Paper 1 Cheat Sheet

1 Measurements and their errors

Precision - There is very little spread around the mean value
Repeatability - If the same experimenter repeats the investigation using the same method and equipment and obtains the same results
Reproducibility - If a different experimenter repeats the investigation, or uses a different experiment or technique, the same results are obtained
Accuracy - Close to the true value

Combination	Operation
Adding or subtracting $a = b + c$	Add the absolute uncertainties $\Delta a = \Delta b + \Delta c$
Multiplying values $a = b \times c$	Add the percentage uncertainties $\epsilon a = \epsilon b + \epsilon c$
Dividing values $a = \frac{b}{c}$	Add the percentage uncertainties $\epsilon a = \epsilon b + \epsilon c$
Power rules $a = b^c$	Multiply the percentage uncertainty by the power $\epsilon a = c \times \epsilon b$

2 Particles and radiation

2.1 Constituents of the atom

Protons and neurons in the centre, with shells of electrons around them

$$\text{Specific charge} = \frac{Q}{m}$$

Isotope - An atom with the same number of protons and electrons as an element, but a different number of neutrons

2.2 Stable and unstable nuclei

2.2.1 The strong nuclear force

$< 0.5fm$	Repulsion
$0.5 - 3fm$	Attraction
$3fm+$	No force

2.2.2 Alpha decay

$$^A_ZX \rightarrow^{A-4}_{Z-2} Y +^4_2 \alpha$$

2.2.3 Beta decay

$$^A_ZX \rightarrow^A_{Z+1} +^0_{-1}\beta + \overline{\nu}$$

Neutrinos were hypothesised to allow for energy to be conserved in the interaction

2.3 Particles, antiparticles and photons

2.3.1 Particle antiparticle pairs and their properties

Property	**Particle**	**Antiparticle**
Mass	x	x
Charge	x	-x
Rest Energy	x	x
Baryon Number	x	-x
Lepton Number	x	-x
Strangeness	x	-x

2.3.1.1 Mesons

2.3.1.1.1 Pions(All 0 Strangeness)

π^0	$U\bar{U}$ or $D\bar{D}$
π^+	$U\bar{D}$
π^-	$D\bar{U}$

2.3.1.1.2 Kaons (All strange)

K^+	$U\bar{S}$
K^-	$\bar{U}S$
K^0	$D\bar{S}$
$\bar{K}^0$	$\bar{D}S$

2.3.2 The photon model of electromagnetic radiation

A photon is a particle whose energy depends on its frequency. Formulas can be found on the data sheet to calculate this relationship

2.3.3 Methods of annihilation and pair production

2.3.3.1 Annihilation

When a particle and an antiparticle meet, they annihilate each other, releasing two photons, with energy sum equivalent to the sum of the energy of the particle and antiparticle. This energy can be calculated from the rest energy values on the data sheet.

