8.1: The First Symmetry - Isospin

The first particles that show an interesting symmetry are actually the nucleon and the proton. Their masses are remarkably close,

$$M_p = 939.566\ \mathrm{MeV/c^2} \quad M_n = 938.272\ \mathrm{MeV/c^2}.$$

If we assume that these masses are generated by the strong interaction there is more than a hint of symmetry here. Further indications come from the pions: they come in three charge states, and once again their masses are remarkably similar,

$$M_{\pi^+} = M_{\pi^-} = 139.567\ \mathrm{MeV/c^2}, \quad M_{\pi^0} = 134.974\ \mathrm{MeV/c^2}.$$

This symmetry is reinforced by the discovery that the interactions between nucleon (p and n) is independent of charge, they only depend on the nucleon character of these particles – the strong interactions see only one nucleon and one pion. Clearly a continuous transformation between the nucleons and between the pions is a symmetry. The symmetry that was proposed (by Wigner) is an internal symmetry like spin symmetry called **isotopic spin** or **isospin**. It is an abstract rotation in isotopic space, and leads to similar type of states with isotopic spin $I = 1/2, 1, 3/2, \ldots$ One can define the third component of isospin as

$$Q = e(I_3 + B),$$

where B is the baryon number ($B = 1$ for n, p, 0 for π). We thus find

	B	Q/e	I	I_3
n	1	0	1/2	−1/2
p	1	1	1/2	1/2
π^-	0	−1	1	−1
π^0	0	0	1	0
π^+	0	1	1	1

Notice that the energy levels of these particles are split by a magnetic force, as ordinary spins split under a magnetic force.