

PHYS 3313 – Section 001

Lecture #10

Monday, Feb. 20, 2017

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- Quantization
- Discovery of the X-ray and the Electron
- Determination of Electron Charge



Announcements

- Reminder: Homework #2
 - CH3 end of the chapter problems: 2, 19, 27, 36, 41, 47 and 57
 - Due this Wednesday, Feb. 22



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 in 1897
 - Observed that cathode rays were charged particles



Cathode Ray Experiments

- In the 1890's scientists and engineers were familiar with cathode rays, generated from a metal plate in an evacuated tube across a large electric potential
- People thought cathode rays have 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.



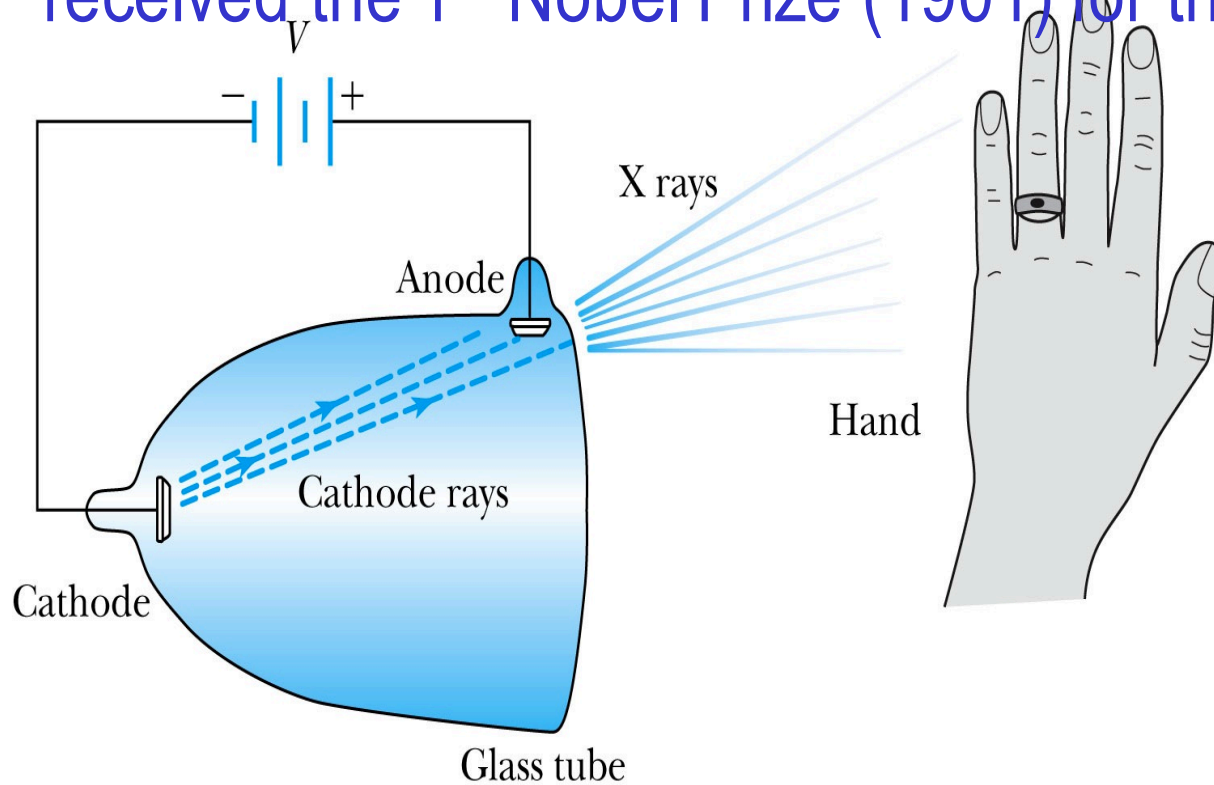
Observation of X Rays

- Wilhelm Röntgen studied the effect of cathode rays passing through various materials.
- He noticed that a nearby phosphorescent screen glow during some of these experiments.
- These rays were unaffected by magnetic fields 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



