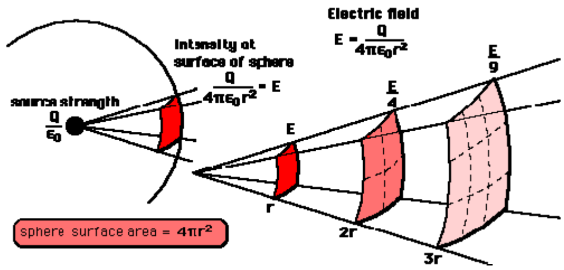
A2 Physics - Electric Fields Q&A Revision Sheet

Give the equation relating to the electrostatic force between point charges in a vacuum	$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$$ ♦ F is the electrostatic force ♦ Q1 and Q2 are the charges ♦ r is the distance between their centres ♦ Ɛo is the permittivity of free space (a vacuum)	♦ **When asked to 'give' an equation** always explain what the letters stand for. ♦ **Equation** from your data sheet. ♦ **Ɛo value** and units - on your data sheet ♦ Calculations will usually be 'point charges' - location will be the centre of the charge. ♦ **Units:** F must be in newton (N); The Qs should be in coulomb (C); r must be in metres
If 'F' (the electrostatic force) is negative what does that mean?	It means that the force is attractive - the charges will be made to accelerate towards each other	You will only get a negative result for the force calculation when one of the charges is positive and one is negative - opposites attract!
If 'F' (the electrostatic force) is positive what does that mean?	It means that the force is repulsive - the charges will be made to accelerate away from each other	You will get a positive result for the force calculation when both charges are the same sign (plus x plus = positive and minus x minus = positive) - opposites attract!
State Coulomb's Law	The magnitude of the electrostatic force of interaction between two point charges is **directly proportional** to the scalar multiplication of the magnitudes of charges and **inversely proportional** to the square of the distances between them. $$F = k_e \frac{q_1 q_2}{r^2}$$ where q is a charge, *r* is the separation distance and k_e is a proportionality constant	Note that **when you are asked to 'state' a law** you are expected to describe the equation in words. If you just write down the equation for the data sheet you will not get all of the marks!  *See http://www.cyberphysics.co.uk/ general_pages/inverse_square/inverse_square.htm*
What is permittivity?	Permittivity relates to how easy it is for a charge to move through the medium. Insulating materials have values of permittivity (Ɛ) given as a multiple of that for a vacuum (Ɛo). For example rubber has a permittivity of seven times that of free space. The force between two charges embedded in rubber would therefore be $^1/_7$th that of two identical charges within a vacuum. ***You will NOT be asked to define this! I have included this so that you can get some idea of what we are dealing with!***	

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What is an electric field?	The electric field is the region of space around a point charge where that charge experiences a force.	The further away from the force that you go the weaker that force will be. The field is three dimensional - but our diagrams only consider two.
What is a 'test charge'?	A 'test charge' is used to determine the strength of a magnetic field. A 'test charge' should be positive. the direction it moves in then shows the direction of the electric field.	It is placed in the field at a particular point and the force exerted on it is measured. The size of its charge and that force can then be used to measure the electric field strength at that point.
Give the equation that defines electric field strength.	$E = {}^{F}/_{Q}$ *E* – the electric field strength at a particular position in an electric field; *F* – the force a test charge would experience if placed at that point in the field; *Q* – the test charge	This is the same whatever the value of the 'test charge'. If we look at the Coulomb equation the test charge becomes one of the Qs. If you double the size of the test charge then F would double and so on... so as the numerator and denominator both increase by the same multiple their ratio will be the same!
Define electric field strength	The **electric field strength** is defined as **force per unit charge**.	It is the force a 'test charge' would experience if it was placed at that point in the electric field.
Is the electrostatic force a scalar or a vector?	Vector	All forces are vectors! You therefore have to add forces by resolving them into horizontal and vertical components and adding those.
Is the electric field strength a scalar or a vector?	Vector	Look at the equation it is a force (vector) divided by a charge (scalar) - so it is a vector. You therefore have to add electric field strengths by resolving them into horizontal and vertical components and adding those.
What is a radial field?	A field where the field lines radiate outwards from a point charge.	The radial electric field strength will therefore vary - getting weaker as you move away from the charge that is the source of the field.
What is the equation for the electric field strength around a point charge Q?	$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$ - From data sheet	If you get a negative value (using a negative charge as Q) that simply means the 'test charge' would accelerate towards the charge making the field and if positive that the 'test charge' would accelerate away - so ignore the sign - the examiners will be asking you to calculate the 'magnitude' of it.

