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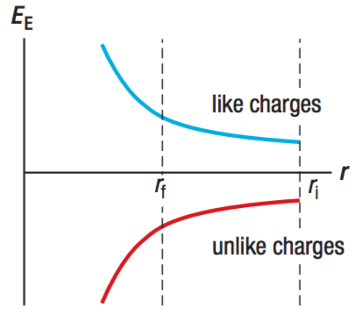
Lesson 3.6: Electric Potential and Electric Potential Energy Due to Point Charges (Chapter 7.5)

In the case of NON-UNIFROM field due to a point charge, we use different way to calculate potential and potential energy.



- $V = \frac{kq_2}{r}$ (scalar, q_2 is the central charge)
- $E_E = \frac{kq_1q_2}{r}$ (scalar)
- $\Delta E_E = \frac{kq_1q_2}{r_f} - \frac{kq_1q_2}{r_i}$

- Figure: E_E approaches zero when the two charges are very far apart. When you move two like charges away from each other, E_E decreases as the F_E does positive work; when you separate two unlike charges away, E_E increases as the F_E attractive and does negative work.

Example 1: How much work must be done to bring a 4.0 uC charged object to within 1.0 m of a 6.0 uC charged object from a long way away?

Example 2: How much electric energy are released to bring a – 7.0 uC charged object to within 0.5 m of a 5.0 uC charged object from a long way away?

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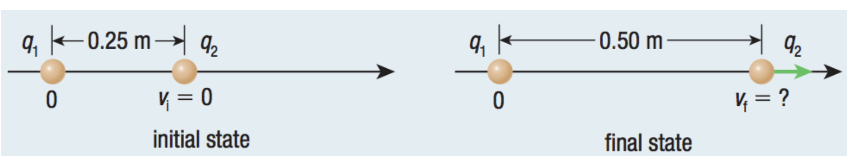
Example 3: A point charge with a charge of $4.0 \times 10^{-8} C$ is 4.00 m due west from a second point charge with a charge of $-1.0 \times 10^{-7} C$.

a) Calculate the total electric potential due to these charges at a point P, 4.00 m due North of the first charge.

b) Calculate the work required to bring a third point charge with a charge of $2.0 \times 10^{-9} C$ from infinity to point P.

Example 4: A point charge q_1 with charge $2.0 \times 10^{-6} C$ is initially at rest at a distance of 0.25 m from a second charge q_2 with charge $8.0 \times 10^{-6} C$ and mass $4.0 \times 10^{-9} kg$. Both charges are positive. Charge q_1 remains fixed at the origin, whereas q_2 travels to the right upon release. Determine the speed of charge q_2 when it reaches a distance of 0.5 m from q_1.



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Example 5: pg359

Two particles, a proton with charge 1.60×10^{-19} C and mass 1.67×10^{-27} kg and an alpha particle (helium-4 nucleus) with charge 3.20×10^{-19} C and mass 6.64×10^{-27} kg, are separated by an extremely large distance. They approach each other along a straight line with initial speeds of 3.00×10^{6} m/s each. Calculate the separation between the particles when they are closest to each other.

