

Core Module: FROM IDEAS TO IMPLIMENTATION

PART 1

1) Increased understanding of cathode rays led to the development of television

- Cathode rays were discovered in 1860s when a high voltage was applied across two electrodes in an evacuated glass tube. As the gas pressure was lowered, there was a glow in the tube. At very low pressures, the glass behind the anode (+) electrode was seen to glow green. The name "cathode rays" was given (later) to the mysterious rays that were emitted from the cathode (-) and travelled through the tube.

- In the 1870s Crookes used a variety of what have become known as Crookes tubes to study the properties of the cathode rays. These tubes included one with a metal Maltese cross that could be flipped into the beam, another which showed the path of the beams (which could show deflection by magnetic fields) and another with a small paddle wheel that the cathode rays were able to turn. Attempts to show deflection by electric fields at first failed.
- There was dispute over whether cathode rays were particles or waves.
 - Waves
 - Traveled in straight lines
 - Opaque objects placed in their path produced a shadow (maltese cross)
 - Could pass through thin metal foils without causing damage

 - Particles
 - Left cathode at 90° to surface
 - Deflected by magnetic fields
 - Small paddlewheels turned when placed in their path
 - Traveled considerably slower than light

The problem with the charged particle theory was that there was apparently no deflection by an electric field. How could they be negatively charged particles, as suggested by deflection by a magnetic field if they were not deflected by an electric field?

In 1897, J.J. Thomson showed this to be a result of inadequate vacuums and used deflection by electric fields and magnetic fields to confirm that the cathode rays had a charge to mass ratio. They must be small negatively charged particles now called electrons.

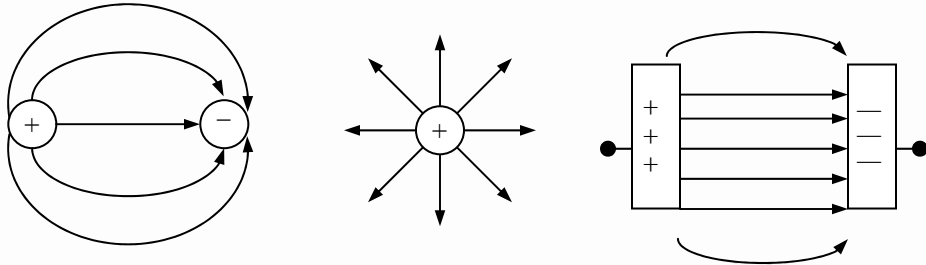
- The force on a charge moving through a magnetic field is given by:

- $$F = qvB \sin \theta$$

- Electric field strength between parallel plates is given by:

- $$E = \frac{V}{d}$$

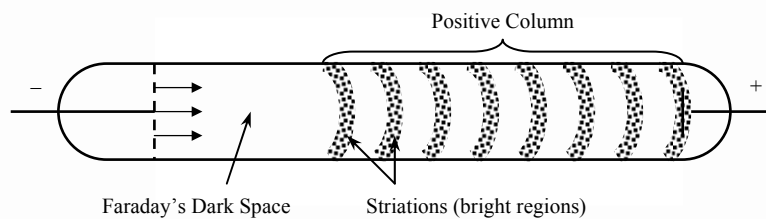
- Some electric fields:



- Crookes tubes with:
 - Maltese cross – leaves a shadow of the cross near positive electrode
 - Electric Plates – deflected towards positive plate
 - Fluorescent Display Screen – traces line traveled by electrons
 - Glass Wheel – rotates when turned on and spins towards positive electrode

Show that the charge on a cathode ray is negative.

- In a discharge tube, as pressure lowers, the light goes from being a uniform glow to having regions of brightness separated by dark spaces



- Joseph John Thomson used a cathode ray tube with parallel charged plates and current carrying coils perpendicular to these plates, so as to produce an electric field and magnetic field at right angles to each other. There were two stages of his experiment:

- First he varied the two fields so that their opposing forces cancelled, leaving cathode rays undeflected. By equating electric and magnetic force equations he was able to calculate the velocity of the cathode rays.
- Second he applied a constant magnetic field and determined the radius of the circular path traveled by the charged particles.

By combining these results he was able to calculate the charge/mass ratio of the electrons.

