Physics (Particles, Quantum Phenomena Electricity)

Electricity

- **Charge, Current and Potential Difference**
  - **Electric Current** is the rate of flow of charge through a material
    - In metals the charge carrier are electrons
    - In salt solutions the charge carriers are ions
  - The unit of charge is the Coulomb
  - The unit of current is the Ampere
  - **Current** is found using: Where I is current, Q is charge and t is time

$$I = \frac{\Delta Q}{\Delta t}$$

  - **Potential Difference** is the work done per unit of charge
  - Potential difference can be found using: where W is work done, Q is charge and V is potential difference

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

  - The Electromotive Force (EMF) of a source of electricity is defined as the electrical energy produced per unit of charge passing through the source
  - The unit of potential difference and EMF is the Volt
  - Ohm's Law: Where V is P.D., I is current and R is resistance

$$V = IR$$

  - In Ohm's law $I \propto V$, this is a special case
  - Power is the amount of energy transferred per second
  - Electrical power is found using:

$$P = IV$$

  - The unit of power is the watt
  - From this the energy can be found:

$$E = IVt$$

  - The power lost in a component can be found using:

$$P = I^2R$$

- **Resistivity**
  - This how resistant a substance is to the flow of electricity
  - It is found using the equation (where ρ is the material's resistivity, R is the resistance and A is the cross sectional area)

$$\rho = \frac{RA}{L}$$

  - An increase in temperature increases the resistance of metal conductors
  - An increase in temperature decreases the resistance of thermistors
- **Superconductors**
  - These materials have a resistance of zero below a certain critical temperature
  - These can be used to to produce very strong electromagnets

- **The Combined Resistance of Resistors in Series**

$$R = R_1 + R_2 ...$$

- **The Combined Resistance of Resistors in Parallel**

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} ...$$

  This means that the combined resistance of two or more resistors in parallel is less than any resistor
- Charge and energy are conserved in a circuit
- **Identical Cells in Parallel**
  - The current through each cell is equal to I/n where I is the total current supplied by the cells
  - The lost pd in each cell is equal to $\frac{Ir}{n}$
  - Therefore the terminal pd across each cell, $V = \xi - \frac{Ir}{n}$
  - Each electron passes through one cell so the EMF is the same but the current is I/n
- **Potential Dividers**
  - Potential dividers are used to provide a variable potential difference
  - The pd across a resistor is found by

$$V_1 = IR_1 = \frac{V_0 R_2}{R_1 + R_2}$$

    V_1 is the pd across R_1, R_1 is the resistance of R_1, V_0 is the total pd, R_2 is the resistance of R_2.
  - The ratio of pds across each resistor is equal to the resistance ratio of the two resistors

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

- **EMF and Internal Resistance**
  - A cell's EMF is the maximum pd across its terminals
  - The internal resistance is the resistance in cell when the cell is connected to a circuit some of the cell's EMF is used against the internal resistance
  - The EMF of a cell is the energy converted into electrical energy per unit of charge that passes through the cell

$$\xi = \frac{E}{Q}$$

  - The EMF can also be defined as

$$\xi = I(r + R)$$

$$\xi = Ir + IR$$

$$\xi = Ir + V$$

    Where V is the terminal potential difference

- **Alternating Current**
  - RMS is the of the value of direct current that would give the same heating effect as the DC
  - RMS is found using:

$$I_{RMS} = \frac{I_0}{\sqrt{2}} \qquad V_{RMS} = \frac{V_0}{\sqrt{2}}$$

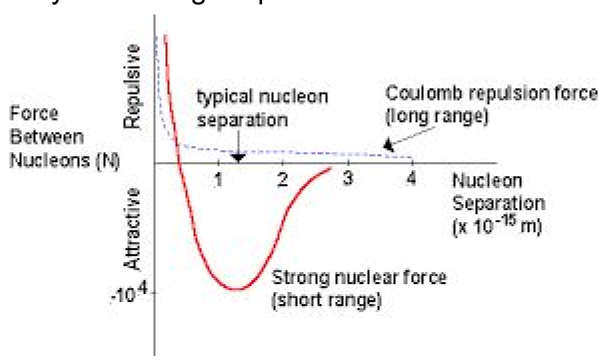
I_0 is the peak current and V_0 is the peak voltage