$$hf_{min} = E_0$$

2.3.3.2 Pair production

In pair production a photon creates a particle and an antiparticle

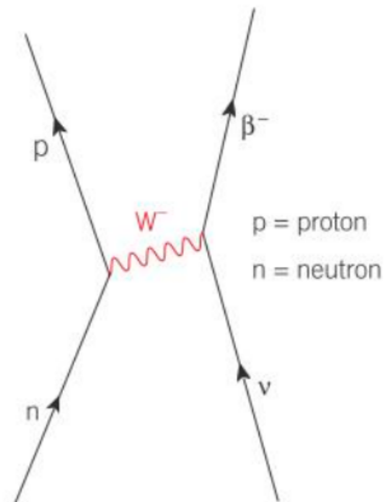
$$hf_{min} = 2E_0$$

2.4 Particle interactions

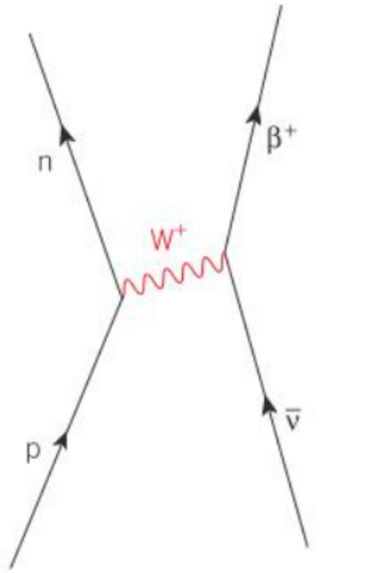
2.4.1 The four fundamental interactions

Force	**Affects**	**Gauge Boson**	**Range**
Gravitational	Mass	Graviton	Infinite
Electromagnetic	Charge	Photon	Infinite
Nuclear Strong	Quarks	Gluon(Pion)	10^{-15}m
Nuclear Weak	Leptons+Quarks	W^+, W^-, Z^0	10^{-18}m

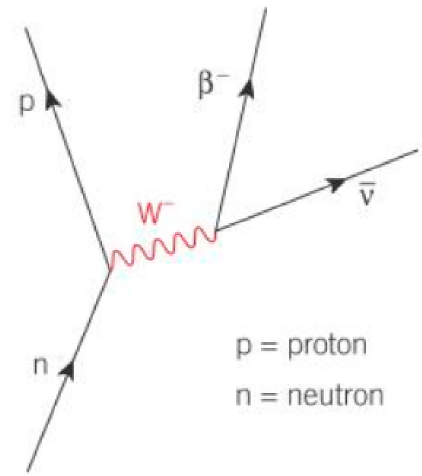
2.4.2 Diagrams to represent the interactions



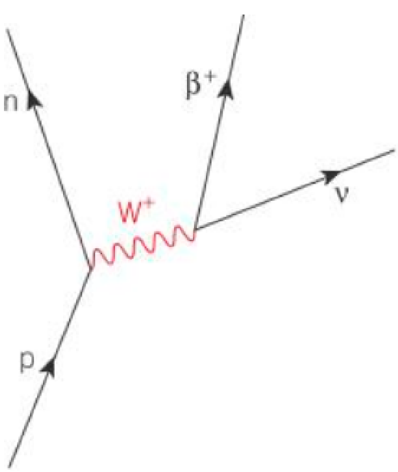
a *A neutron–neutrino interaction*



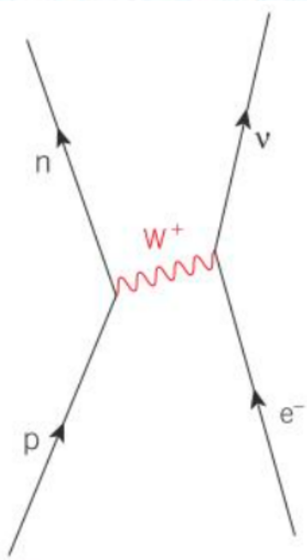
b *A proton–antineutrino interaction*



a *β⁻ decay*



b *β⁺ decay*



▲ **Figure 5** *Electron capture*

2.5 Classifications of particles

	Hadron		Lepton			
	Baryon	Meson	Electron	Muon	Electron neutrino	Muon neutrino
What it is	3 quarks	Quark antiquark pair				

2.5.0.1 Baryons

- Baryon number is conserved during interactions
- The proton is the only stable baryon, all other baryons decay to it

2.5.0.2 Kaons and pions

Kaons (K mesons) decay into Pions(π mesons), they decay by the weak interaction, so strangeness need not be conserved

$$K^+ \to \mu^+ + \nu_\mu$$
$$K^+ \to \pi^+ + \pi^0$$
$$K^- \to \mu^- + \overline{\nu_\mu}$$
$$K^- \to \pi^- + \pi^0$$
$$K^- \to \pi^0 + \mu^- + \overline{\nu_\mu}$$

2.5.0.3 Leptons

Lepton number is conserved in an interaction, muons decay into electrons

$$\mu^- \to e^- + \overline{\nu_e} + \nu_\mu$$

$$\mu^+ \to e^+ + \nu_e + \overline{\nu_\mu}$$

2.5.0.4 Strange particles

Strange particles are produced through the strong interaction and decay through the weak interaction, this is because strangeness is conserved during the strong interaction, but not during the weak interaction.

