18 Electric fields

18.1 Electric fields and field lines

- **Electric field strength** is defined as **the electrostatic force per unit positive charge acting on a stationary point charge at that point.**
- You can find the electric field strength (E) with the following equation

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

Here F is the electrostatic force on the charge (N) and q is the charge (C).

- Electric field is a vector quantity with SI unit of NC^{-1}
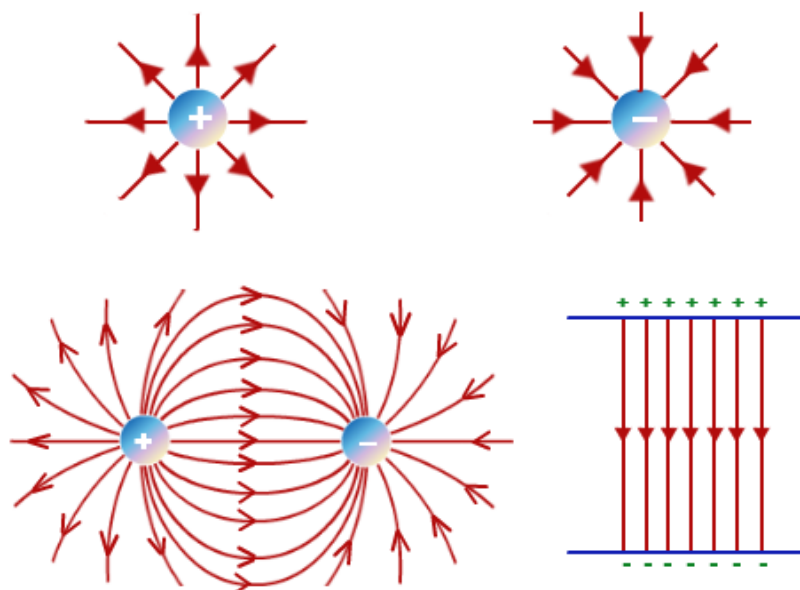
- **Opposite** charges **attract** each other.
- **Like** charges **repel** each other.
- The electric field equation can be rearranged for the force (F) on a charge (q) in an electric field (E)

$$F = QE$$

- The direction of the force is determined by the charge.
- If the charge is **positive**, the force is the **same** direction as the E field.
- If the charge is **negative**, the force is in the **opposite** direction to the E field.
- The force on the charge will cause the charged particle to accelerate if it is in the same direction as the E field, or decelerate if in the opposite.

## 18.2 Uniform electric fields

Candidates should be able to:

1   recall and use $E = \Delta V / \Delta d$ to calculate the field strength of the uniform field between charged parallel plates
2   describe the effect of a uniform electric field on the motion of charged particles

- The **electric field strength** (E) of a uniform field between **two charged parallel plates** is defined as:

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

Where ΔV is the potential difference between the plates and Δd is the separation between plates (m).
- E is now also defined by the units **Vm^{-1}**
- The equation above can only be used for **two charged parallel plates.**
- A charged particle will move through an electric field due to a force on it that is caused by said electric field.
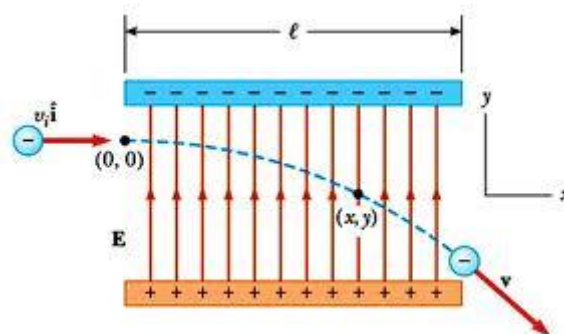
- The trajectory, as shown in the diagram above is **parabolic.**
- The direction of parabola depends on the charged of the particle.
- In the diagram above, the charge is **negative** hence it is deflected to the **positive** side of the plate.
- If the charge was **positive**, it would have deflected to the **negative** side.
- The **amount of deflection** depends on three things:
  -**Mass**: the greater the mass, the smaller the deflection and vice versa

-**Charge**: the greater the magnitude of the charge of the particle, the greater the deflection and vice versa
-**Speed**: the greater the speed of the particle, the smaller the deflection and vice versa.

Candidates should be able to:

1   understand that, for a point outside a spherical conductor, the charge on the sphere may be considered to be a point charge at its centre
2   recall and use Coulomb's law $F = Q_1Q_2/(4\pi\varepsilon_0 r^2)$ for the force between two point charges in free space

- Coulomb's Law states that **the electrostatic force (F) between two point charges is proportional to the product of the charges and inversely proportional to the square of their separation.**
- The coulomb equation is defined as

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Here Q_1 and Q_2 are the point charges (C), ε_0 is the permittivity of free space (8.85×10^{-12} Fm^{-1}), r is the distance from the centre of the point charge (m).

- If there is a **positive** and **negative** charge, then the electrostatic force is **negative (attractive)**.
- If the charges are the **same**, they are **positive (repulsive)**
- The equation above is analogous to **Newton's Law of Gravitation Force (F = Gm$_1$m/r^2).**

18.4 Electric field of a point charge (this should be right after 18.2!)

Candidates should be able to:

1   recall and use $E = Q/(4\pi\varepsilon_0 r^2)$ for the electric field strength due to a point charge in free space

- The electric field at a distance (r) due to a point charge (Q) in free space is defined by

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

- This equation is only used for electric field around **a point charge.**

- This equation is analogous to the **gravitational field strength (g = Gm₁/r²)** around a point mass.

18.5 Electric potential

- **Electric potential** is defined as **the work done per unit positive charge in bringing a small test charge from infinity to a defined point.**
- Electric potential is a **scalar** quantity.
- Although electric potential (V) is a scalar quantity it can have a **negative** or **positive** sign.
- The electric potential in the field due to a point charge is defined as:

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

- Here Q is the point charge producing the charge (C)
- This equation is analogous to **gravitational potential equation (ɸ = -Gm₁/r).**
- The **electric potential energy (EPE or E_p)** is **the work done in bringing a charge from infinity to that point**

$$EPE = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$$

- The equation above is the work done to move point charge Q₂ from infinity towards point charge Q₁.

If you want to calculate change in potential energy (ΔEPE) from a distance r₁ to a distance r₂ use the following equation

$$\Delta E_p = \frac{Q_1 Q_2}{4\pi\varepsilon_0}(\frac{1}{r_1} - \frac{1}{r_2})$$