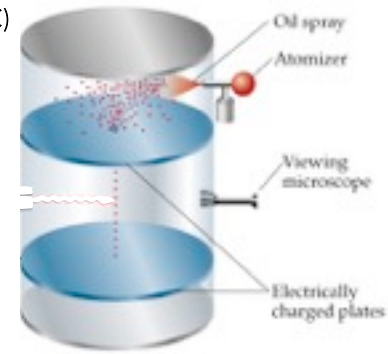
Name______________________________Pd________

Millikan and More!



1) One of the most famous experiments in physics is the Millikan Oil Drop Experiment. Robert Millikan (UofC) took a spray bottle filled with oil so that microscopic droplets came out and passed between two charged metal plates with a vacuum between them. He could see the oil droplets through a tiny microscope. He changed the voltage between the plates until an oil droplet was suspended without falling in the electric field. He did this thousands of times and noticed that the charge on the droplets was always a multiple of one constant number–he'd found the charge of an electron!

a) If the spray bottle was made of a material that gave up its electrons easily as the oil rubbed against the inside of the spray tube, what charge had to be on the lower plate of the apparatus?

NEGATIVE; The oil droplets would be negatively charged, so to be repelled upward, the lower plate would also have to be negative.

b) In one experimental trial, Millikan used oil with a density of 800 kg/m^3, and viewed a drop with a diameter of $1.2 \cdot 10^{-6}$ m (1.2μm, or 1.2 microns). He needed an electric field of 1131 V/m between the plates to make this drop stop falling. How many extra electrons were on this particular oil drop? First, find the mass of the oil droplet: $m = \rho V = (800)(4/3\pi(0.6 \cdot 10^{-6})^3 = 7.23 \cdot 10^{-16}$ kg

Since the droplet isn't falling, $F_G = F_E$ (you should have a force diagram here), and $F_G = 7.23 \cdot 10^{-15}$ N

We know that $F_E = qE$ and the electric field is 1131 V/m, so $7.23 \cdot 10^{-15} = q\,(1131)$ $q = 6.4 \cdot 10^{-18}$ C

Divide the total charge by the charge of an electron to find the number of electrons: $6.4 \cdot 10^{-18} / 1.6 \cdot 10^{-19} = 40$ electrons

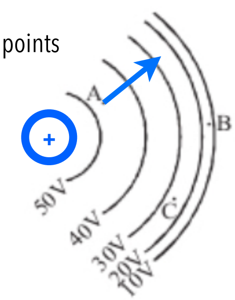
c) If Millikan saw a different oil drop move upward in the next trial without touching anything else, what would that mean?

If we assume all droplets were about the same size, it would mean the droplet had more charge;

It could also have had less mass, and that's why Millikan had to take so many measurements!

d) If Millikan saw a third oil drop that fell downward no matter what the voltage setting was, what would that mean?

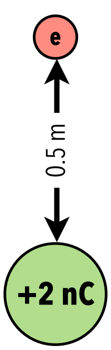
Since the droplet didn't react to an electric field, but does react to a gravitational field, it must be NEUTRAL.



2) In the picture at right, we see lines of constant potential in a region where an electric field is present. Which of the labeled points has the greatest electric field strength, and draw in the direction of the electric field at that point if you can.

(POINT A) POINT B POINT C THEY ARE ALL THE SAME YOU CAN'T TELL

The field lines would be radially outward, and closest together nearest the positive charge.



3) A +2 nC charge is placed at the origin. An electron is placed at a point 0.5 m away along the +y-axis.

a) Find the force (including direction) acting on the electron

b) Find the electric field at the position of the electron (incl. direction) due to the positive charge

c) Find the electrical potential energy of the electron at that point

d) Find the voltage at the position of the electron due to the positive charge

a) $F = kQq/d^2 = 9 \cdot 10^9 (2 \cdot 10^{-9})(1.6 \cdot 10^{-19})/(.5)^2 = 1.152 \cdot 10^{-17}$ N, downward (–y direction)

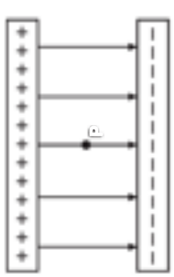
b) $E = kQ/d^2 = 9 \cdot 10^9 (2 \cdot 10^{-9})/(.5)^2 = 72$ N/C, upward (+y direction) (or you could take the easy route after calculating part d: 72 V/m)

c) $E_{PE} = kQq/d = 9 \cdot 10^9 (2 \cdot 10^{-9})(1.6 \cdot 10^{-19})/(.5) = 5.76 \cdot 10^{-18}$ J (or you could take the easy route after calculating part d: 36 eV)

d) $V = kQ/d = 9 \cdot 10^9 (2 \cdot 10^{-9})/(.5) = 36$ V

What I want you to see in this problem is how easy the calculations are if you find voltage first!

4) A proton is placed near the positive plate of two oppositely charged plates. The uniform electric field between the plates is 20 N/C and the plates are separated by 10 cm.

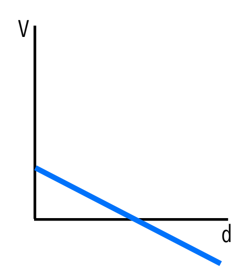


a) What's the voltage difference between the plates?

b) How much potential energy (relative to the negative plate) does the proton have at the positive plate?

c) What will be the speed of the proton right as it hits the negative plate?

d) Quickly sketch the potential vs distance graph where the positive plate is at the origin for distance.



a) $V = Ed = 20\,(0.1) = 2$ V

b) $E_{PE} = qV = (1e)\,(2V) = 2$ eV (or $3.2 \cdot 10^{-19}$ J)

c) $E_{PE} = E_K$, so $3.2 \cdot 10^{-19} = ½(1.67 \cdot 10^{-27})v^2$ therefore $v = 19{,}576$ m/s

d) Should be a straight line decreasing to the right.