Electric Field Basics

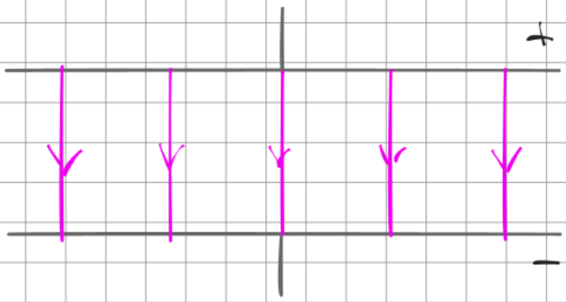
4th Dec

Electric field: a region in space where a charged object experiences a non-contact electrostatic force

Electric field strength: force per unit positive charge $E = \frac{F}{q}$ in $N\,C^{-1}$ (or $V\,m^{-1}$)

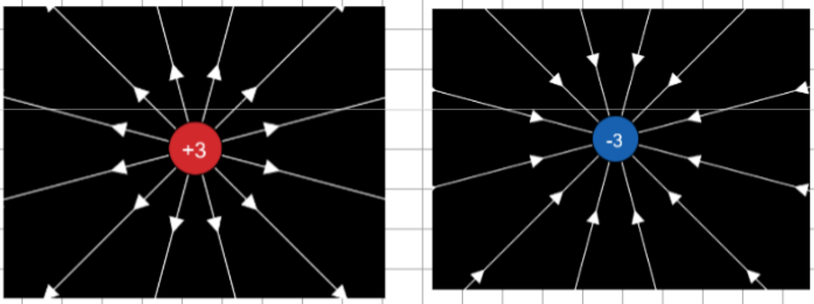
Field strength is a vector quantity. The DIRECTION of an electric field is defined by the effect it has on a POSITIVE CHARGE.

Uniform Field:

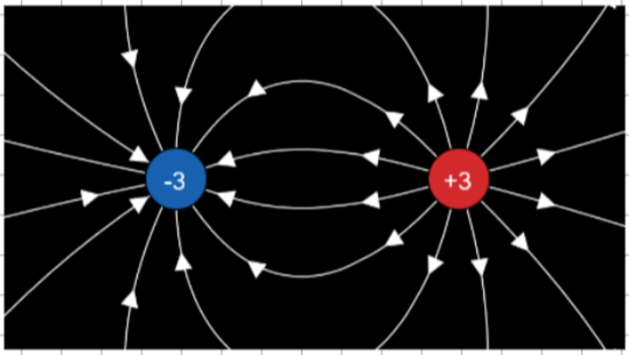


- Field strength is constant Hence a constant field line density
- A positive charge would move in the direction of the field, a negative particle would move in the opposite direction to the field

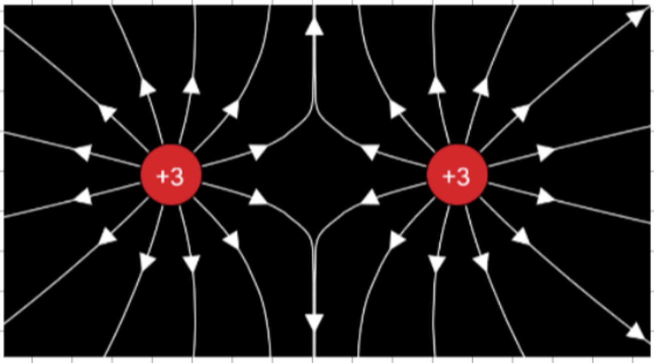
Radial Fields



These two fields have the same field line density at all distances as they have the same magnitude of charge. The charges have opposite polarities, so the field lines have opposite directions.



In this situation the force experienced by a positive charge placed in the centre would act away from the +3 C charge and towards the - 3 C charge.



If a small positive charge was placed in the centre of these two larger charges, it would experience NO RESULTANT FORCE. Hence, there are no field lines in the centre.

By definition the net electric field strength at this location is ZERO (a null point).

Force between Charges and Electric Field Strength

8th Dec

The electrostatic force between two point charges is:

Coulomb's Law

- Proportional to the products of the charges
- inversely proportional to the square of their separation

$F \propto Qq$ $\qquad$ $F \propto \frac{1}{r^2}$

$$F \propto \frac{Qq}{r^2}$$

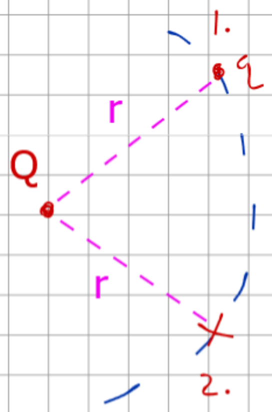
$$F = k\frac{Qq}{r^2} \quad \text{where} \quad k = \frac{1}{4\pi\varepsilon_0}$$

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

ε_0 is the permittivity of free space

$\varepsilon_0 = 8.85 \times 10^{-12}\ Fm^{-1}$

Consider the space around a charged particle with a charge Q:



1. Force experienced by our smaller charge q, placed a distance r away from Q:

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

There are a few scenarios possible depending on the charge of each object:

	q positive	q negative
Q positive	+F; repulsion	-F; attraction
Q negative	-F; attraction	+F; repulsion

2. The electric field strength at a distance r from a charge Q is given by:

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

So, to calculate the force our smaller charge q experiences when placed a distance r away from the larger charge Q:

$$F = \text{field strength} \times q = \frac{Q}{4\pi\varepsilon_0 r^2} \times q$$