- The force on a charge in a magnetic field is:

- $$F = qvB \sin \theta$$

- The strength of an electric field is given by:

$$E = \frac{V}{d} \quad \text{and} \quad E = \frac{F}{q} \quad \therefore \text{units are either in } \text{Vm}^{-1} \text{ or } \text{NC}^{-1}$$

- Parts of a cathode ray tube:

- Electron Gun – a filament heats the cathode that releases electrons by thermionic emission. The electron are then accelerated by a high potential difference applied across electrodes.
- Electrodes – control the brightness of the beam, focus the beam, and accelerate the electrons along the tube.
- Electric Field (in a cathode ray oscilloscope)– this is supplied by two pairs of parallel deflecting plates that deflect the beam up or down, left or right, so that all points on the fluorescent screen can be hit. The vertical plates sweep the electrons across the screen and the signal is usually applied to the horizontal plates (which produce vertical deflections of the electron beam.)

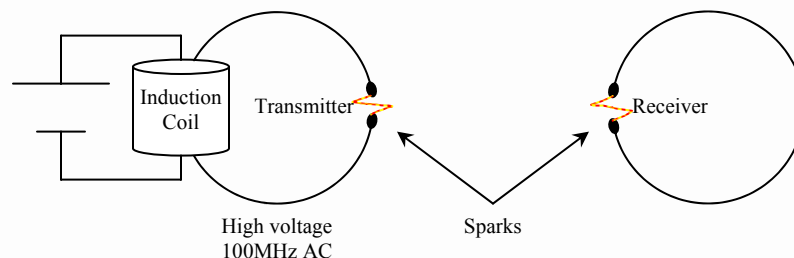
OR Magnetic field (in a television set)– the deflection of the electron beam is produced by the magnetic field of current carrying coils.

- Fluorescent Screen – emits light when high energy electrons hit it.

- Cathode Rays are used in:
 - Oscilloscopes – plot voltage as a function of time. Short pulses and waveforms can be displayed and measured. Can measure voltage of input waveform. Beam deflected by X and Y plates.
 - Television – screen is coated with 3 coloured phosphors that are stimulated by 3 separate electron beams. Each image is swept twice, writing the odd and then the even lines. The phosphors phosphoresce for a short period after they have been hit, reducing screen flicker.

2) The reconceptualisation of the model of light led to an understanding of the photoelectric effect and black body radiation

- In the 1700s, light had generally been considered to be a particle. In the early 1800s, the work of Young and Fresnel led to the acceptance that light was a wave.
- In the 1860s Maxwell predicted the existence of electromagnetic radiation. This was entirely theoretical work based on his study of electric and magnetic fields.
- According to Maxwell, electromagnetic radiation would be produced by accelerating electric charges.
- Hertz produced electromagnetic radiation (radio waves) using an induction coil. Electromagnetic radiation was produced when a spark jumped across a gap.
- Hertz detected the radio waves by using loop of wire with a small gap in it. When a spark jumped between electrodes of his transmitter, it produced sparks across the gap in the loop of wire. Hertz also noticed that by shining UV radiation onto the spark gap, a brighter spark was produced. He did not investigate this any further, but it was a demonstration of the photoelectric effect.



- Hertz used the interference pattern between direct and reflected radio waves, found where maximums occurred and calculated the wavelength of these waves. He did this by noticing that whenever a maximum occurred the difference between the distances traveled by the direct and reflected waves must be a whole number of wavelengths. He substituted his value for wavelength and frequency into:

$$v = f\lambda \quad (v - \text{velocity} \quad f - \text{frequency} \quad \lambda - \text{wavelength})$$

and got a value similar to the velocity of light determined by Fizeau, and which corresponded to the speed predicted by Maxwell's equations. They also possessed similar properties, able to be reflected by mirrors and refracted by prisms like light waves.

- Radio waves can be produced relatively easily by oscillating electric charge in an antennae. This is done using AC current of the same frequency as the wavelength generated. This is used in radios, televisions, mobile phones, and microwave cooking.
- A black body is an object which absorbs all incoming radiation, and thus the only radiation coming from it will be that produced by it (i.e. no reflected radiation). Blackbody radiation is thermal radiation. Its colour depends on temperature with red being cool, white being very hot and blue being extremely hot.
- According to classical theory, as λ decreased, the intensity of the blackbody radiation would increase. This would violate the principle of conservation of energy. This effect was called the ultraviolet catastrophe. Observations showed that as wavelength decreased, the intensity increased, had a maximum value, and then dropped off to zero. As temperature decreased, the wavelength increased, and the maximum intensity was lower.

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