Homework: pg361. #1, 4, 6 – 8 & pg370 – 371. #2, 3, 6, 8 – 12, 14 – 17

Practice

1. Three charges, $q_1 = +6.0 \times 10^{-6}$ C, $q_2 = -3.0 \times 10^{-6}$ C, $q_3 = -3.0 \times 10^{-6}$ C, are located at the vertices of an equilateral triangle (**Figure 5**). K/U T/I
   (a) Calculate the electric potential at the midpoint of each side of the triangle. [ans: between q_1 and q_2 is $V_1 = 7.6 \times 10^3$ J/C; between q_1 and q_3 is $V_2 = 7.6 \times 10^3$ J/C; between q_2 and q_3 is $V_3 = -1.5 \times 10^4$ J/C]
   (b) Calculate the total electric potential energy of the group of charges. [ans: -8.1×10^{-2} J]
2. Four point charges, each with $q = 4.5 \times 10^{-6}$ C, are arranged at the corners of a square of side length 1.5 m. Determine the electric potential at the centre of the square. K/U T/I [ans: 1.5×10^5 J/C]
3. Two electrons start at rest with a separation of 5.0×10^{-12} m. Once released, the electrons accelerate away from each other. Calculate the speed of each electron when they are a very large distance apart. K/U T/I [ans: 7.1×10^6 m/s]
4. Two protons move toward each other. They start at infinite separation. One has an initial speed of 2.3×10^6 m/s, and the other has an initial speed of 1.2×10^6 m/s. Calculate the separation when the protons are closest to each other. K/U T/I [ans: 4.1×10^{-14} m]

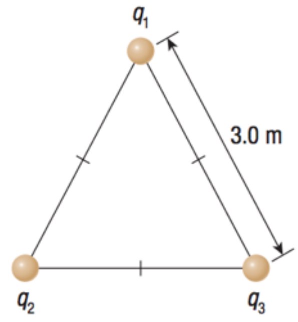
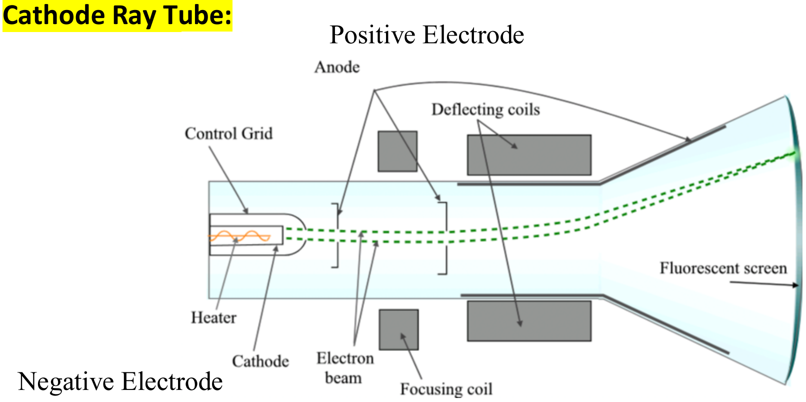
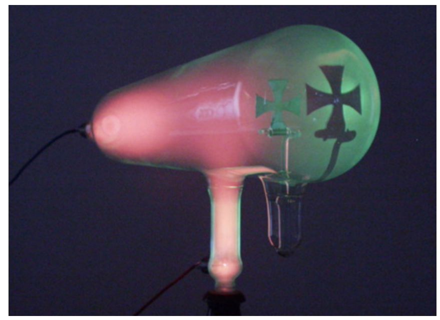


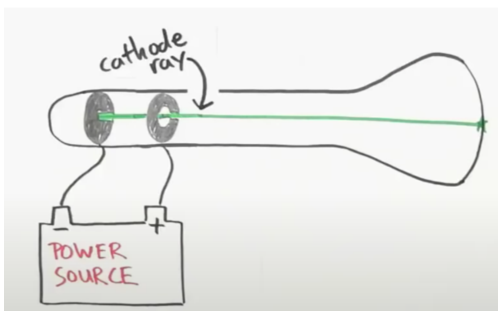
Figure 5

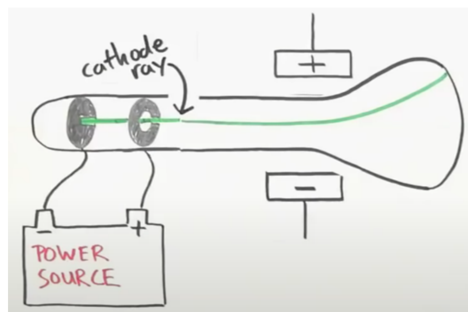
Lesson 3.7: The Millikan Oil Drop Experiment – elementary charge

