Antimatter, annihilation and pair production

Antimatter

British Physicist Paul Dirac predicted a particle of equal mass to an electron but of opposite charge (positive). This particle is called a positron and is the electron's *antiparticle*.

Every particles has its own antiparticle. An antiparticle has the same mass as the particle version but has opposite charge. An antiproton has a negative charge, an antielectron has a positive charge but an antineutron is also uncharged like the particle version.

American Physicist Carl Anderson observed the positron in a cloud chamber, backing up Dirac's theory.

Anti particles have opposite Charge, Baryon Number, Lepton Number and Strangeness.

If they are made from quarks the antiparticle is made from antiquarks

Annihilation

Whenever a particle and its antiparticle meet they annihilate each other. Annihilation is the process by which mass is converted into energy, particle and antiparticle are transformed into two photons of energy.

Mass and energy are interchangeable and can be converted from one to the other. Einstein linked energy and mass with the equation:

$$\boxed{E = mc^2}$$

You can think of it like money; whether you have dollars or pounds you would still have the same amount of money. So whether you have mass or energy you still have the same amount.

The law of conservation of energy can now be referred to as the conservation of mass-energy.

The total mass-energy before is equal to the total mass-energy after.

Photon

Max Planck had the idea that light could be released in 'chunks' or packets of energy. Einstein named these wave-packets photons. The energy carried by a photon is given by the equation:

$$\boxed{E = hf}$$

Since $c = f\lambda$ we can also write this as: $\boxed{E = \frac{hc}{\lambda}}$

How is there anything at all?

When the Big Bang happened matter and antimatter was produced and sent out expanding in all directions. A short time after this there was an imbalance in the amount of matter and antimatter. Since there was more matter all the antimatter was annihilated leaving matter to form protons, atoms and everything around us.

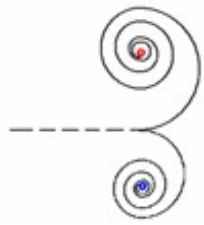
Pair Production

Pair production is the opposite process to annihilation, energy is converted into mass. A single photon of energy is converted into a particle-antiparticle pair. (This happens to obey the conservation laws)

This can only happen if the photon has enough mass-energy to "pay for the mass".

Let us image mass and energy as the same thing, if two particles needed 10 "bits" and the photon had 8 bits there is not enough for pair production to occur.

If two particles needed 10 bits to make and the photon had 16 bits the particle-antiparticle pair is made and the left over is converted into their kinetic energy.



If pair production occurs in a magnetic field the particle and antiparticle will move in circles of opposite direction but only if they are charged. (The deflection of charges in magnetic fields will be covered in Unit 4: Force on a Charged Particle)

Pair production can occur spontaneously but must occur near a nucleus which recoils to help conserve momentum. It can also be made to happen by colliding particles. At CERN protons are accelerated and fired into each other. If they have enough kinetic energy when they collide particle-antiparticle pair may be created from the energy.

The following are examples of the reactions that have occurred:

$p + p \rightarrow p + p + p + \bar{p}$ $\qquad$ $p + p \rightarrow p + p + \pi^+ + \pi^-$ $\qquad$ $p + p \rightarrow p + p + n + \bar{n}$

In all of these reactions, we can see that the conservation laws of particle physics are obeyed.