# Leptons

## Fundamental Particles

A fundamental particle is a particle which is not made of anything smaller. Baryons and Mesons are made from quarks, so they are not fundamental, but quarks themselves are. The only other known fundamental particles are Bosons (see Forces and Exchange Particles) and Leptons.

## Leptons

Leptons are a family of particles that are much lighter than Baryons and Mesons and are not subject to the strong interaction. There are six leptons in total, three of them are charged and three are uncharged.
The charged particles are electrons, muons and tauons. The muon and tauon are similar to the electron but bigger. The muon is roughly 200 times bigger and the tauon is 3500 times bigger (twice the size of a proton).
Each of the charged leptons has its own neutrino. If a decay involves a neutrino and a muon, it will be a muon neutrino, not a tauon neutrino or electron neutrino.
The neutrino is a chargeless, almost massless particle. It isn't affected by the strong interaction or EM force and barely by gravity. It is almost impossible to detect.

| Lepton | | Charge (Q) | Lepton Number (L) |
|---|---|---|---|
| Electron | $e^-$ | -1 | +1 |
| Electron Neutrino | $\nu_e$ | 0 | +1 |
| Muon | $\mu^-$ | -1 | +1 |
| Muon Neutrino | $\nu_\mu$ | 0 | +1 |
| Tauon | $\tau^-$ | -1 | +1 |
| Tauon Neutrino | $\nu_\tau$ | 0 | +1 |

| Anti Lepton | | Charge (Q) | Lepton Number (L) |
|---|---|---|---|
| Anti Electron | $e^+$ | +1 | -1 |
| Anti Electron Neutrino | $\bar{\nu}_e$ | 0 | -1 |
| Anti Muon | $\mu^+$ | +1 | -1 |
| Anti Muon Neutrino | $\bar{\nu}_\mu$ | 0 | -1 |
| Anti Tauon | $\tau^+$ | +1 | -1 |
| Anti Tauon Neutrino | $\bar{\nu}_\tau$ | 0 | -1 |

## Conservation Laws

For a particle interaction to occur the following laws must be obeyed, if either is violated the reaction will never be observed (will never happen):

*Charge*: Must be conserved (same total value before as the total value after)
*Baryon Number*: Must be conserved
*Lepton Number*: Must be conserved
*Strangeness*: Conserved in EM and Strong Interaction. Doesn't have to be conserved in Weak Interaction

### *Examples*

In pair production a photon of energy is converted into a particle and its antiparticle

| | $\gamma$ | → | $e^-$ | + | $e^+$ | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Q | 0 | → | -1 | + | +1 | 0 | → | 0 | Conserved |
| B | 0 | → | 0 | + | 0 | 0 | → | 0 | Conserved |
| L | 0 | → | +1 | + | -1 | 0 | → | 0 | Conserved |
| S | 0 | → | 0 | + | 0 | 0 | → | 0 | Conserved |

Let us look at beta plus decay as we knew it at GCSE. A neutron decays into a proton and releases an electron.

| | n | → | p | + | $e^-$ | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Q | 0 | → | +1 | + | -1 | 0 | → | 0 | Conserved |
| B | +1 | → | +1 | + | 0 | +1 | → | +1 | Conserved |
| L | 0 | → | 0 | + | +1 | 0 | → | +1 | Not Conserved |
| S | 0 | → | 0 | + | 0 | 0 | → | 0 | Conserved |

This contributed to the search for and discovery of the neutrino.

### *Number Reminders*

There may be a clue to the charge of a particle; $\pi^+$, $K^+$ and $e^+$ have a positive charge.
It will only have a baryon number if it **IS** a baryon. Mesons and Leptons have a Baryon Number of zero.
It will only have a lepton number if it **IS** a lepton. Baryons and Mesons have a Lepton Number of zero.
It will only have a strangeness if it is made from a strange quark. Leptons have a strangeness of zero.