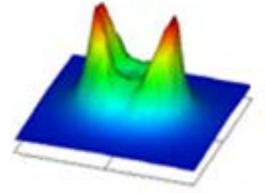


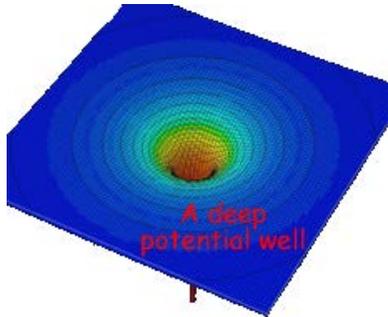
## Fields - A2 Summary

A field is the sphere of influence of a force that acts to lower the potential of the object.

- It is the region over which the force is experienced.
- It can be thought of as topography - a landscape of ups and downs - hills and dales - various gradients and heights.
- The force experienced causes changes in potential energy of the object affected. If you supply energy to the system (**do work**) you will push in opposition to the force and give the object more **potential energy**. If you allow the system to naturally act the object will naturally move to a lower potential and you can use that movement to do work for you.



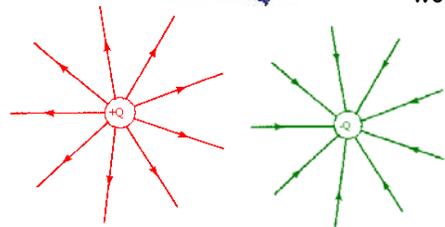
Around a mass there is a **gravitational field**



- the field lines show the direction a point mass would move if it was placed there. As all masses are attractive to each other, the field lines around a mass move point masses towards that mass (arrows on field lines point towards the mass). You can think of the field lines as forming a 'dip' in the space continuum - other masses would roll into the 'dip'. It is a gravitational potential 'well'.

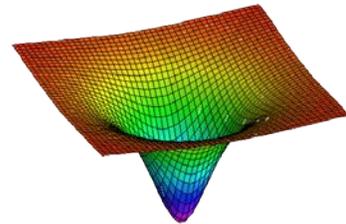
Around a charged particle there is an **electric field**

- the field lines show the direction a point positive charge would move if it was placed there.

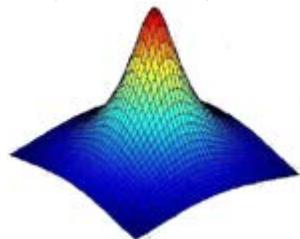


As all opposite charges are attractive to each other, the field lines around a negative charge move point positive charges towards that negative charge (arrows on field lines point towards the charge).

You can think of the field lines around a negative charge as forming a 'dip' in the electric continuum - positive charges would roll into the 'dip'.



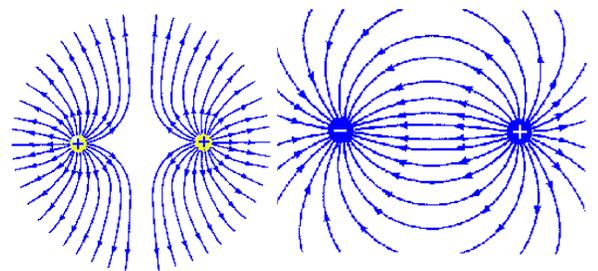
As all like charges are repulsive to each other, the field lines around a positive charge move point positive charges away from that positive charge (arrows on field lines point away from the charge).



You can think of the field lines around a positive charge as forming a 'mound' in the electric continuum - positive charges would roll away from the 'mound'.

Combinations of charges form complex patterns - the field lines merge. Field lines for gravitational fields always start on a force and then spread outwards, but

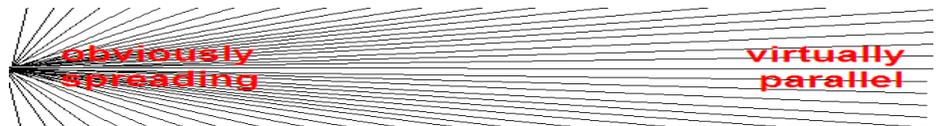
electric field start on a positive charge and finish on a negative one.



