18 Electric fields

18.1 Electric fields and field lines

Candidates should be able to:

1 understand that an electric field is an example of a field of force and define electric field as force per unit positive charge

2 recall and use $F = qE$ for the force on a charge in an electric field

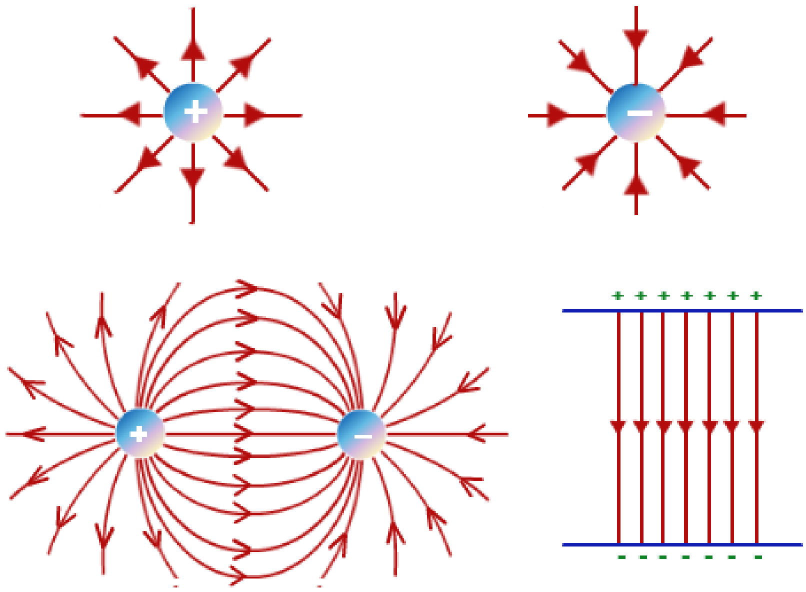
3 represent an electric field by means of field lines

- **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 change 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:

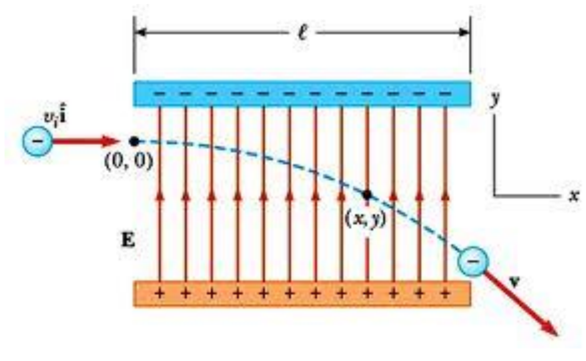
1 recall and use $E = \Delta V / \Delta d$ to calculate the field strength of the uniform field between charged parallel plates

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.

18.3 Electric force between point charges (this should be taught after 18.4 or before 18.1)

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 ($F = Gm_1m/r^2$)**.

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 ($g = Gm_1/r^2$)** around a point mass.

18.5 Electric potential

Candidates should be able to:

1 define electric potential at a point as the work done per unit positive charge in bringing a small test charge from infinity to the point

2 recall and use the fact that the electric field at a point is equal to the negative of potential gradient at that point

3 use $V = Q / (4\pi\varepsilon_0 r)$ for the electric potential in the field due to a point charge

4 understand how the concept of electric potential leads to the electric potential energy of two point charges and use $E_p = Qq / (4\pi\varepsilon_0 r)$

- **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 (ϕ = $-Gm_1/r$)**.
- 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 Q_2 from infinity towards point charge Q_1.

If you want to calculate change in potential energy (ΔEPE) from a distance r_1 to a distance r_2 use the following equation

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