

Coulomb's law

Coulomb's law gives the **electric force between two charges**



$$F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$$

where ϵ_0 is a constant called the **permittivity of free space**.
 $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$

Therefore, the force between two charges follows the **inverse square law**.
 Force increases with greater charge or smaller distance.

F = force Q = charge r = distance between charges

Exam Tip!

Air can be considered a vacuum when determining forces between charges

Exam Tip!

A charged sphere can be modelled as a point charge at the centre of the sphere



Exam Tip!

Attractive forces are negative, repulsive forces are positive

Electric and gravitational fields

Electric and gravitational fields have many similarities!

	Gravitational	Electrostatic
Source of force field	Mass	Charge
Interaction	Masses always attract	Charges can attract or repel
Force	Inverse square law relationship with respect to distance between masses $F = \frac{Gmm}{r^2}$	Inverse square law relationship with respect to distance between charges $F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$
Field strength	Force per unit mass	Force per unit charge
Potential in radial field	Always less than zero	Sign depends on the charges

Electric fields

Work done to move charge Q :

$$\Delta W = Q\Delta V$$

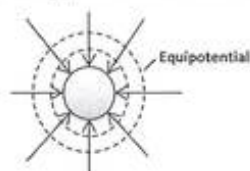
A potential difference of 1 V will do 1 J of work on a charge of 1 C.

Equipotential surfaces

Equipotential surfaces are **surfaces of constant potential**.

When travelling along an equipotential the potential remains constant, there is no change in potential (ΔV)

Therefore, since $\Delta W = Q\Delta V$, then **no work is done when moving along an equipotential**.
 Electrons move in equipotentials around the nucleus.



Electric potential

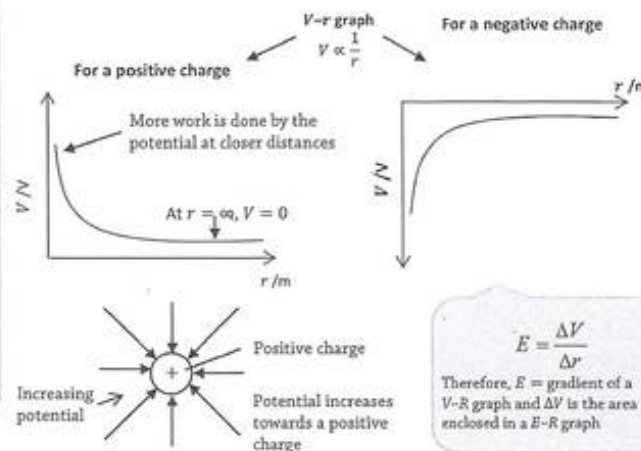
Electric potential, V : the work done per unit charge on a positive charge when it is moved to a **given position from infinity**.
 The value for electric potential at infinity is zero.

Magnitude of electric potential in radial field:

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$$

W = work done on charge
 V = electric potential
 r = distance between charges

Electric potential decreases with increasing distance



Electric field strength

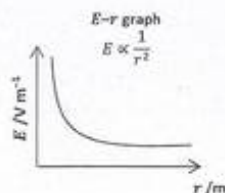
Electric fields arise due to a charged object and can be represented by field lines that show the **path a positive charge would take** if placed in the field. When a charged object is in the presence of an electric field it will experience an electrostatic force that is exerted by the field.

Electric field strength is defined as the **force, F , per unit charge, Q** , in the field:

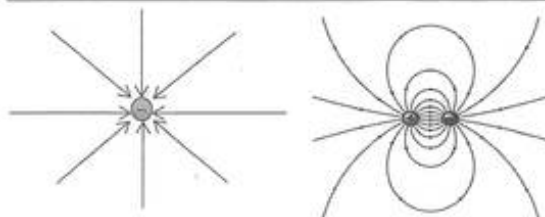
$$E = \frac{F}{Q}$$

E = electric field strength
 F = force on charge
 Q = charge

So a greater electric field strength produces a larger force on a charge.



Radial fields



The radial field around a negative point charge.

It is attractive because electric fields are always drawn with reference to a positive point charge.

The electric field strength created by a point charge is given by

$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$$

The field lines of a positive and negative charge brought close together.

A positive charge would be attracted to the negative charge and repelled from the positive charge.

Electric field strength in a uniform field

When a potential is applied across parallel plates, a uniform electric field is created.

Deriving the electric field strength in a uniform field
 Start with the work done moving a charge through a potential

$$Fd = Q\Delta V$$

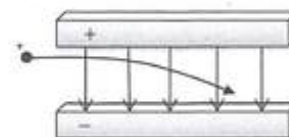
which rearranges to

$$\frac{F}{Q} = \frac{\Delta V}{d}$$

$$F/Q = E \text{ so}$$

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

d = distance between parallel plates



A moving positive charge in a uniform electric field takes a parabolic path as it is repelled by the top plate and attracted by the bottom plate. A negative charge would move up.