PHYS 3313 – Section 001
Lecture #9

Wednesday, Feb. 13, 2019

Dr. Jaehoon Yu

- Quantization
- Discovery of the X-ray and the Electron
- Determination of Electron Charge
- Line Spectra
- Blackbody Radiation
- The Photoelectric Effect

Announcements

- Reminder: Homework #2
  - CH3 end of the chapter problems: 2, 19, 27, 36, 41, 47 and 57
  - Due Wednesday, Feb. 20
- Reminder: Quiz #2 coming Monday, Feb. 18
  - Beginning of the class
  - Covers CH1.1 – what we finish today, Feb. 13
  - You can bring your calculator but it must not have any relevant formula pre-input
  - BYOF: You may bring a one 8.5x11.5 sheet (front and back) of handwritten formulae and values of constants for the exam
  - No derivations, word definitions, or solutions of any problems !
    - Lorentz velocity addition NOT allowed!!
    - Maxwell's equations NOT allowed!!
  - No additional formulae or values of constants will be provided!
- Colloquium at 4pm today in SH101
  - Dr. J. Masabni at TAM

Physics Department
The University of Texas at Arlington
COLLOQUIUM

Vegetable Research and Extension at Overton

Joe Masabni
Extension Vegetable Specialist
Research and Extension Center at Overton

Wednesday February 13, 2019
4:00 p.m. Room 101 Science Hall

Abstract

Dr. Masabni is the Extension Small-Acreage Vegetable Specialist with Texas A&M AgriLife Extension located at Overton, TX. Dr. Masabni will present his research and extension activities he leads at Overton Center. Dr. Masabni will present in some detail his research on aquaponics and on grafted tomato trials he has conducted over the last 2 years.

Refreshments will be served at 3:30 p.m. in the Physics Library

What does the word "Quantize" mean?

- Dictionary: To restrict to discrete values
- To consist of indivisible discrete quantities instead of continuous quantities
  - Integer is a quantized set with respect to real numbers
- Some examples of quantization?
  - Digital photos
  - Lego blocks
  - Electric charge
  - Photon (a quanta of light) energy
  - Angular momentum
  - Etc…

Discovery of the X Ray and the Electron

- X rays were discovered by Wilhelm Röntgen in 1895.
  - Observed X rays emitted by cathode rays bombarding glass
- Electrons were discovered by J. J. Thomson.
  - Observed that cathode rays were charged particles

Cathode Ray Experiments

- In the 1890's scientists and engineers were familiar with cathode rays, generated from one of the metal plates in an evacuated tube across a large electric potential
- People thought cathode rays had something to do with atoms.
- It was known that cathode rays could penetrate matter and their properties were under intense investigation during the 1890's.

