AS Physics

1   Matter and radiation

1.1   Inside the atom

1.1.1   Specific charge

$$\text{Specific Charge} = \frac{\text{Charge}}{\text{Mass}}$$

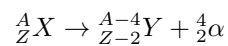## 1.2   Stable and unstable nuclei

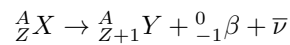### 1.2.1   The strong force

0fm - 0.5fm - Repulsion
0.5fm - 3fm - Attraction
3fm+ - No force

1.2.2   Radioactive decay

1.2.2.1   Alpha Radiation

$$^{A}_{Z}X \rightarrow ^{A-4}_{Z-2}Y + ^{4}_{2}\alpha$$

1.2.2.2   Beta radiation

$$^{A}_{Z}X \rightarrow ^{A}_{Z+1}Y + ^{0}_{-1}\beta + \overline{\nu}$$

1.2.2.3   Gamma Radiation

This is emitted by an unstable nucleus. It has no mass and no charge. It is caused by a nucleus having too much energy, following an alpha or beta emissions.

1.3   Photons
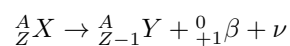
1.3.1   Electromagnetic waves

$$\text{The power of a laser beam} = nhf$$

n is the number of photons that pass a fixed point in a second

1.4   Particles and antiparticles

1.4.1   Antimatter

1.4.1.1 β^+ decay

$$^{A}_{Z}X \rightarrow ^{A}_{Z-1}Y + ^{0}_{+1}\beta + \nu$$

1.4.1.2   Theory of antiparticles

For every type of particle, there is a corresponding antiparticle that:

- Annihilates the particle and itself if they meet, converting their total mass into photons

- Has exactly the same rest mass as the particle

- Has exactly opposite charge to the particle if the particle has a charge

Pair production - A photon with sufficient energy can change into a particle-antiparticle pair

To find the energy of an electron, use $E = mc^2$

1.5   How particles interact

1.5.1   The weak nuclear force

This affects both leptons and quarks

1.5.1.1   Exchange particle

The W bosons:

- Have a non-zero rest pass

- Have a very short range (0.001fm)

- Are positively charged($W+$) or negatively charged (W^-)

Strangeness is not conserved with the weak nuclear force

1.6   Electron capture

$$p + e^- \rightarrow n + \nu$$

2   Quarks and leptons

Particle	Charge	Antiparticle	Interaction
Proton	+1	Antiproton $\overline{p}$	Strong, weak, electromagnetic
Neutron	0	Antineutron $\overline{n}$	Strong, weak
Electron e^-	-1	Positron e^+	Weak, electromagnetic
Neutrino ν	0	Antineutrino $\overline{v}$	Weak
Muon μ^-	-1	Antimuon μ^+	Weak, electromagnetic
π meson π^+, π^0, π^-	+1,0,-1	Inverse symbol, π^0 is own antiparticle	Strong, electromagnetic (charged only)
K meson K^+, K^0, K^-	+1,0,-1		Strong, electromagnetic (charged)

2.1   Leptons at work

2.1.1   Lepton rules

2.1.1.1   Rule 1

In an interaction between a **lepton** and a **hadron**, a neutrino or antineutrino can change into or from a corresponding charged lepton.

$$\nu_e + n \rightarrow p + e^-$$

2.1.1.2   Rule 2

In **muon** decay, the muon changes into a muon neutrino. In addition an electron and electron neutrino are created to conserve charge.

$$\mu^- \rightarrow E^- + \overline{\nu_e} + \nu_\mu$$

3   Quantum phenomena
3.1   Photoelectricity

3.1.1   The discovery of photoelectricity

Observations made about photoelectricity:

1. Photoelectric emission of electron does take place if the frequency is below the **threshold** frequency

2. The number of electrons emitted per second is proportional to the intensity of the incident radiation

3. Photoelectric emission occurs instantaneously

3.1.2 Formulae

$hf = \phi + E_{Kmax}$
$\phi = hf_0$ = Work Function - The minimum energy needed for an electron to escape from the metal surface

3.2 Collisions of electrons with atoms

3.2.1 Ionisation

Ion - An atom where the number of protons is not the same as the number of electrons
Ionisation energy of a gas atom = eV

3.2.2 Excitation

Excitation is where gas atoms absorb energy from electron collisions without ionising. This causes electrons to increase in the energy levels.

3.3 Energy levels

3.3.1 Electrons in atoms

Ground state - The lowest energy state of an atom
Excited state - An energy state above the ground state

3.3.2 De-excitation

Excited atoms are unstable and so will tend towards their ground state. When an electron moves down an energy level a photon is emitted with energy equivalent to the loss of energy by the electron.

3.3.3 Excitation using photons

An electron can absorb a photon and move to an outer shell where there is a vacancy. However the energy of the photon must be exactly the same as the gain of energy in the electron. If it is not then the photon will not be absorbed by the electron.

3.4 Energy levels and spectra

When the light from a filament lamp is split into a spectrum many discrete lines will be seen. These correspond to each of the energy levels of the atom

3.5 Wave particle duality

Wave nature - Diffraction
Particle nature - Photoelectric effect

The wavelength of a matter particle is calculated by:

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

4 Electric current

4.1 Potential difference and charge

Potential difference - Work done per unit charge
emf - The electrical energy produced per unit charge passing through the source

4.2 Resistance

4.2.1 Superconductivity

A superconductor has **zero** resistivity at and below a **critical temperature**
Superconductors are used to make high-power electromagnets

5 Direct current circuits

5.1 Circuit rules

5.1.1 Current

Series: Current in = Current out. Current through multiple components is the same as through one
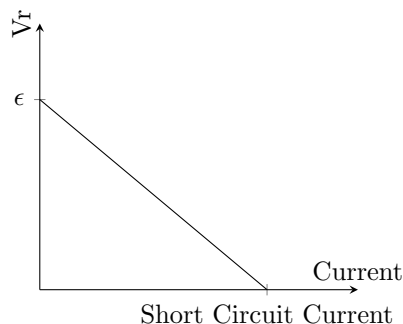**Parallel**: Current into a junction = current out of a junction

5.1.2 Voltage

Series: Total voltage = the sum of voltages in the circuit
Parallel: Voltage in parallel components is equal

5.2 Electromotive force and internal resistance

Switch Open	Switch Closed
Voltmeter reads ϵ	Voltmeter reads $\epsilon - IR$

5.3 The potential divider

$$V_{Out} = V_{In} \times \frac{R_2}{R_1 + R_2}$$

Sensors reduce their resistance if the condition of the environment increases.

6 Forces in equilibrium

6.1 Moments

6.1.1 Couples

Couple - A pair of equal and opposite forces acting on a body

Moment/Torque of a couple = Force $\times$ Perpendicular distance between the lines of action of the forces

6.2   Stability

Stable - Returns of equilibrium after displacement
Unstable - Does not return to equilibrium after displacement.

6.2.1   Tilting and toppling

An object will fall if the line of action of the centre of mass of the object lies outside the base.