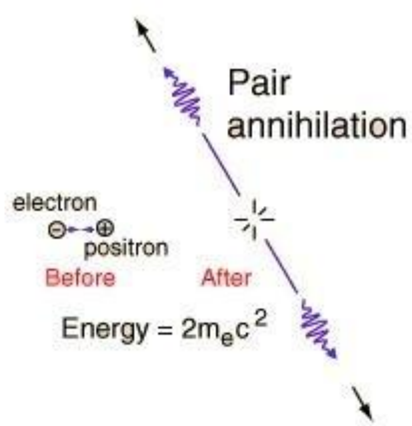
Particle Physics

12.3.1 Outline the concept of antiparticles and give examples

12.3.2 Outline the concepts of particle production and annihilation and apply the conservation laws to these processes.

Every known particle has an associated anti-particle. That is a particle that has all the opposite quantum numbers, electric charge, lepton or baryon number, strangeness etc. As far as we know anti-matter does not have negative mass and still falls down. Tests have been done to see if anti-matter "falls up." No conclusion test has been done to show that anti-matter falls up.



When a particle and its associated antiparticle collide they completely and totally annihilate turning into pure energy, in accordance to Einstein's relation of E = mc2. An example of this is the annihilation of an electron and a positron (positively charged electron, basically). When they collide their mass is turned into energy in the form of two high energy gamma rays. During the annihilation mass-energy and momentum are conserved.

If a photon has a higher energy than the rest mass of the electron and positron, it is possible for a electron and positron to be spontaneously created.

12.3.4 List the three classes of fundamental particle

12.3.5 State that there are three classes of observed particle

There are over 240 subatomic particles. We classify them by how they interact with forces. There are 3 classes of observed particles.

Class of Particle	Description	Example
Lepton	Fundamental particles. Not effected by the strong force. There are 3 particles and associated neutrinos. Leptons are not affected by the strong force. Leptons appear to have no geometrical size, but they do have mass.	Electron, Muon, Tau, Electron Neutrino, Muon Neutrino, and Tau Neutrino
Hadron	Particles affected by the strong force. They are made up of quarks. Include Baryons and Mesons.	Protons, Neutrons and Pions.
Exchange Boson	Fundamental particles that are exchanged between other particles. The exchange is the force.	Gluon, W & Z, Photon, Graviton

Leptons come in three families each with an associated neutrino:

Lepton	Mass	Associated Neutrino
Electron	0.000511 GeV	Electron Neutrino
Muon	0.1066 GeV	Muon Neutrino
Tau	1.777 GeV	Tau Neutrino

Electrons, muons and tau particles all have the same electric charge, but different masses. Both the muon and tau particle are unstable and decay relatively fast. The mean life of a Muon is 10-6 seconds whereas the tau's mean lifetime is only 10-12 seconds. Neutrinos are electrically neutral, as their name suggests, where or not neutrinos have mass is a topic of current research. Neutrinos are so plentiful and neutral that they can pass straight through the earth and you have millions going through your body as you read this.

In quantum physics there are many new properties that appear to be conserved. These new conservation laws were discovered experimentally and appear to hold true. One of the new conservation laws is the conservation of “Lepton number.” Neutron undergoes negative beta decay, it gives off an electron with a lepton number of 1 and anti-electron neutrino with a lepton number -1. Thus the lepton number is conserved.

Hadrons are spilt into two groups, Baryons and Mesons. Hadrons by definition are particles that are affected by the strong force. They are some times referred to as “strongly interacting particles.”

Baryons are hadrons that are made of three quarks. Neutrons and protons are two common examples of baryons. All baryons have spin ½. Protons are the only baryons that are stable. Neutrons by themselves will break down, by beta negative decay, into protons. A neutron has a half life on the order of a 608 seconds and is relatively stable. There are baryons that are many times the mass of protons or neutrons but they all have very short half-lives and thus are not observed in daily life. Baryons that are heavier than nucleons are call hyperons.

Mesons are hadrons that are made of two quarks, one “normal” quark and an anti-matter quark. Mesons consist of pions, kaons, eta and several other particles. Mesons are responsible for mediating the strong force between hadrons or nucleons.

Quarks - Fundamental particles that make up all Hadrons. Quarks can come in three different colors and the respective anti-color, red, blue and green. The color charge is analogous to electric or mass charge. Color has nothing to do with the color as see by a human eye, physicists simply ran out of descriptive terms… Only “white combinations” are possible. In other words neutrons and protons have a red blue and green quark. Whereas mesons must have a quark of one color and a quark of the anti-color… Quarks are subject to the strong force via gluons, that literally glue the particle together.

In a Hadron the quarks are held together with gluons, however the gluons can not leave the Hadron, and thus the attraction between nucleons can not be due to gluons, but are in fact due to gluon exchanging quark pairs, or mesons.

Quark	**Charge**	**Mass**
Up	+2/3	360 MeV
Down	-1/3	360 MeV

Charm	+2/3	1500 MeV
Strange	−1/3	540 MeV
Top	+2/3	174 GeV
Bottom	−1/3	5 GeV

12.3.6 Outline the structure of nucleons in terms of quarks

Since nucleons are baryons they are made of three quarks. The table below shows the combination of quarks that makes up protons and neutrons. They differ by only one quark. All matter in the world around you is made of up and down quarks in combination with leptons. When a proton or neutron undergoes beta decay one of the quark changes flavor. The weak nuclear force is the only force that can change the flavor of a quark.

Nucleon	**Quark Configuration**
Proton	uud
Neutron	udd

12.3.3 List and outline the four fundamental interactions

12.3.7 Outline the concept of an interaction as mediated by exchange of particles

Force	**Exchange Particle**
Gravity	Graviton
Weak Force	W+, W− & Z
Electromagnetic	Photon
Strong	Gluon, pions, mesons

Color	Gluon

The strong force can be seen as an extension of the color force beyond the confines of the quarks or nucleon. In order of relative strength, weakest to strongest:

Gravity < Weak Force < Electromagnetic < Strong

In recent years the weak force and electromagnetic force were shown to be the same fundamental force, which has been called the electroweak force. Work is under way to theoretically or mathematically combine all four forces into one force, so that all phenomena can be explained by one force!

Source: http://ibphysicsstuff.wikidot.com/particle-physics