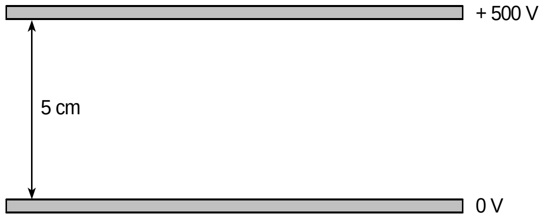
Electric fields summary problems HW – Complete + Self-mark using answers at the back.

Part 1: Uniform Electric fields problems

1) Here are two closely spaced metal plates connected to a 500 V supply.



Draw solid lines to represent the electric field both between the plates and just outside the plates. Add arrows to indicate the direction of the field.

2) Add, and label, dotted lines to the diagram of question 1, to represent lines of equipotential at 100 V intervals.

3) In an experiment to measure the charge on an oil drop, the potential difference between two parallel metal plates 5 mm apart was 300 V.

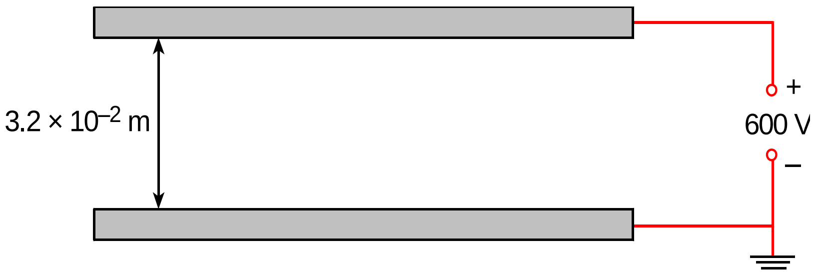
a) Calculate the electric field strength between the plates.

b) Calculate the electrical force on a small oil drop carrying a charge of 3.2×10^{-18} C.

4) Calculate the energy, in joules, gained by an electron accelerated through a potential difference of 50 kV in an X-ray machine.

5) Calculate the speed of an electron with a kinetic energy of 100 eV.

These next questions are about an experiment designed to measure the charge on an electron. In this experiment, 'Millikan's Oil Drop Experiment', two parallel metal plates, 3.2×10^{-2} m apart, are connected to a 600 V power supply:



6) Draw four arrowed lines on the diagram to show the electric field between the plates, well away from the edges of the plates.

7) Add dotted lines to the diagram to represent the 200 V and 400 V equipotentials between the plates. Indicate which is which.

8) Calculate the electric field strength between the two plates.

9) The electric field between the plates just supports the weight of an oil drop of mass 1.8×10^{-15} kg, which has acquired a charge due to a few excess electrons. Calculate the charge on the oil drop.

10) What is the most likely number of excess electrons acquired by the oil drop?

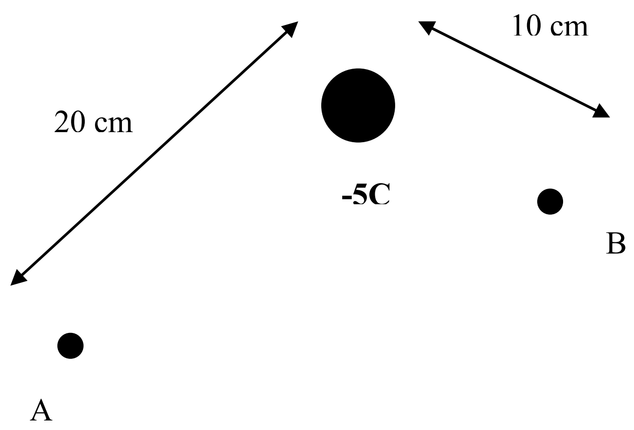
Part 2: Non-Uniform Electric field problems

1) Where the field strength is 1000 N C^{-1}, what is the force on a 1 C charge? On an electron?

2) A charged sphere is placed in a field of strength 3×10^4 N C^{-1}. If it experiences a force of 15 N, what is the charge on the sphere?

