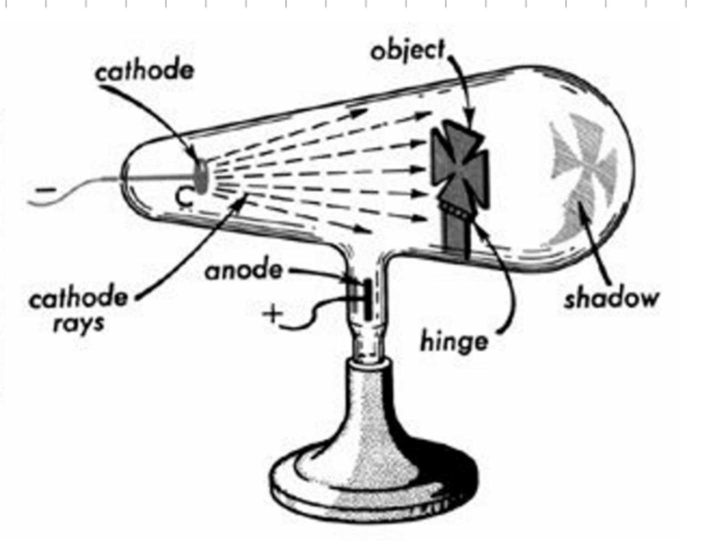
Cathode Rays

13th March



Crooke's Tube:

- High potential difference between anode and cathode
- Tube contains a low pressure gas
- Gas glows

- glow casts shadows [travels in straight lines]
- travels from cathode to anode [negatively charged]
- deflected by magnetic fields [charged]
- can rotate a wheel [have momentum]

JJ Thomson improved design in 1880s. Replaced the cathode with a small coil of thin wire. Pass an electric current through the coil, raising it's temperature.

Electrons in the coil gain enough kinetic energy to 'boil' away from the surface. This is called THERMIONIC EMISSION.

This meant cathode rays can be produced with a much lower accelerating potential difference between the anode and cathode.

3. Excitation of electrons in the gas atoms due to collision with electrons that have been accelerated from the cathode. Glow is due to photon emission during deexcitation.

2. Collisions happen, but accelerated electron velocity is too low to cause excitation.

1. Positive ions accelerate back towards the cathode and liberate electrons from the cathode; recombination of these electrons with the ions can cause photon emission.

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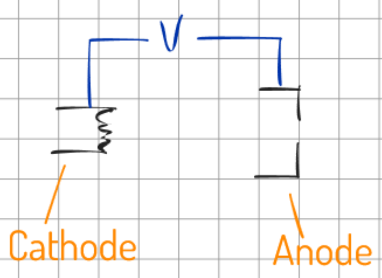
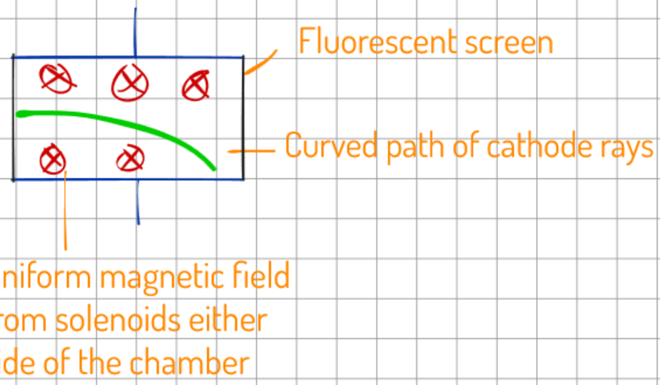
Experimental determination of Specific Charge

23rd March

Deflection with magnetic fields in Fine Beam Tube





(Takes place in evacuated chamber)

Force from the magnetic field causes the cathode rays to follow a circular path.

$$\frac{mv^2}{r} = BQv$$

$$r = \frac{mv}{BQ}$$

Work done by the p.d. between the cathode and the anode increases the kinetic energy of the electrons.