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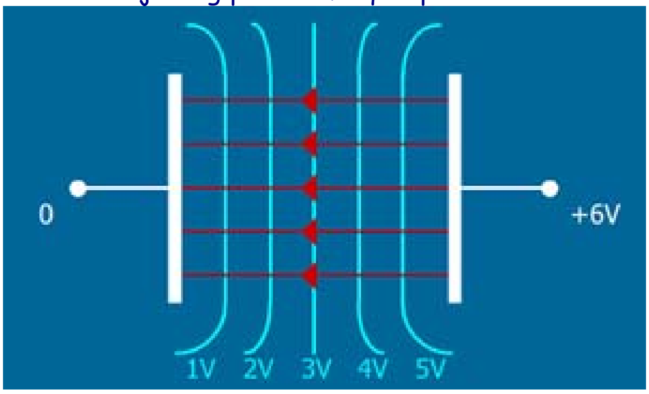
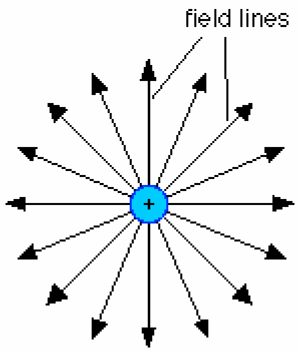
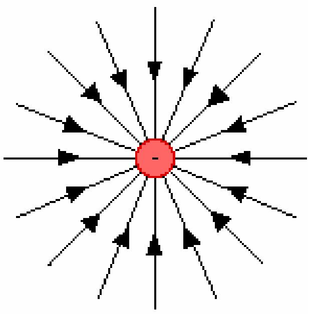
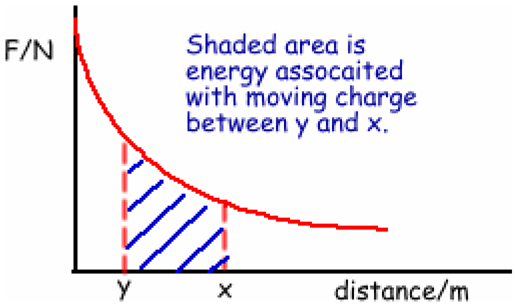
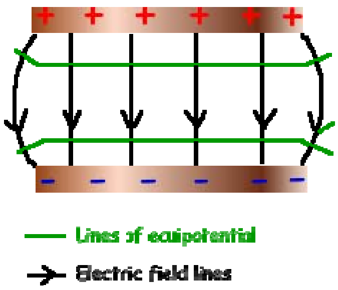
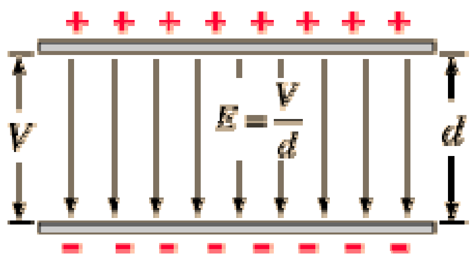
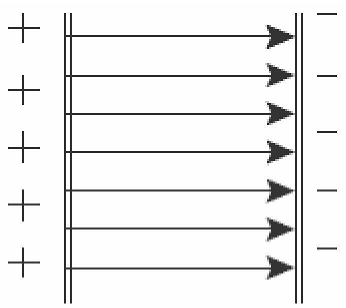
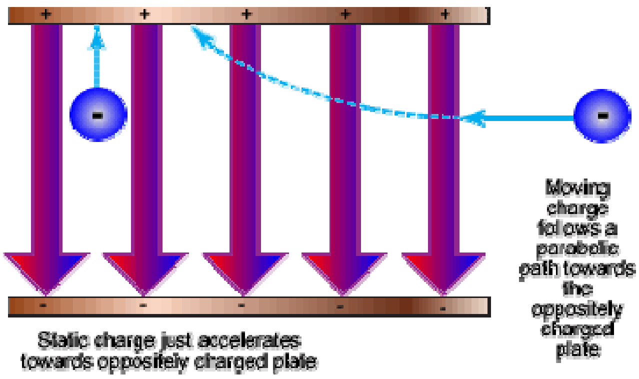
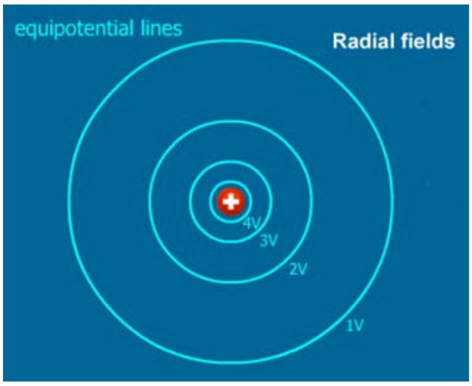
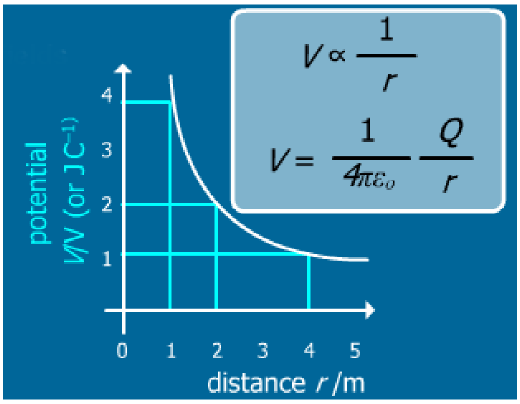
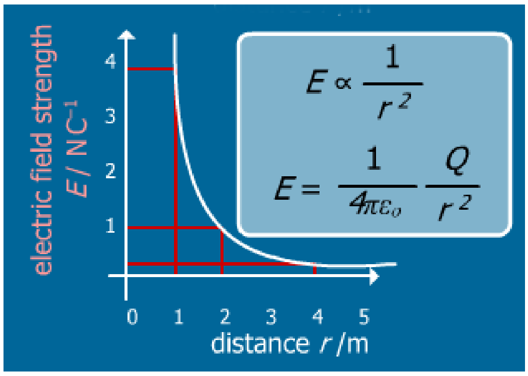
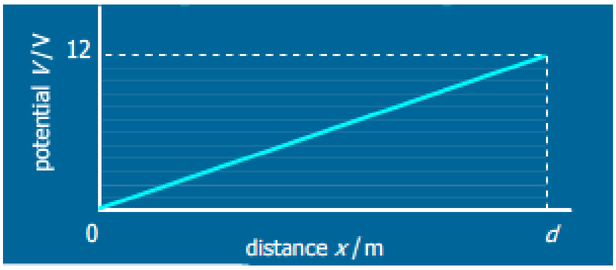
What is an electric field line?	It is the path that a single point charge would follow if placed in the field.	
What is an equipotential line?	It is a line joining points of equal potential.  	Equipotential lines are always perpendicular to field lines. In a uniform field they are evenly spaced. The red lines are field lines and the cyan ones are equipotential lines.
Sketch the field lines around a point positive charge.	  The electric field from an isolated positive charge	Field lines show you the direction that point positive 'test charge' would move within the field. So -think! Positive and positive repel so the lines must be given arrows pointing outwards.
Sketch the field lines around a point negative charge.	 The electric field from an isolated negative charge	Field lines show you the direction that point positive 'test charge' would move within the field. So -think! Negative and positive attract so the lines must be given arrows pointing inwards.
How can you tell the strength of an electric field from a field line diagram?	Stronger fields have more field lines per unit area - the field lines are closer together.	
How can you find energy	The area under the graph line is the energy	Energy is the integral of the force distance equation.

