# 22 Electric Field

## 22.1 Field Patterns

Like charges repel, unlike charges attract.

- **Electrons** are responsible for charging in most situations.

  An **uncharged atom** contains equal numbers of protons and electrons, an **uncharged solid** contains equal numbers of electrons and protons.

- **Electrical conductors** contains lots of **free electrons** - they are not attached to any one atom.

  An isolated conductor can be charged by direct contact with any charged object.

- **Electrically insulating material** do not contain free electrons - all electrons in an insulator are attached to individual atoms.

  Some insulator are **easy to charge** because their surface atoms easily gain or lose electrons.

The **gold leaf electroscope** is used to detect charge.

1. If a charged object is in contact with the metal cap, some of the charge of the object **transfer to the electroscope**.
2. As a result, the **gold leaf** and the **metal stem** attached to the cap **gain the same type of charge** and the leaf rises because it is repelled by the stem.

#### Field Lines and Patterns

Any two charged object exerts equal and opposite forces on each other without being directly in contact.

- An electric field is said to surround each charge.
- The path a **free positive test charge** is called a **field line**.

  The direction of an electric field line is the direction a positive test charge would move along.

## 22.2 Electric Field Strength

The electric field strength $E$ at a point in the field is defined as the **force per unit charge** on a positive test charge placed at that point.

The unit of $E$ is the **newton per coulomb** $\mathrm{N\,C^{-1}}$.

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

**Uniform Electric Field**

The field lines between two oppositely charged flat plates are

- **Parallel** to each other.
- At **right angle** to the plates.
- From the positive plate to the negative plate.

The field between the plates in **uniform** because the electric field strength has the same magnitude and direction everywhere between the plates.

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

**Field Factors**

- An electric field exists near any charged body.
- The greater the charge on the body, the stronger the electric field is.
- For a **charged metal conductor**, the charge on it spread across the surface.
- The **more concentrated** the charge is on the surface, the greater the strength of the electric field strength is above the surface.

The electric field between two oppositely charged parallel plates depends on the **concentration of charge** on the surface of the plates. The charge on each plate is spread evenly across the surface of the plate.

$$E \propto \frac{Q}{A}$$

And introduce a constant of proportionality such that

$$\frac{Q}{A} = \varepsilon_0 E$$

where $\varepsilon_0 = 8.85 \times 10^{-12} \mathrm{F\,m^{-1}}$, also called the **permittivity of free space**. It represents that **charge per unit area** on a surface in a vacuum that produces an electric field strength of one volt per metre between the plates.

## 22.3 Electric Potential

The electric potential at a pertain position in any electric field is defined as the **work done per unit positive charge** on a positive test charge when it is moved from infinity to that point.

$$V = \frac{E_p}{Q}$$

the unit of electric potential is the **volt**, equal to $1 \mathrm{J\,C^{-1}}$.

**Potential Gradients**

The equipotentials for an electric field are like equipotential for a gravitational field.

- Both are lines of **constant potential energy** for the appropriate test object.
- In one case a test charge, the other case a test mass.

The **potential gradient** at any point in an electric field is the **change of potential per unit change of distance** in a given direction.

- The closer the equipotentials are, the greater the potential gradient is at right angles to the equipotentials.
- If the field is uniform (between two oppositely charged parallel plates), the potential gradient is
  - Constant.
  - The potential **increases in the opposite direction** to the electric field.
  - Equal to $\frac{V}{d}$

The electric field strength is equal to the **negative of the potential gradient**.

$$E = -\frac{dV}{dx}$$