Cathode Ray Tube:





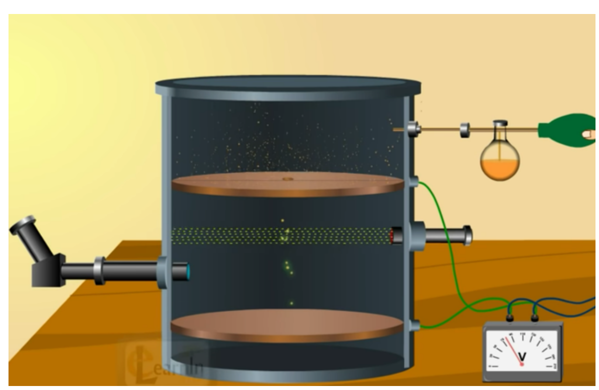




- Cathode rays were discovered by Julius Plücker and Johann Wilhelm Hittorf.
- They observed that some unknown rays were emitted from the cathode which could cast shadows on the fluorescent screen, indicating the rays were traveling in straight lines.
- In 1890, Arthur Schuster demonstrated cathode rays could be deflected by electric fields, and William Crookes showed they could be deflected by magnetic fields.
- In 1897, J. J. Thomson succeeded in measuring the charge-mass-ratio of cathode rays, showing that they consisted of negatively charged particles smaller than atoms, the first "subatomic particles".
- In 1910, Robert Millikan determined elementary charge by conducted oil droplet experiment.

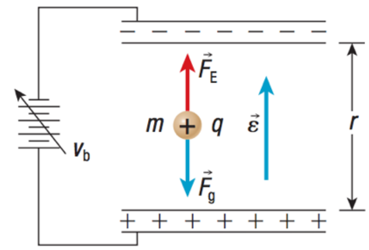
Robert Millikan Oil Droplet Experiment:

https://www.youtube.com/watch?v=UFiPWv03f6g



- Fine mist of oil droplets with certain mass sprayed from an atomizer, and dropped to fall into a parallel plates
- Cathode ray is passing by to ionize oil droplet, make them to carry multiple negative charges.

- Parallel plates connect to a series of adjustable batteries so he could adjust the magnitude of the potential difference, V.



- He can also adjust the distance between two plates, so does $\vec{\varepsilon}$ and $\overrightarrow{F_E}$ of the oil droplet. ($\vec{\varepsilon} = -\frac{\Delta V}{\Delta d}$ & $\vec{\varepsilon} = \frac{F_E}{q_1}$)

- Such adjustment can bring the oil droplet eventually to rest where $\overrightarrow{F_E}$ balances off gravity.

Hence, $\overrightarrow{F_E} = mg \rightarrow q\varepsilon = mg \rightarrow q\frac{\Delta V}{\Delta d} = mg \rightarrow \boldsymbol{q = \frac{mg\,\Delta d}{\Delta V}}$

However, how to measure the mass of an oil droplet?

- He knew the density of the oil, so he could determine the droplet's masses from their observed radius and volume.
- He also confirmed the mass by simply switched off the electric field and observed the final speed of the drop as it fell onto the bottom plate.

After thousands times of repeat, he realized:

- The charges values were always approximately a whole-number multiple of some smallest value. $\boldsymbol{q = Ne}$
- This smallest value were confirmed and improved by other researchers.
- The final accepted charge $e = -1.602 \times 10^{-19} C$

Example: In a Millikan-type experiment, two horizontal plates maintained at a potential difference of 360V are separated by 2.5 cm. A latex sphere with a mass of 1.41×10^{-15} kg hangs between the plates, the upper plate of which is positive.

a) Is the sphere negatively or positively charged?

b) Calculate the magnitude of the charge on the latex sphere?

c) Determine the number of excess of deficit particles on the sphere.

Read Textbook pg 362 – 364. Do questions on pg365. #1 – 6