The Standard Model of the Atom

- The model of the atom started out as a simple indivisible mass. It has now evolved to a complex theory that contains multiple subatomic particles of extremely small size (ie. quarks, leptons, bosons, fermions, mesons, hadrons, etc.)!

- The **standard model** is the current theory that is used to describing the nature of matter/atom in terms of 12 fundamental particles (quarks, leptons, and bosons) and the fundamental forces
    - The forces/interactions between all particles is based on the four fundamental types of forces

FORCE	DEFINITION	RANGE
Strong nuclear	The force that holds the nucleus and quarks together.	Nuclear size
Electromagnetic	The force of attraction or repulsion between charged particles.	Infinite
Weak nuclear	The force that allows the transmutation of quarks involved in beta negative and beta positive nuclear reactions	Nuclear size
Gravitational	The force responsible for the attraction of two masses.	Infinite

strong → weak

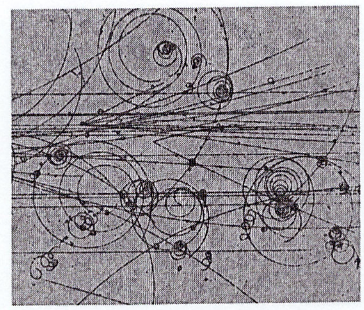
Important to understand!

- * In order for physicist to have been able to break neutrons and protons down into smaller subatomic particles, extremely large amounts of energy was needed to overcome the strong nuclear forces that were holding the nucleus and the quarks together.
    - * This is the reason particle physicists collided atoms with each other at very high speeds in order to overcome the strong nuclear forces and break the atoms down into their subatomic particles
    - The development and use of the Hadron Collider in Switzerland

- Not only did particle physicist need to be able to break the atom down into subatomic particles, they also needed some way to detect such same particles
    - Scientists use *bubble and cloud chambers* to track the path of small subatomic particles released after a collision.

- A **cloud chamber** contains dust-free air supersaturated with vapour from a liquid such as water or ethanol and a **bubble chamber** contains a liquefied gas on the verge of boiling.
    - As a *charged particle* speeds through the chamber, either the charged particle will cause the vapour in a cloud chamber to condense into droplets or cause the liquefied gas in a bubble chamber to vapourize into gas bubbles. Either way, the charged particle leaves behind a track.
    - * Neutral particles do not leave tracks in cloud or bubble chambers

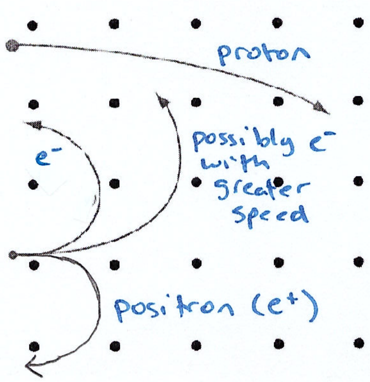
- An external magnetic field is applied to these chambers to cause the charged particles to move in a circular path, which is useful for helping physicists to determine what type of particle left that particular track



EXAMPLES:

1. The picture below shows the tracks left behind from a proton, electron, and a positron. Identify the path from each particle.

* use 3rd left hand rule!
↳ curving down = "+" particle!



$F_m = F_c$

$qvB_\perp = ma_c$

$qvB_\perp = \frac{mv^2}{r}$

$rqB_\perp = mv$

$\therefore r \propto m$ & $r \propto v$

2. List three types of subatomic particles that do not leave tracks in a bubble chamber.

- neutron
- neutrino
- antineutrino

} any neutral particle

3. Describe and explain the difference in the tracks made in a bubble chamber by the particles in each pair:
    a. protons and alpha particles
    b. protons and electrons

a.) - same direction of curvature
- b/c $r \propto \frac{m}{q}$, alpha particle will have a larger radius b/c even though the charge of an alpha particle is 2X larger than proton, the mass is 4X larger

b.) - opposite directions of curvature
- radius of proton will be larger b/c larger mass

- One of the subatomic particles that was discovered and is a basic building block in the standard model is a *quark*.
- **Quarks** are subatomic particles that have fractional charges (ie. charges less than the elementary charge)

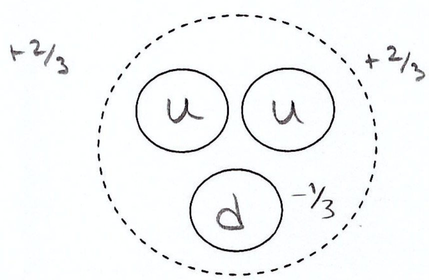
on data sheet →

NAME (FLAVOUR)	CHARGE
Up (u)	+2/3 e-
Anti-up ($\bar{u}$)	-2/3 e-
Down (d)	-1/3 e-
Anti-down ($\bar{d}$)	+1/3 e-

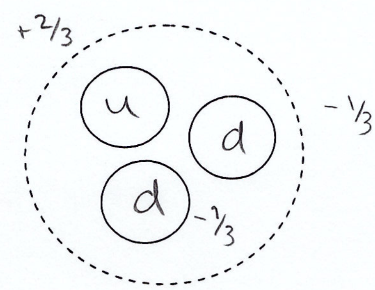
  - * Combinations of quarks make up protons and neutrons based on the conservation of charge (principle #7)
  - * Stable matter (such as neutrons and protons) can only be composed of up and down quarks (no antimatter)
  - * Unstable matter contains at least one anti-quark

- Quark composition of a proton and neutron based on the conservation of charge

$(+\frac{2}{3}) + (+\frac{2}{3}) + (-\frac{1}{3}) = +1$ $\qquad$ $(+\frac{2}{3}) + (-\frac{1}{3}) + (-\frac{1}{3}) = 0$



Proton (+1)



Neutron (0)

* both stable ∴ cannot contain any anti-quarks!

- Explaining Beta Decay
  - Beta Negative Decay

$^{1}_{0}n \rightarrow ^{1}_{1}p + ^{0}_{-1}\beta + \bar{\nu}$ (nucleons)

$udd \rightarrow uud + e^- + \bar{\nu}$ (quarks)

  - Beta Positive Decay

$^{1}_{1}p \rightarrow ^{1}_{0}n + ^{0}_{+1}\beta + \nu$ (nucleons)

$uud \rightarrow udd + e^+ + \nu$ (quarks)

*****Now try pg. 339 #1-4, 6-11, 14 & pg. 346 #1, 4, 5c, 6-9, 11, 13, 19*****