from a force/ distance graph		(Remember the Hooke's Law graph?)
How can you find electric potential energy from an electric field strength against distance graph?		The area under the graph represents the **energy transformed** when we moved a charge form one point to another in an electric field. We would have to do a job of work against the force of the field (or get work out if it were with the field), so there is an energy change.
What is a uniform field?	A uniform field is one in which the electric field strength is constant. This means that the field lines must be parallel to each other and equally spaced. Wherever you place the charge in the field it will have the same push from the Coulomb Force.	It can be approximated by placing two conducting plates parallel to each other and maintaining a voltage between them. It is only an approximation because of 'edge effects'. therefore any experiments must avoid the edge area. 
What is the equation for a uniform field?	$$E = \frac{V}{d}$$ where V is the potential difference between the plates and *d* is the distance separating the plates	
Sketch a field line diagram for two charged vertical plates (right one negative and left one positive).		Field line must go from positive to negative as a **positive test charge would move towards the negative plate**. The field lines should be equally spaced as the field is uniform.
What	The field lines will get closer together	E = V/d so if d gets smaller E gets bigger

happens to the field lines if two electric plates move closer together?		- the electric field strength will increase - therefore the field lines will get closer together
What happens to a charged particle if a) it is placed between charged plates b) it enters the region between charged plates		The stationary one simply accelerates towards the oppositely charged plate. In the diagram it has no initial horizontal velocity. The moving one continues to move horizontally at a steady rate while accelerating in the vertical plane - revise projectiles from AS - it therefore follows a parabolic path.
Define a volt.	There is a potential difference of one volt between two points within an electric field, if one joule of energy is required to move a charge of one coulomb between those two points.	$V = \frac{W}{Q}$ Voltage is the change in electric potential energy per unit charge - 1 volt is when Q = 1C and W = 1J
What is absolute electric potential?	At an infinite distance from a charge (at infinity) electric potential (V) is said to be zero. Absolute potential is related to that. The absolute electric potential is the work done in bringing unit positive charge from infinity to that point in the field.	As you are bringing positive charge in towards another positive charge you will have to do work against repulsion so the voltage will be positive at any point in the positive charge's field. If the charge was negative you would not have to put the effort in - it would be attracted - the energy you supplied would therefore be negative and the potential around a negative charge would be negative too.
Is electric potential a scalar or a vector?	It is a scalar	It has positive or negative values - but no direction! It is at a point in space. Points have no direction. You can therefore simply add potentials to get a net result.
What is the equation for the electric potential at a distance r from a point	$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$	- From data sheet - note that if the charge is negative the potential is negative too.

