = \frac{Qq}{4\pi\varepsilon_0 r^2}$

Electric field strength for a radial field: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$

Electric potential: $V = \frac{Q}{4\pi\varepsilon_0 r}$