Observation of x Rays

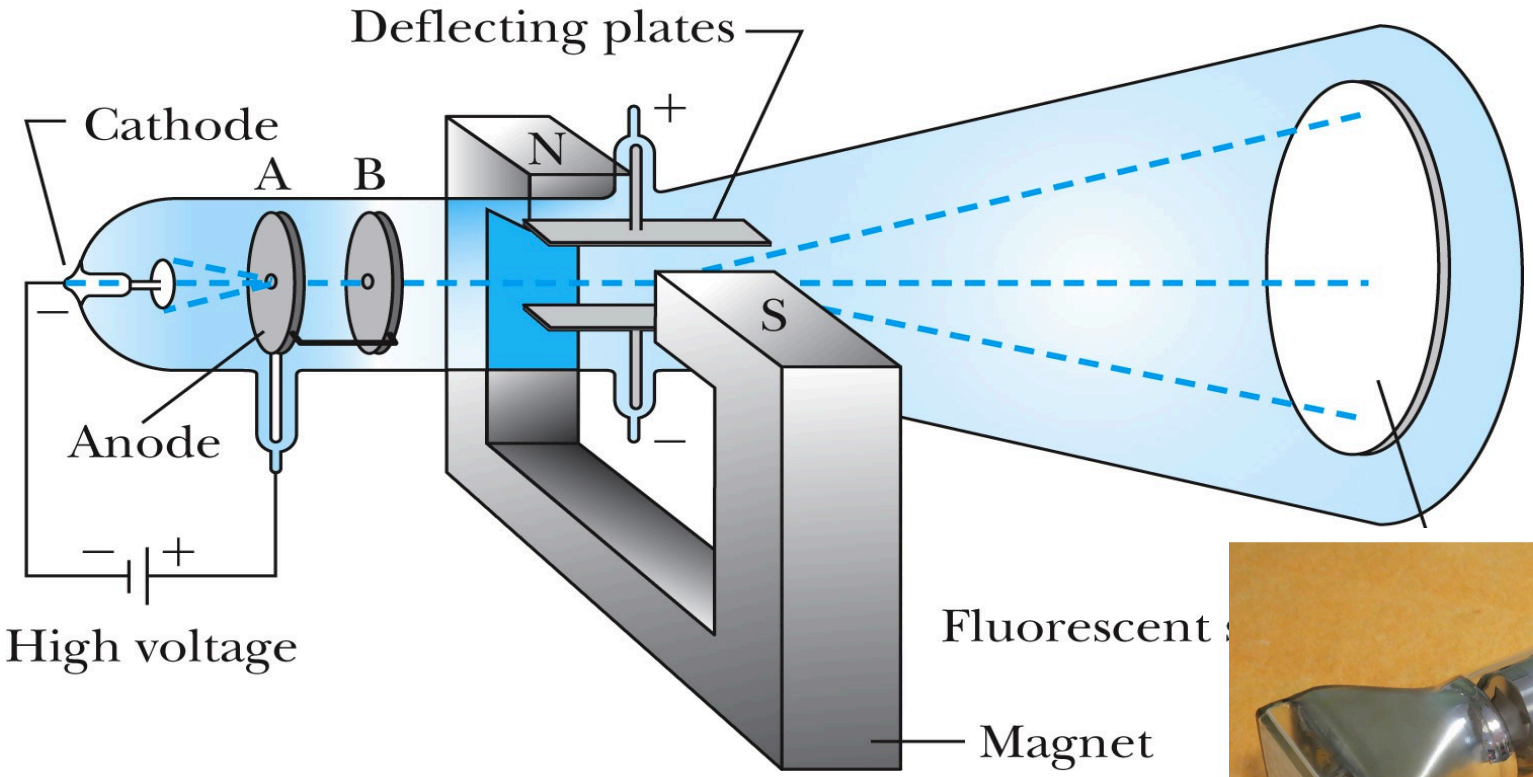
- Wilhelm Röntgen studied the effect of cathode rays passing through various materials.
- He noticed that a nearby phosphorescent screen glowed during some of these experiments.
- These rays were unaffected by magnetic field and penetrated materials more than cathode rays.
- He called them **x rays** and deduced that they were produced by the cathode rays bombarding the glass walls of his vacuum tube

Röntgen's X Ray Tube

- Röntgen produced the X-ray by allowing cathode rays to impact the glass wall of the tube.
- Took image of the bones of a hand on a phosphorescent screen.
- Tremendous contribution to medical imaging, and Röntgen received the 1st Nobel Prize in 1901 for this!