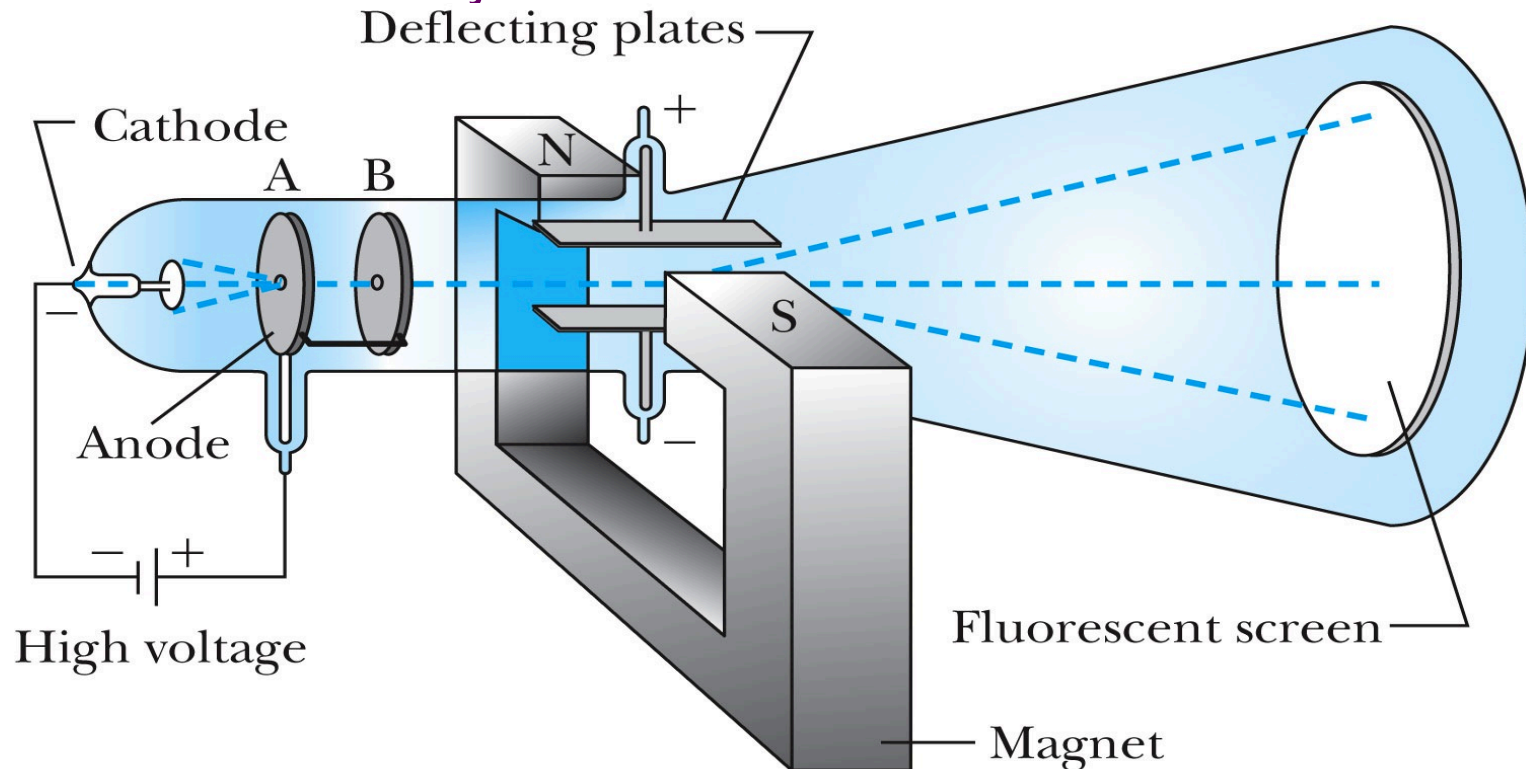
Röntgen's X Ray Tube

- 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 (1901) for this!



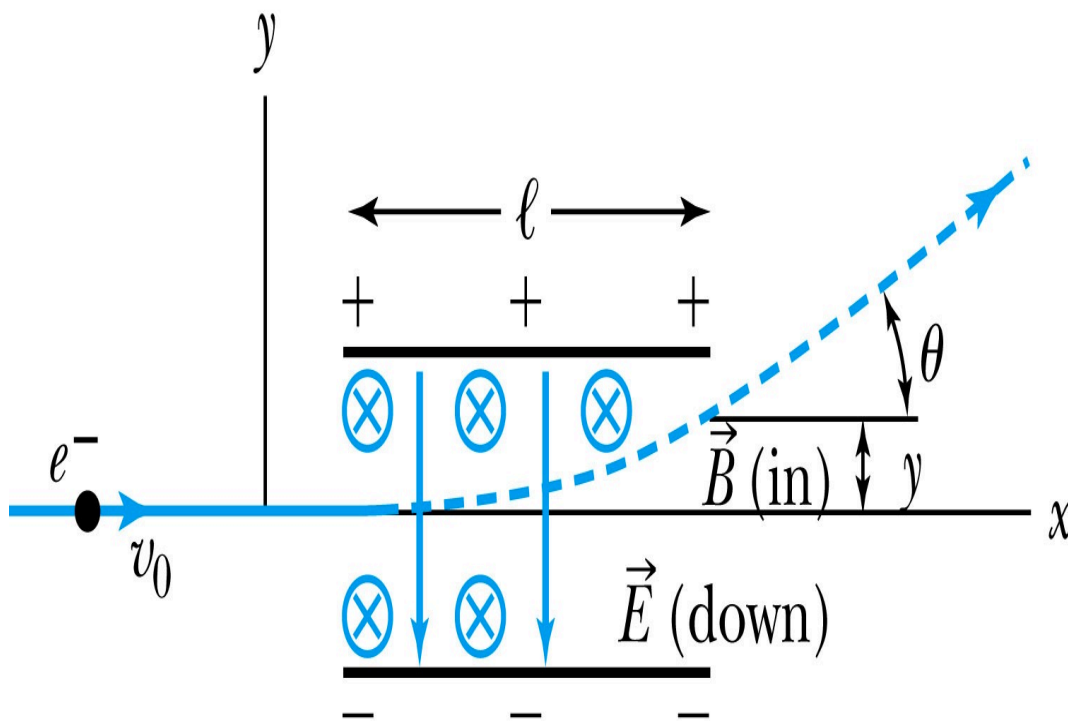
J.J. Thomson's Cathode-Ray Experiment

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



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 the 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

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

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

- 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 $1.2 \times 10^4 \text{ V/m}$. Without the magnetic field, we find an angular deflection of 30° , and with a magnetic field of $8.8 \times 10^{-4} \text{ T}$ 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:

$$v_0 = v_x = \frac{E}{B} = \frac{1.2 \times 10^4}{8.8 \times 10^{-4}} = 1.4 \times 10^7 \text{ m/s}$$

- q/m is then

$$\frac{q}{m} = \frac{E \tan \theta}{B^2 l} = \frac{1.2 \times 10^4 \tan 30^\circ}{(8.8 \times 10^{-4})^2 \cdot 0.05} = 1.8 \times 10^{11} \text{ C/kg}$$

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

$$\frac{q}{m} = \frac{1.6022 \times 10^{-19}}{9.1094 \times 10^{-31}} = 1.759 \times 10^{11} \text{ C/kg}$$