$$QV = \frac{1}{2}mv^2$$

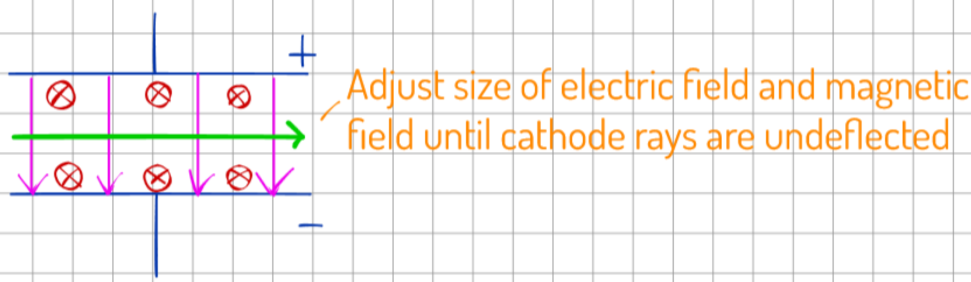
$$v^2 = \frac{2QV}{m}$$

$$r^2 = \frac{m^2}{B^2Q^2} \cdot \frac{2QV}{m}$$

$$r^2 = \frac{2mV}{B^2Q}$$

Using Crossed Fields

Cathode rays produced as before



When undeflected;

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$F_E = F_B$

$EQ = BQv \quad , \quad v = \frac{E}{B} \qquad v^2 = \frac{E^2}{B^2}$

We also know that; $QV = \frac{1}{2}mv^2 \qquad \frac{Q}{m} = \frac{v^2}{2V}$

$$\frac{Q}{m} = \frac{E^2}{2VB^2}$$

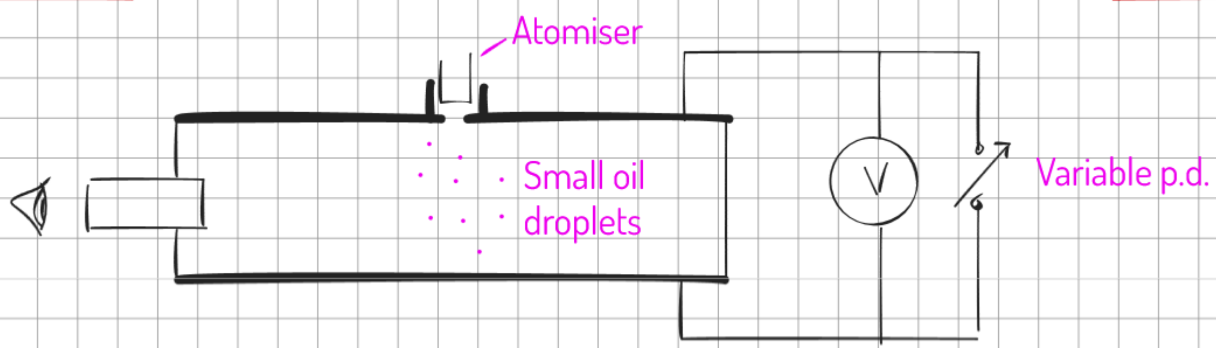
Found from $E = \frac{V}{d}$ ← p.d. between plates

Accelerating p.d.

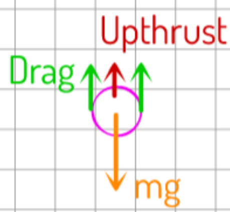
The measured value for Q/m was found to be much larger than the highest known value (that of the Hydrogen ion) which led to the assumption that the mass of the particle involved in cathode was was much lower than of the hydrogen ion (if we assume they have the same charge).

Millikan's Oil Drop

27th March



Electric field off. Droplet falls freely and reaches terminal velocity.



mg = Drag + Upthrust

Ignore upthrust as $\rho_{air} << \rho_{oil}$

mg = Drag

From Stoke's Law: Drag, $F_D = 6\pi\eta r v$

η (eta) is the viscosity of oil in Pa s

r is the radius of the droplet

v is the velocity of the droplet

$mg = 6\pi\eta r v$

$\rho V g = 6\pi\eta r v$ as $m = \rho V$

$\frac{4}{3}\pi r^3 \rho g = 6\pi\eta r v$ as droplets are spherical

$$r = \sqrt{\frac{9\eta v}{2\rho g}}$$

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Turn electric field on. Adjust the magntiude of the p.d. between the plates in the chamber until the droplet is held stationary.

Force from field = weight

$$QE = mg$$

$$\frac{QV}{d} = mg$$

$$Q = \frac{mgd}{V}$$

- Millikan found that the charge on every droplet was always in multiples of 1.6×10^{-19} C.

- Thomson concluded that this was a fundamental property. Charge was QUANTISED.

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