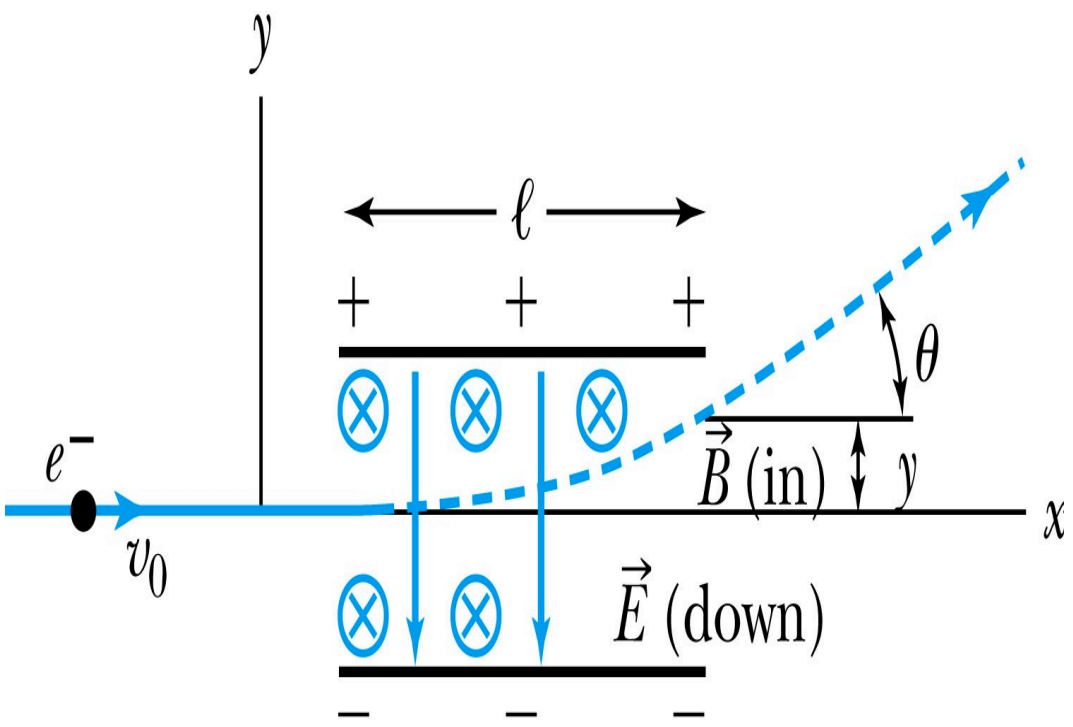
J.J. Thomson's Cathode-Ray Experiment

- Thomson showed that the cathode rays were negatively charged particles (electrons) – 1906 Nobel Prize! How?
  - By deflecting them in electric and magnetic fields.



Thomson's Experiment

- Thomson measured the ratio of the electron's charge to mass by sending electrons through a region containing a magnetic field perpendicular to an electric field.



- Measure the deflection angle with only E!
- Turn on and adjust B field till no deflection!
- What do we know?
  - ℓ, B, E and θ
- What do we not know?
  - v_0, q and m

Calculation of *q*/*m*

- An electron moving through the electric field w/o magnetic field is accelerated by the force: $F_y = ma_y = qE$
- Electron angle of deflection: $\tan\theta = \frac{v_y}{v_x} = \frac{a_y t}{v_0} = \frac{qE}{m}\frac{l/v_0}{v_0} = \frac{qE}{m}\frac{l}{v_0^2}$
- Adjust the perpendicular magnetic field until it balances E and keeps electrons from deflecting in y-direction

$$\vec{F} = q\vec{E} + q\vec{v}\times\vec{B} = 0$$

$$F_y = -qE + qv_xB = 0 \Rightarrow qE = qv_xB \Rightarrow v_x = \frac{E}{B} = v_0$$

- Charge to mass ratio:

$$\tan\theta = \frac{qE}{m}\frac{l}{v_0^2} \Rightarrow \frac{q}{m} = \frac{v_0^2\tan\theta}{El} = \frac{(E/B)^2\tan\theta}{El} = \frac{E\tan\theta}{B^2 l}$$

Ex 3.1: Thomson's experiment

- In an experiment similar to Thomson's, we use deflecting plates 5.0cm in length with an electric field of $1.2\text{x}10^4$V/m. Without the magnetic field, we find an angular deflection of 30^o, and with a magnetic field of $8.8\text{x}10^{-4}$T we find no deflection. What is the initial velocity of the electron and its q/m?
- First v_0 using E and B, we obtain:

$$v_0 = v_x = \frac{E}{B} = \frac{1.2\times10^4}{8.8\times10^{-4}} = 1.4\times10^7\ m/s$$

- q/m is then

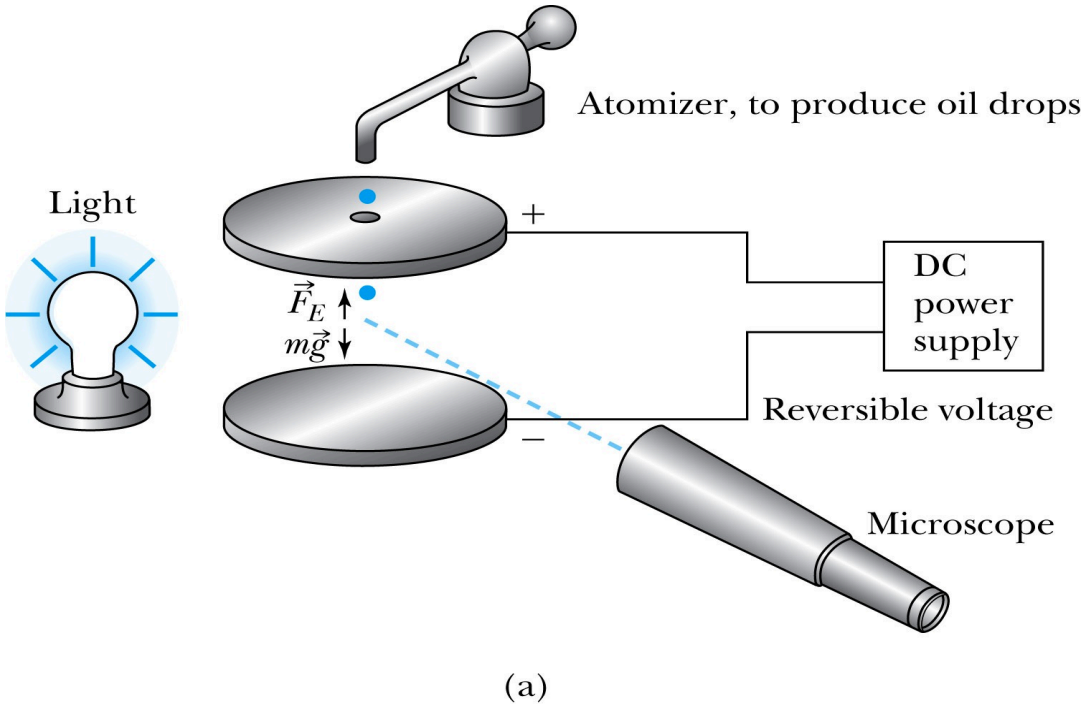
$$\frac{q}{m} = \frac{E\tan\theta}{B^2 l} = \frac{1.2\times10^4\tan 30^\circ}{\left(8.8\times10^{-4}\right)^2\cdot 0.5} = 1.8\times10^{11}\ C/kg$$