Particles and Radiation

- Constituents of the atom
  - The atom is made up of three components:

Name	Relative Charge	Relative Mass
Proton	+1	1
Electron	-1	1/2000
Neutron	0	1

- Isotopes are atoms of elements that have different number of neutrons
- The strong nuclear attraction is a fundamental force that holds together the nucleons.
  - The nuclear attraction only occurs at very small ranges.
  - There is a short-range attraction to about 3 fm
  - There is a very-short range repulsion to about 0.5 fm



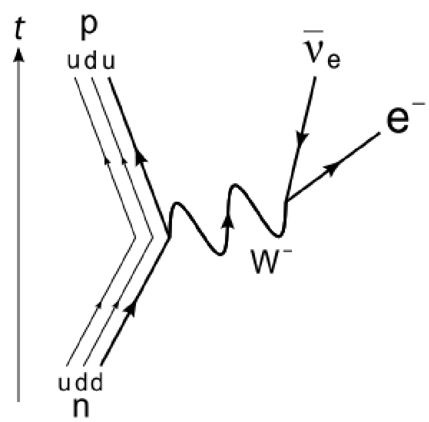
- Radioactive Decay
  - Alpha Decay

$$^{222}_{88}\text{Ra} \longrightarrow \, ^{4}_{2}\text{He} + \, ^{218}_{86}\text{Rn}$$

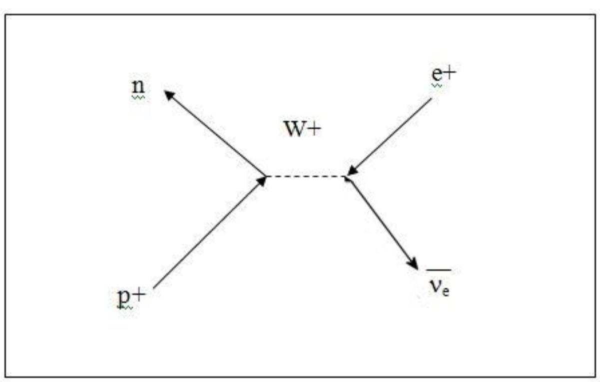
- Beta Decay

$$^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$$

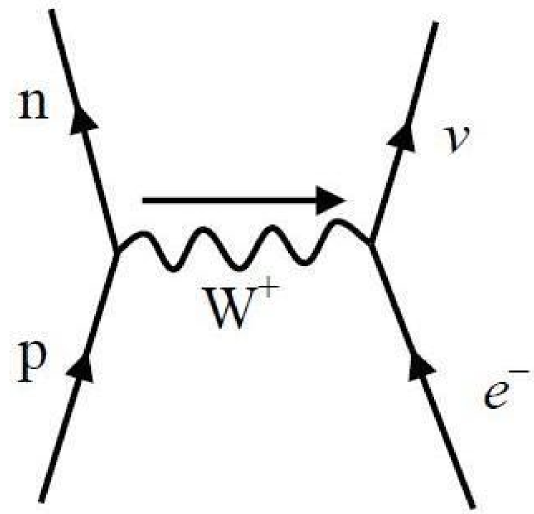
- Particles
  - For every particle there is a corresponding antiparticle e.g.
    - Proton - Antiproton
    - Electron - Positron
    - Neutron - Antineutron
    - Neutrino - Antineutrino
- If a particle and its antiparticle meet they are destroy, this is annihilation, the particles are converted into energy
- In pair production a particle and its antiparticle are produced from energy
- Exchange particles can be used to describe the fundamental interactions they are:
  - Electromagnetic interaction - Virtual photon
  - Weak interaction - W^+ Boson, W^- Boson and the Z Boson
  - Strong interaction - The Gluon
- Feynman Diagrams
  - **β**⁻ Decay:



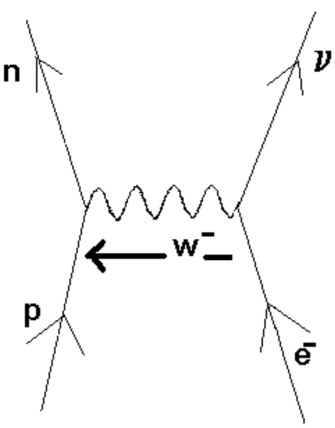
  - **β**⁺ Decay:



- Electron Capture:



- Electron-proton Collision:



Electron-proton collision

- Hadrons:
  - Will interact with **all** of the fundamental forces
  - There are two types of hadron:
    - Baryons
      - More massive of the two
      - Constructed of a quark triple
      - All decay into protons
      - e.g. Protons, Neutrons, Δ particle, Σ particles, ect.
    - Measons
      - Have a smaller mass
      - Constructed of a quark and an antiquark doublet
      - e.g. Π^+, Π^-, Π^0, K^-, K^+,K^0, ect.