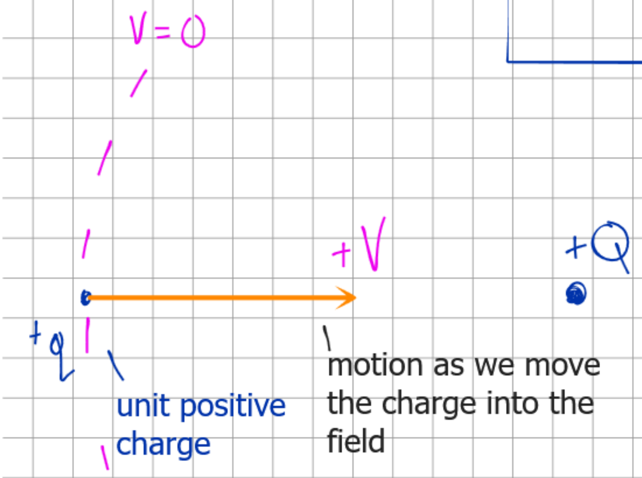
Electric Potential

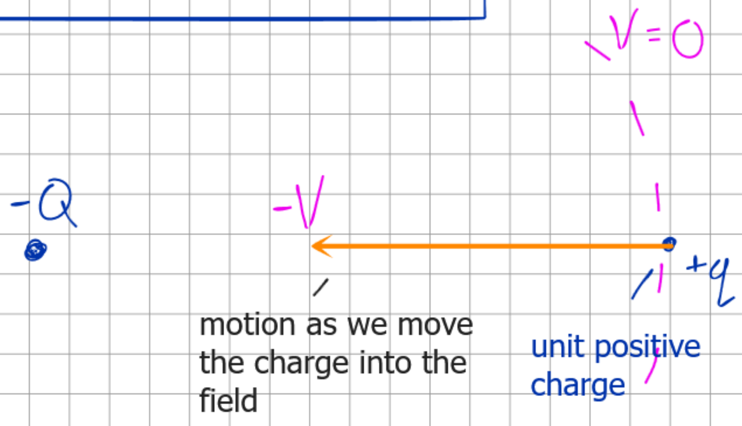
11th Dec

Electric potential: work done in moving a UNIT POSITIVE CHARGE from infinity to a point in an electric field

The electric potential energy of a charge is the work that was done to move it from an infinite distance to a point in an electric field. We can find the electric potential energy (U) of a charge by multiplying the electric potential (V) of its location by the magnitude of its charge (Q).

$$\boxed{V = \frac{U}{Q} \quad \text{in J C}^{-1} \text{ or Volts} \quad \text{a SCALAR quantity}}$$





The potential of the space around a positive charge is POSITIVE as we would have to do work against the electric field to move our unit positive charge in from infinity.
The POTENTIAL ENERGY of the unit charge increases.

The potential of the space around a negative charge is NEGATIVE as the work done to move the positive charge from infinity is done by the field.
The POTENTIAL ENERGY of the unit charge decreases.

The potential a distance r away from a charge Q is given by:

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

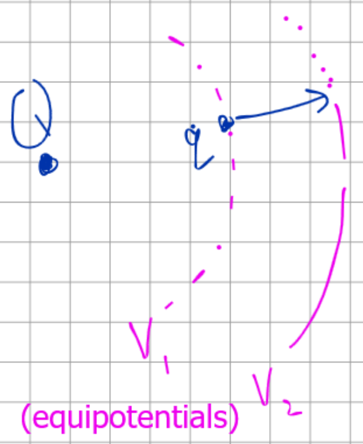
Q — the charge that is generating the electric field

r — the distance away from that charge

If we are given a scenario where there are two charges, we can calculate the potential any point by calculating the potential caused by each charge, and adding them.

$$V_1 = \frac{Q_1}{4\pi\varepsilon_0 r} \qquad V_2 = \frac{Q_2}{4\pi\varepsilon_0 r} \qquad V_A = V_1 + V_2$$

Consider a charge q being moved between two positions in an electric field:



To find the change in potential:

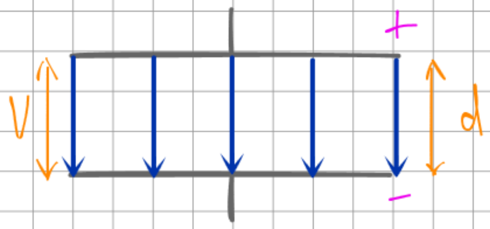
$$\Delta V = V_2 - V_1 \quad \text{(final - initial)}$$

To find the work done in moving the charge, we need to find the change in potential energy:

$$\Delta U = q\Delta V$$

Uniform Field Strength and Potential

15th Dec



Field lines always point in the direction of decreasing potential.

The magnitude of the field strength can be found if we know how much the potential changes by over a certain distance.

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

When considering moving a positive charge from one plate to the other in the uniform field above:

$$E = \frac{F}{Q} \qquad \text{and} \qquad W = Fd$$

$$F = EQ \qquad\qquad F = \frac{W}{d}$$

$$EQ = \frac{W}{d}$$

By definition then work done when moving a charge across a potential difference:

$$W = VQ$$

Hence:

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

In a uniform field:

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

– potential difference between plates

– separation of the plates