- What is the actual value of q/m using the known quantities?

$$\frac{q}{m} = \frac{1.6022\times10^{-19}}{9.1094\times10^{-31}} = 1.759\times10^{11}\ C/kg$$

Determination of Electron Charge

- Millikan (and Fletcher) in 1909 measured the charge of electron and showed that the free electric charge is in multiples of the basic charge of an electron – 1923 Nobel Prize



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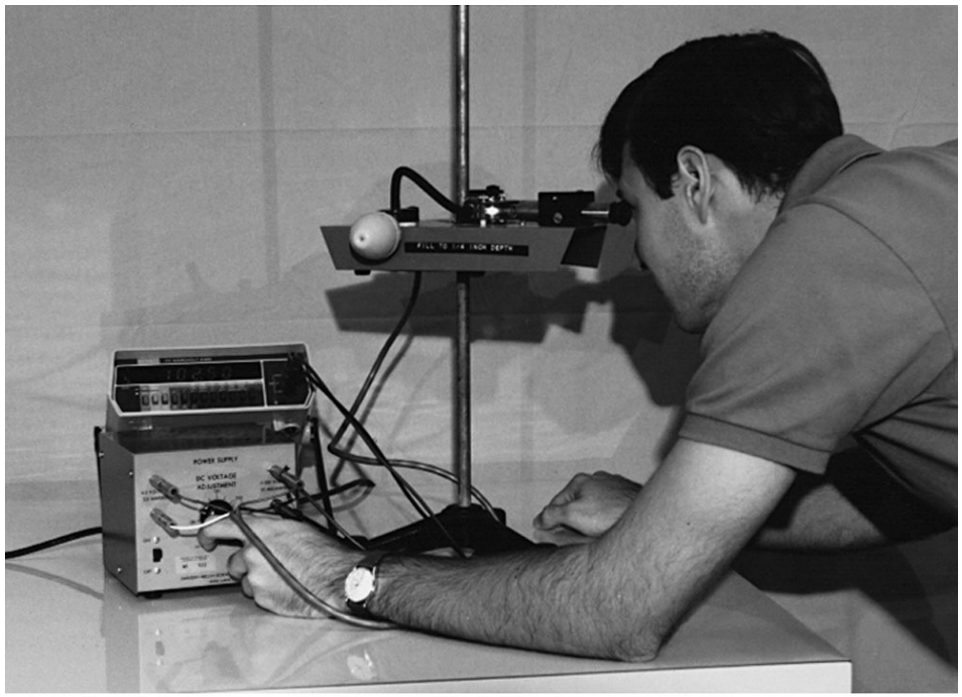

Calculation of the oil drop charge

- Used an electric field and gravity to suspend a charged oil drop $\vec{F}_E = q\vec{E} = -m\vec{g} \Rightarrow qV/d = mg$
- So the magnitude of the charge on the oil drop $q = \frac{mgd}{V}$
- Mass is determined from Stokes' relationship of the terminal velocity to the radius, medium viscosity and density $r = 3\sqrt{\eta v_t / 2g\rho}$

$$m = \frac{4}{3}\pi r^3 \rho = \frac{4}{3}\pi \cdot 3\left(\frac{\eta v_t}{2g\rho}\right)^{\frac{3}{2}} \rho = \frac{4\pi}{\sqrt{\rho}}\left(\frac{\eta v_t}{2g}\right)^{\frac{3}{2}}$$

- Thousands of experiments showed that there is a basic quantized electron charge $q = 1.602 \times 10^{-19}\ C$