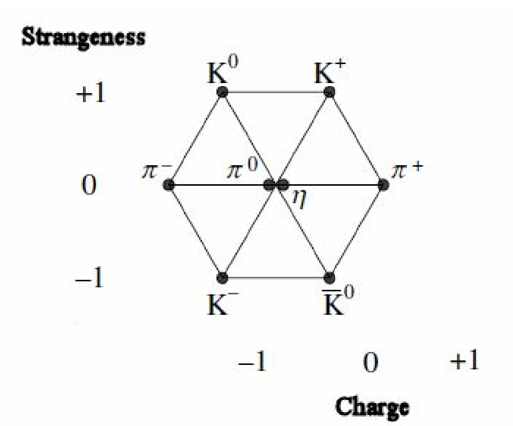
- Leptons
  - Will interact with the
    - Electromagnetic Force
    - Weak Nuclear Force
    - Gravity
  - Types of Lepton:

Symbol	Name	Charge	Electron Lepton Number	Muon Lepton Number	Tauon Lepton Number
e^-	Electron	-1	1	0	0
ν_e	Electron Neutrino	0	1	0	0
M	Muon	-1	0	1	0
ν_M	Muon Neutrino	0	0	1	0
τ	Tauon	-1	0	0	1
ν_τ	Tauon Neutrino	0	0	0	1

- Fermions have one half integer spin, ±½ħ, ±1.5ħ
  - e.g. Protons, neutrons, electrons ect.
- Bosons have integer spin, 0, ±ħ, ±2ħ
  - e.g. Photon, W^+, W^-, Z^0, gluons
- Quarks

Name	Charge	Strangeness
Up	+⅔	0
Down	-⅓	0
Strange	-⅓	-1

- Constituent of mesons



- In particle interactions the following are always conserved
  - Energy
  - Momentum
  - Charge
  - Baryon Number
  - Lepton Number
  - Strangeness (but can change by one in a weak interaction)

<u>Photoelectric Effect</u>

- The photoelectric effect shows that light must be a particle, the energy must be carried in discrete packets
- Increasing the intensity of the light increases the number of electrons released
- Increasing the frequency of the light increase the maximum kinetic energy of the released electrons
- The energy of a photon can be calculated using the equation

$$hf = \phi + E_K$$

  Where h is planck's constant, f is the frequency, ϕ is the work function of the metal, E_K is the maximum kinetic energy of the released electrons
- The electron volt is a unit of energy, it is the energy of an electron
  - $1eV = 1.6\times10^{-19}J$
- When an electron is given more energy it is excited, it moves into a higher energy level
- When an excited electron gives out a photon it is de-excited and moves to a lower energy level
- Electrons will only release or absorb discrete amounts of energy, if the photons have too much or too little energy it will have no effect
- In fluorescence the electrons absorbs a large amount of energy from a high frequency photon, becoming excited. It then releases the light as a number of lower energy photons (with smaller frequencies)
- When elements are heated and give out light there light is specific wavelengths, these are the line spectra of the element
- These lines show that the element's energy levels are discrete because only specific photons with the energy difference of the energy levels are produced, if the energy levels weren't discrete the spectra would be continuous
- The difference of energy of the energy levels and the frequency of the photon are linked by the equation

$$hf = E_1 - E_2$$

  Where h is planck's constant, f is the frequency and E_1 and E_2 are the energy levels
- Electron diffraction suggests that electrons have a wave nature
- The photoelectric effect suggests that light have a particle like nature
- Wave-particle duality states that everything exhibits both wave and particle like behavior
- The de Broglie wavelength of an object can be calculated using the equation

$$\lambda = \frac{h}{mv}$$

Where λ is the wavelength, h is planck's constant, m is the mass and v is the velocity, mv is the momentum of the object.