2.5.1 Quarks and antiquarks

Differences between quarks and antiquarks

- Opposite strangeness
- Opposite charge
- Opposite strangeness

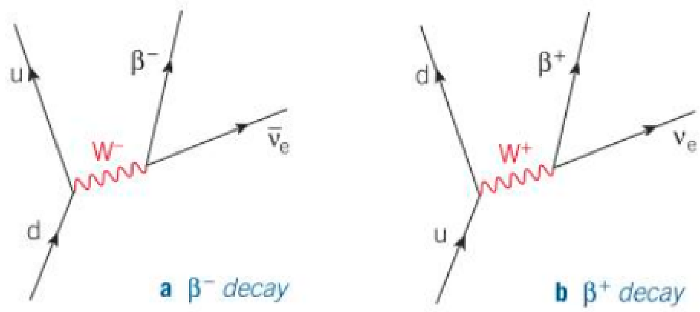
2.5.1.1 Quark compositions

- Proton -UUD
- Neutron - DUD
- Pion - Not strange, sign indicates charge
- Kaon - Strange, sign indicates charge

2.5.2 Applications of conservation laws

Changes of quark nature

- β^-, down $\rightarrow$ up
- β^+, up $\rightarrow$ down



▲ **Figure 3** *Quark changes in beta decay*

In all interactions, energy and momentum must be conserved

2.6 Electromagnetic radiation and quantum phenomena

2.6.1 The photoelectric effect

Photoelectric effect - The emission of electrons from a metal surface when the surface is illuminated by a light of frequency greater than a minimum value known as the threshold frequency

2.6.1.1 Threshold frequency

Because the energy of a photon is proportional to its frequency ($E = hf$), a minimum frequency must be reached so that the electrons have sufficient energy to escape the surface

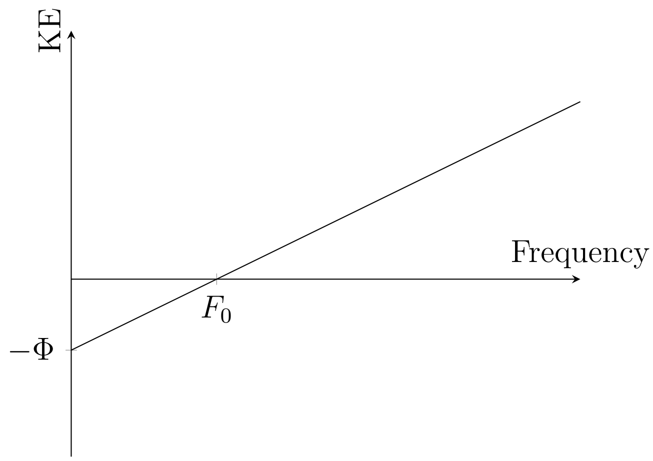
2.6.1.2 Work function and stopping potential

Work function - The minimum amount of energy needed by an electron to escape from a metal surface
Stopping potential - The potential difference required to stop an electron

2.6.1.3 The photoelectric equation

$$hf = \phi + E_{K(Max)}$$

hf is the energy of the incident photon
ϕ is the work function
$E_{K(max)}$ is the maximum kinetic energy
Electrons emitted will have a range of kinetic energies, depending how much work is done to escape



the metal
The gradient of the line is Planck's constant

2.6.2 Collisions of electrons with atoms

2.6.2.1 Ionisation and excitation

Ion - A charged atom
Ionisation - The process of creating ions
Excitation - The process in which an atom absorbs energy without becoming ionised as a result of an electron inside an atom moving from an inner shell to an outer shell

2.6.2.2 •