3) What is the field strength if an electron experiences a force of 4.8×10^{-14} N?

4) Work out the field strengths at the points labelled A and B in the diagram below. What do you notice about the values, and why is this? Add arrows at A and B to indicate the electric field strengths there.



5) In an experiment to test Coulomb's law, two expanded polystyrene spheres, each with a charge of 1.0 nC were 0.060 m apart (measured from their centres). Calculate the force acting on each sphere.

6) The electric field strength field at a distance of 1.0×10^{-10} m from an isolated proton is 1.44×10^{11} N C^{-1} and the electrical potential is 14.4 V.

   a) Calculate the electric field strength at a distance of 2.0×10^{-10} m from the proton.

   b) Calculate the electrical potential at a distance of 2.0×10^{-10} m from the proton.

7) A simple model of a hydrogen atom can be thought of as an electron 0.50×10^{-10} m from a proton.

   a) Calculate the electrical potential 0.50×10^{-10} m from a proton.

   b) The electron is in the electric field of the proton. Calculate the electrical potential energy of the electron and proton in joules.

8) When a uranium nucleus containing 92 protons and rather more neutrons emits an alpha particle of charge + 3.2×10^{-19} C the remaining nucleus then behaves like a sphere of charge of magnitude + 1.4×10^{-17} C.

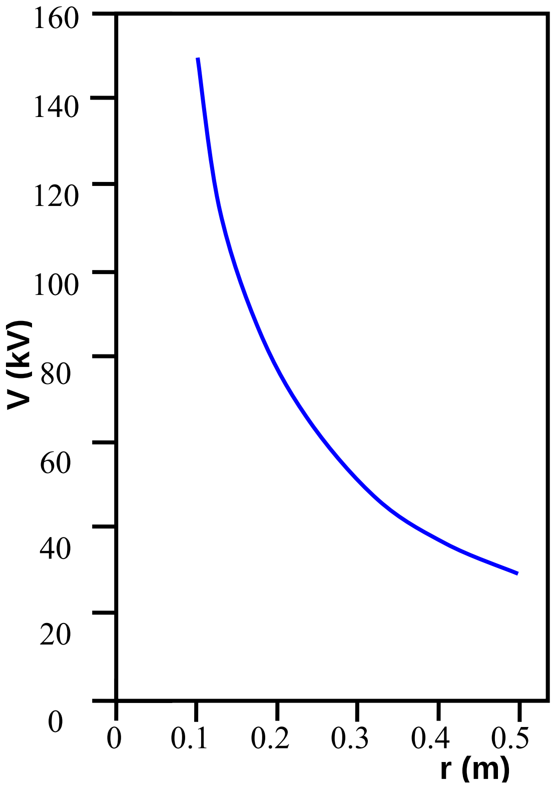
   a) Assuming that the alpha particle is 2.0×10^{-14} m from the centre of the nucleus on release, calculate the electric field experienced by the alpha particle.

   b) Calculate the force on the alpha particle when at this distance.

   c) Calculate the maximum acceleration of the alpha particle (of mass 6.6×10^{-27} kg).

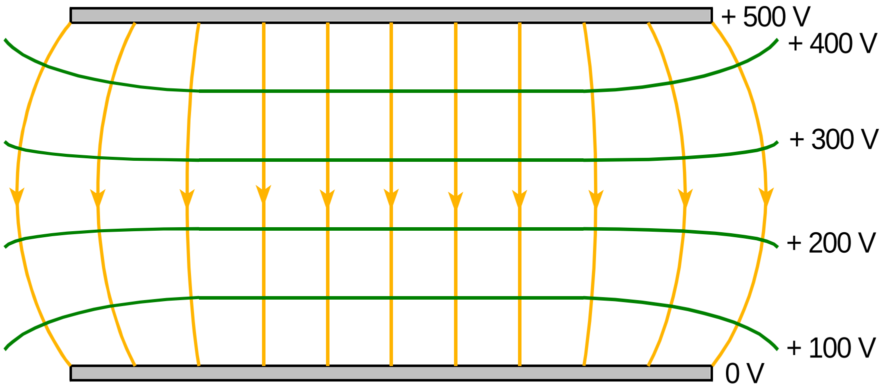
9) The graph shows the variation of potential with distance from the charged dome of a van de Graaff generator.