Around a **moving charge** as well as an electric field there is a **magnetic field**

- the magnetic field lines (or flux lines) show the direction a search compass would point if it was placed there.
- The field lines of a magnetic field are all **complete loops**. They have no beginning and no end - they do not cross each other or meet at all - they are rather like contour lines on a map.
- If a moving charge enters a magnetic field it may experience a force or may not! It all depends on the direction it is moving in. It has to be moving with a component of velocity perpendicular to the field if it is to experience a force.
- The direction of that force is then found using **Fleming's Left hand Rule**.

If you look at the **radial field lines** a long way from the source they are virtually parallel to each other over a short distance. They are then said to be a



## Fields - A2 Summary

### uniform field.

This is the case when we look at the gravitational force lines at the Earth's surface.

### Field Strength

This is force acting on unit 'something':

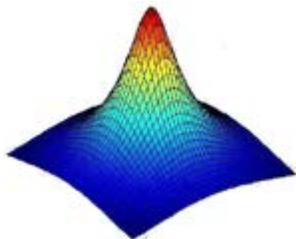
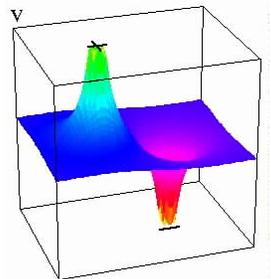
- **Gravitational field strength** ( $g$ ) is force acting on unit mass (a kilogram) - measured in N/kg
- **Electric field strength** is force acting on unit positive charge (a coulomb) - measured in N/C (or V/m - we'll get to that later!)
- **Magnetic field strength** ( $H$ ) is not on the syllabus so don't worry about it. All you have to think of it as is the density of flux (closer flux lines stronger field). Field strength is proportional to flux density  $B$  (measured in tesla (T))

### When objects are placed in fields they experience a force -

- **Gravitational force** only pushes and pulls masses it has no effect on charges.
- **Electric Force** only pushes and pulls charges - you ignore the mass when looking at it and
- **Magnetic force** only pushes and pulls MOVING charges - the mass here has an effect on the speed of movement so magnetic forces are a bit more complicated

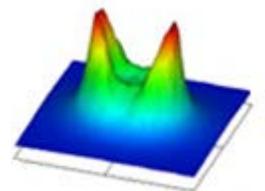
### Potential in a field

- The **gravitational potential** at a point in a gravitational field is the **work done in bringing unit mass (a kilogram) from infinity to that point in the field.**
- The sign of this would always be negative as you would not have to 'do' work - any mass 'falls' towards another.
- The **electric potential** ( $V$ ) at a point in an electric field is the **work done in bringing unit positive charge (a coulomb) from infinity to that point in the field.** It is measured in volts. Think of electric 'height' as being measured in volts.
- The net sign of this would be positive if the field was made from a positive charge being in the vicinity as you would have to 'do' work to overcome the repulsion - push it 'up hill'.
- The net sign of this would be negative if the field was made from a negative charge



being in the vicinity as you would not have to 'do' work they would attract each other - it would just 'roll down' into the potential 'well' or 'dip' in the field.

- Points that are an equal distance from a charge are at equal potential - this is called an **equi-potential surface** and is an imaginary sphere around the point charge.
- Charges have an electric landscape around them like a hill or hollow dip - at a given distance from the centre the 'land' is at the same 'height'.
- If you are considering the potential at a point that is in the field of more than one charges you work out the potential for each charge at that point and then add them together to give the total potential for that point.
- 'Hillocks' and 'dips' from two charges in the landscape would combine to give an undulating landscape.
- The **potential difference** between two points in an electric field is numerically equal to the work done in moving a unit positive charge from the point at lower potential to the point at the higher potential.
- This is like a difference in 'height' in the electric landscape.



## Fields - A2 Summary

Uniform motion in a circle where is angular speed

$$\omega = \frac{v}{r} \quad \omega = 2\pi f \quad a = \frac{v^2}{r} = r \omega^2$$

You need to use these with charges in magnetic fields

Centripetal force equation : recall and use of

$$F = \frac{mv^2}{r}$$

Derive the equation for centripetal acceleration from this and F=ma

Gravity, Newton's law, the gravitational constant G

Recall and use of

$$F = -\frac{Gm_1m_2}{r^2}$$

State and explain the significance of the terms in the equation including why the -ve sign is included. Carry out calculations of gravitational force of attraction. Understand what the inverse square relationship means. Compare the magnitudes of the fundamental forces.

