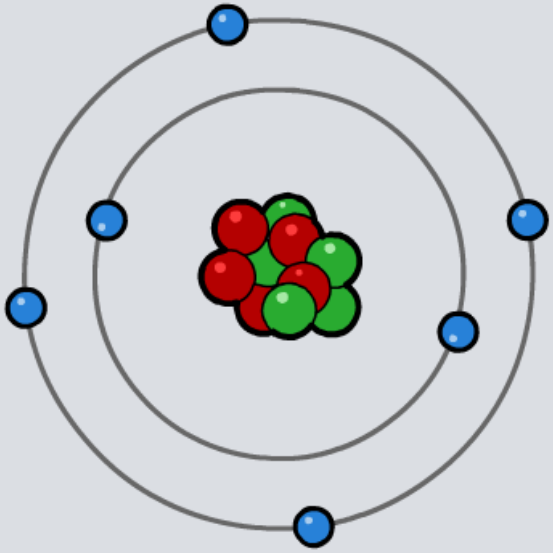
Quarks and Antimatter



Introduction to antimatter

For every particle there is a corresponding **antiparticle**. **Antimatter** is made up of antiparticles in the same way that matter is made up of particles.

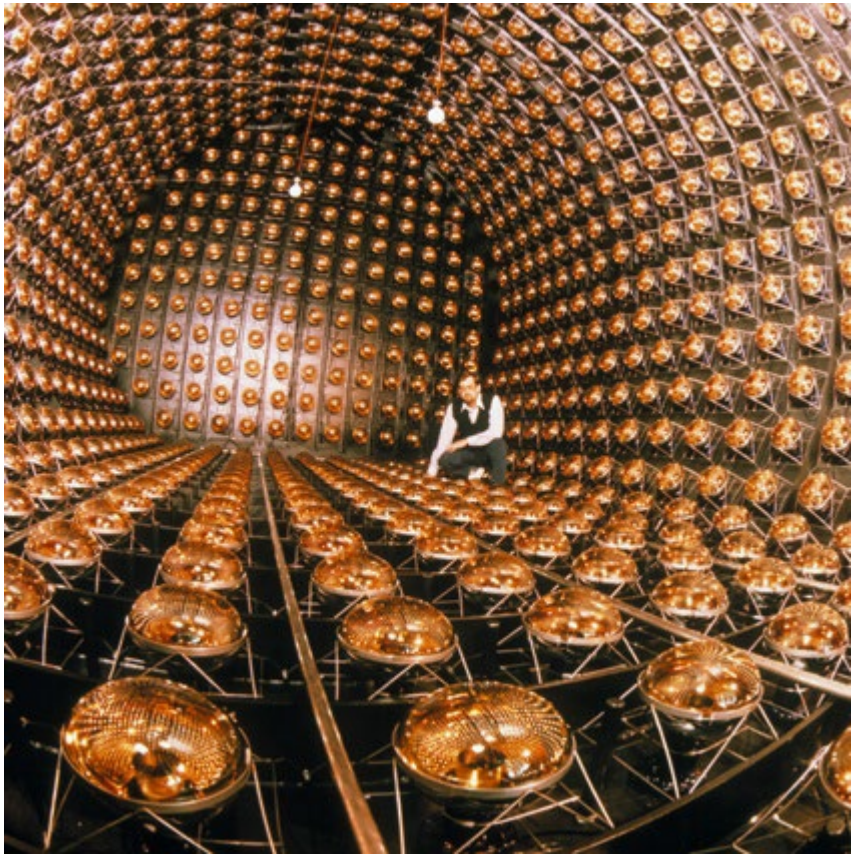
Antimatter was predicted in 1928 by Paul Dirac. In 1932 Carl Anderson discovered the first antiparticle. It was called the positron and is the antiparticle of the electron.

One of the biggest problems for physics is understanding why most of the observable universe seems to be made up of matter rather than antimatter.

The neutrino

Neutrinos and their antiparticles, **antineutrinos**, come in three different types, two of which are:

- electron neutrinos, ν_e and $\bar{\nu}_e$
- muon neutrinos, ν_μ and $\bar{\nu}_\mu$



They are created by radioactive decay or nuclear reactions in the Sun.

Neutrinos are elementary particles that travel close to light speed. They have an extremely small (but non-zero) mass and are uncharged.

Particles and antiparticles

Quarks

Quarks are fundamental particles. They are not thought to be composed of any smaller particles.

Hadrons, such as protons and neutrons, are composed of quarks.

Quarks and their antiparticles, **antiquarks**, come in several types, called “flavors”:

flavor	quark symbol	antiquark symbol
up	u	$\bar{u}$
down	d	$\bar{d}$
strange	s	$\bar{s}$
charm	c	$\bar{c}$
top	t	$\bar{t}$
bottom	b	$\bar{b}$

Properties of quarks

Quarks and antiquarks have the properties charge and strangeness (shown below for three flavors of quarks).

	quark			antiquark		
	up	down	strange	up	down	strange
charge	$+\frac{2}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{2}{3}$	$+\frac{1}{3}$	$+\frac{1}{3}$
strangeness	0	0	–1	0	0	+1

Adding up the charge or strangeness for the quarks composing a hadron gives the charge or strangeness of that hadron.

For example a hadron composed of two up quarks and a down quark would have charge 2/3 + 2/3 – 1/3 = +1 and strangeness 0.

Complete the sentences

What are the missing words about particles?

1. Antimatter is made up of **A** ▼. Particles and their corresponding antiparticles have **B** ▼ mass, **C** ▼ charge and **D** ▼ rest energy. Rest energy is the **E** ▼ energy a particle can have.

2. Neutrinos are **F** ▼ particles. They come in three different types, including **G** ▼ neutrinos and **H** ▼ neutrinos.