Use the graph, together with the equation $E = -\frac{dV}{dr}$ to find the electric field strength at a



distance of 0.3 m from the dome. (You may like to check your answer with an alternative calculation).

Answers: Uniform electric fields problems:



2) Green lines above (without arrows).

3) a) $E = V/d = 300 / 0.005 = 6 \times 10^4$ V m^{-1}.

b) $F = EQ = 6 \times 10^4 \times 3.2 \times 10^{-18} = 1.92 \times 10^{-13}$ N

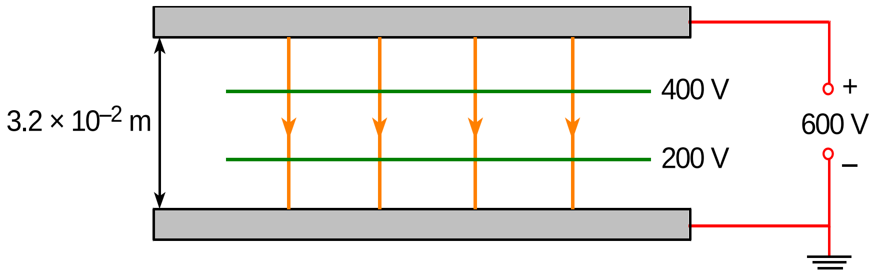
4) $W = QV = 1.6 \times 10^{-19} \times 50{,}000 = 8 \times 10^{-15}$ J

5) The energy gained will have a positive value. Both the charge and the potential difference are negative:

$$100 \text{ eV} = 100 \times (1.6 \times 10^{-19} \text{ J})$$
$$= 1.6 \times 10^{-17} \text{ J}$$
$$\tfrac{1}{2} mv^2 = 1.6 \times 10^{-17} \text{ J}$$

so

$$v = \{[2 \times (1.6 \times 10^{-17} \text{ J})] / (9.1 \times 10^{-31} \text{ kg})\}^{1/2}$$
$$= 5.9 \times 10^6 \text{ m s}^{-1}.$$



6) Orange lines above, with arrows

7) Green lines above, without arrows

8) $E = V/d = 600 / 3.2 \times 10^{-2} = 18{,}750$ V m^{-1} = 1.9×10^4 V m^{-1} (2sf)

9) electric force upward = weight downward

$EQ = mg$

$Q = mg/E = 1.8 \times 10^{-15} \times 9.81 / 1.9 \times 10^4 = 9.4 \times 10^{-19}$ C

10) $9.4 \times 10^{-19} / 1.6 \times 10^{-19} = 5.9$

Therefore, most likely number of extra electrons = 6.

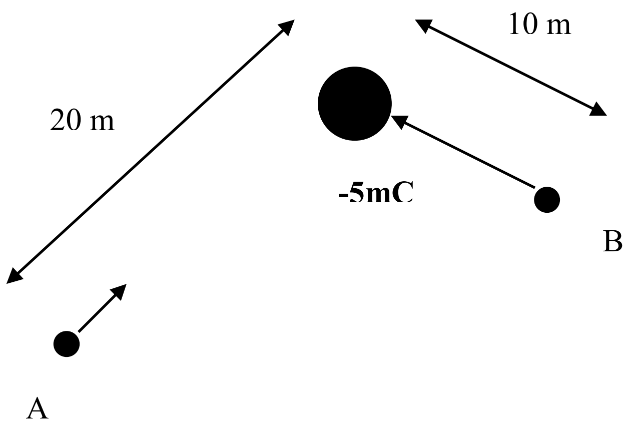
Non-Uniform fields problems answers.

