Electrostatics

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$$\text{Force between point charges in vacuo, } F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$$

- ε_0 = permittivity of free space
  - Air can be treated as a vacuum when calculating force between charges
  - For a charged sphere charge may be considered to be concentrated at the centre

- Electric fields can be represented by field lines - the direction of which is positive to less positive
  - An electric line of force is the path along which a free positive charge would tend to move

- Electric field strength at a point in an electric field is the force exerted by the field by a unit positive charge placed at that point

$$\text{Electric field strength, } E = \frac{F}{Q} \quad \text{unit: N C}^{-1} \text{ or V m}^{-1}$$

Therefore the force exerted on charge Q at a point is given by F = EQ

$$\text{magnitude of field strength in a } \textbf{uniform} \text{ field, } E = \frac{V}{d}$$

This can be derived from the work done moving a charge between the plates:
F d = QΔV

$$\text{field strength in a } \textbf{radial field}\text{, } E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

Electric potential

The electric potential at a certain position in any electric field is the *"work done per unit positive charge on a positive test charge when it is moved from infinity to that position"*.
Hence electric potential = 0 at infinity.

$$\text{Electric potential, } V = \frac{work\ done, W}{Q} \quad \text{unit: J C}^{-1}$$

Work done moving charge Q, ΔW = QΔV

$$\text{Magnitude of electric potential in a radial field, } V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

Unlike gravitational potential, electric potential is a scalar quantity.

The electric potential of a positively charged particle increases as it moves to a point at higher potential - it gains energy from work having to be done to move it against electrostatic repulsion.

Potential difference between two points in an electric field is equal to the work done in moving a unit positive charge from the point at lower potential to the point at higher potential.

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

$$\text{electric field strength, } E = -\text{potential gradient } = -\frac{\Delta V}{\Delta r}$$

- E-r graph follows an inverse-square law as E $\propto$ 1 , but there is no electric field strength inside the charged sphere itself.
    - Hence graph starts at r rather than 0, and rapidly approaches 0
    - ΔV can be found from the area under this graph as $E = -\frac{\Delta V}{\Delta r}$

- V—r graph is constant from 0 to r, then falls at a rate lesser than E-r graph as V $\propto \frac{1}{r}$

A charged particle aimed through a uniform field will accelerate in one plane only, resulting in a parabolic arc similar to a ball thrown horizontally on Earth.
Relative strength: electric forces in a hydrogen atom are approximately 10^{39} times stronger than the gravitational forces acting.