Gravitational field strength g

$$g = \frac{F}{m} \quad g = -\frac{GM}{r^2} \text{ (radial field)}$$

$$g = -\frac{\Delta V}{\Delta r}$$

Define gravitational field strength as force acting on unit mass. Explain significance of -ve sign. Refer to **vector nature** of g.

Gravitational potential V

$$V = -\frac{GM}{r} \text{ (radial field)}$$

Graphical representations of variations of g and V with r

Define gravitational potential as work done in taking unit mass to infinity. Explain significance of -ve sign. Refer to **scalar nature** of V.

Motion of masses in gravitational fields

Circular motion of planets and satellites including geosynchronous orbits

Moving masses move in orbits according to the velocity vector that is at right angles to the field lines – stationary ones accelerate towards the source of the field.

## Fields - A2 Summary

	Compare and contrast radial and uniform fields in terms of gravitational field strength and gravitational potential NB this must include graphs
Coulomb's law, permittivity of free space $\epsilon_0$ Recall and use of	The gravitational force of attraction provides the centripetal force for orbital motion. Use the equations for circular motion to derive the relationship between r and T (period of orbit).
$F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$	
Electric field strength E	Application example estimation of forces at closest approach in Rutherford alpha particle scattering E is the <b>force on unit charge</b> – look at the force equation – replace one of the charges with 1C and you get this one! Force – so it's a vector. For the uniform field you can think of E as a potential gradient (volts per metre)
$E = \frac{F}{Q} \quad E = \frac{V}{d} \text{ (uniform field)}$	
$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \text{ (radial field)}$	
Electric potential V	Comparison with gravitational fields, NB can have +ve and -ve charge and therefore attractive and repulsive forces. Draw diagrams to show field patterns for radial and uniform fields. Graphs for E and V against r Refer to <b>vector nature of E</b> . Calculations involving position of 'null' point. You integrate E to get V – it is therefore a scalar. Resultant <b>V as scalar sum</b> of potentials due to charges.
$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$	
Motion of charged particles in an electric field  Trajectory of particle beams	Parabolic – field makes charges accelerate – move like projectiles under gravity – but can accelerate up as well as down
Similarities and differences between electric and gravitational fields	Use analogy with motion in a gravitational field ie. projectile motion. Recognise difference in behaviour between +ve and -ve charges.
Force on a current carrying wire in a magnetic field $F = B I l$ (field perpendicular to current)	Compare and contrast electric and gravitational fields

## Fields - A2 Summary

Motion of charged particles in a magnetic field

$$F = BQv \text{ (field perpendicular to velocity)}$$

Circular path of particles; application, e.g. charged particles in a cyclotron

Use Fleming's left hand rule to establish force at right angles to motion. Relate this to the condition for circular motion.

Equate expression for centripetal force to  $BQv$ . Establish effect on radius of orbit if  $B$ ,  $m$  or accelerating voltage change.

Magnetic flux density  $B$ , flux  $\phi$ , flux linkage  $N\phi$

$$\mathbf{BA} = \phi \text{ (B normal to A)}$$

Define  $B$  and Relate the two terms using a diagram, this will also explain the value of when  $B$  is not perpendicular to the area concerned (  $=BA \cos\theta$  )

For a flux change at a uniform rate:

$$\text{magnitude of induced e.m.f.} = N \frac{\Delta\Phi}{\Delta t}$$

Electromagnetic induction

Faraday's and Lenz's laws

Applications, e.g. p.d. between wing-tips of aircraft in flight

Recall **Faraday's Law**: that the magnitude of the induced EMF in a circuit is directly proportional to the rate of change of flux linkage (or to the rate of cutting of magnetic flux).

Recall **Lenz's Law**: that the direction of the induced EMF is such that the current which it causes to flow opposes the change which is producing it.

Know that the induced EMF is therefore:

- directly proportional to the number of turns of wire
- proportional to the rate of cutting of flux (how fast the flux lines are cut by the wire)
- produced in such a way as to make a current flow that has a magnetic field that opposes the field of the one causing the induction.