1) $F = EQ = 1000 \times 1 = 1000N$ $F = EQ = 1000 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-16}$ N

2) $Q = F/E = 15 / (3 \times 10^4) = 5 \times 10^{-4}$ C or 0.5 mC.

3E = $F/Q = 4.8 \times 10^{-14} / (1.6 \times 10^{-19}) = 3 \times 10^5$ N C^{-1}

4)



$E_A = kQ/r^2 = 9.0 \times 10^9 \times -5 \times 10^{-3} / 20^2 = -1.125 \times 10^5$ N C^{-1}

$E_B = kQ/r^2 = 9.0 \times 10^9 \times -5 \times 10^{-3} / 10^2 = -4.5 \times 10^5$ N C^{-1}

The negative signs are there simply because the charge creating the field is negative (they are actually from the more precise vector equation for field strength).

The directions of the field are given on the diagram above.

5) $F=kQ_1Q_2/r^2 = 9.0 \times 10^9 \times 1.0 \times 10^{-9} \times 1.0 \times 10^{-9} / 0.060^2 = 2.5 \times 10^{-6}$ N

6 a) Field strength is proportional to $1/r^2$. Therefore doubling the distance decreases field strength by a factor of 4. Thus, answer is $1.44 \times 10^{11} / 4 = 3.6 \times 10^{10}$ N C^{-1}

b) Potential is proportional to 1/r. Thus doubling the distance halves the potential. The answer is therefore 14.4 / 2 = 7.2 V

7 a)

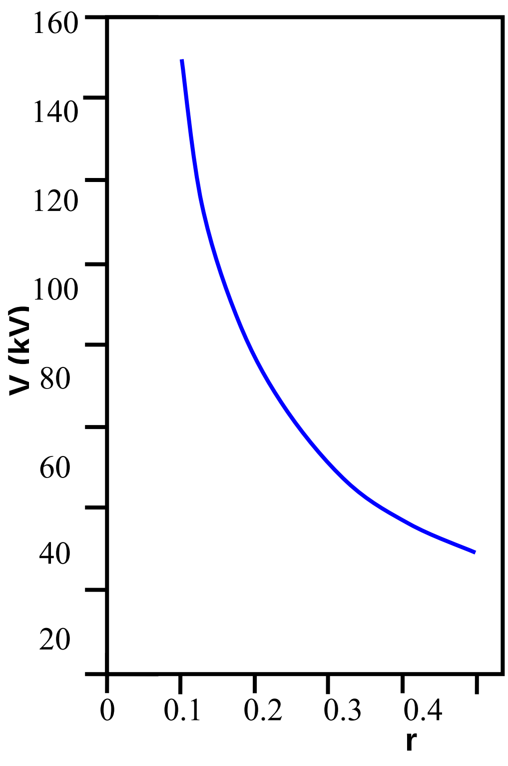
$V = kQ/r = 9.0 \times 10^9 \times 1.6 \times 10^{-19} / (0.50 \times 10^{-10}) = 28.8$ V

b) $EPE = VQ = 28.8 \times 1.6 \times 10^{-19} = 4.61 \times 10^{-18}$ J

8) a) $E = kQ/r^2 = 9.0 \times 10^9 \times 1.4 \times 10^{-17} / (2.0 \times 10^{-14})^2 = 3.2 \times 10^{20}$ N C^{-1}

b) $F = EQ = 3.2 \times 10^{20} \times 3.2 \times 10^{-19} = 101$ N (3sf)

c) $a = F/m = 101 / 6.6 \times 10^{-27} = 1.5 \times 10^{28}$ m s^{-2}



The field strength will be the negative of the gradient at r = 0.3m. This should give a value of around 1.7×10^5 N C^{-1}.

To calculate this we note that at 0.3 m the potential is 50 kV. Now V=kQ/r, and we note that $E=kQ/r^2$, so numerically, we can see that E = V/r. In other words, in this case E = 50,000 / 0.3 = 1.7×10^5 N C^{-1}.