charge Q?		
Sketch a diagram of equipotential lines for a point charge.		Equipotential points at one volt intervals get further away from each other as the field gets weaker.
Sketch a graph of electric potential against distance and another of electric field strength against distance for a radial field.	 Note the difference in shape of a inverse relationship and in inverse square relationship	 Make sure you can sketch these accurately - with potential 4 goes to 2 then to one - with field strength 4 goes to 1 the one quarter!
Sketch a graph of potential difference against distance for a uniform field		If we take the potential at one plate to be zero then the potential at distance x from it increases steadily. The potential gradient is constant - equipotential lines are evenly spaced.
Compare and contrast electric and gravitational fields	**Similarity**: both inverse square law fields - both are non-contact forces - both are infinite range forces **Difference**: coulomb force relates to the interaction of charges whereas gravitational force relates to the interaction of masses; masses always attract but charges may attract or repel. The Coulomb force is much stronger than the gravitational force - constants of proportionality differ	In the exam compare the form of the equations - comment on the structure and variation in constants. Main thing is there is no negative mass - so gravity cannot be repulsive.

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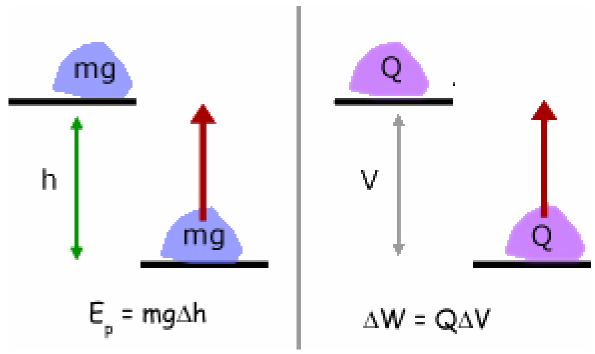
<table>
<tr>
<td>Compare work done in gravitational and electric fields</td>
<td>


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

compares to

$$\Delta E_p = mg\Delta h$$

from lower down the school as we then deal with problems where 'g' is constant. At A2 we link g and Δh into ΔV as 'g' also changes. This gives an equation that compares to the one for electric fields even better than before!

$$\Delta W = m\Delta V$$
</td>
<td>For a gravitational field if we compare the energy difference between a rock at the bottom of a cliff and the energy in moving it to the top of the cliff. An energy difference exists between the top of the cliff and the bottom. The amount of energy difference depends on the size of the rock and the height of the cliff (G.P.E. = mgh) .
For an electric field work has to be done in moving a coulomb between two points in an electric field.
In our analogy, difference in height relates to potential difference and rock weight relates to the amount of charge.
Work is done on the rock against the force of gravity.
Work is done on the charge in moving it against an electrostatic force.</td>
</tr>
<tr>
<td>What is E?</td>
<td>The electric field strength - also called electric intensity</td>
<td>Must be measured in NC^{-1} or Vm^{-1}
It is a vector</td>
</tr>
<tr>
<td>What is d?</td>
<td>The distance between two parallel plates</td>
<td>Must be in metres (m)</td>
</tr>
<tr>
<td>What is V</td>
<td>The potential difference between two points</td>
<td>Must be in volts (V)</td>
</tr>
<tr>
<td>What is r?</td>
<td>In the Electrostatic force equation it is the distance between two charges</td>
<td>Must be in metres (m)</td>
</tr>
<tr>
<td>What is Q?</td>
<td>The symbol for charge</td>
<td>Must be in coulombs (C)
It is a scalar that can be positive or negative.</td>
</tr>
<tr>
<td>Relevant Data Sheet Extracts</td>
<td colspan="2">

permeability of free space	μ_0	$4\pi \times 10^{-7}$	$H\,m^{-1}$
permittivity of free space	ε_0	8.85×10^{-12}	$F\,m^{-1}$
magnitude of the charge of electron	e	1.60×10^{-19}	C

ELECTRIC FIELDS AND CAPACITORS

force between two point charges	$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$	*electric potential*	$\Delta W = Q\Delta V$ $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$
force on a charge	$F = EQ$	*capacitance*	$C = \frac{Q}{V}$
field strength for a uniform field	$E = \frac{V}{d}$	*decay of charge*	$Q = Q_0 e^{-t/RC}$
field strength for a radial field	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$	*time constant*	RC
		capacitor energy stored	$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

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