The Standard Model Summary

http://physics.info/standard/summary.shtml

Summary

- Elementary Particles (pdf) concept map
- Fermions
    - Fermions…
        - are the particles of matter
        - obey Fermi-Dirac statistics
        - have half integral spin quantum numbers (±½ for elementary particles; ±1½, ±2½, … for composite particles)
        - come in one of twelve flavors
        - belong to one of three generations.
            I. ordinary matter (the parts needed to make an atom)
            II. exotic matter (produced in high energy collisions)
            III. very exotic matter (produced in high very energy collisions)
    - The elementary fermions are either quarks or leptons.
        - Quarks (q)…
            - have spin ½
            - come in one of six flavors
                - three in the up group, each with a charge of +⅔ e
                    I. up (u)
                    II. strange (s)
                    III. top (t)
                - three in the down group, each with a charge of −⅓ e
                    I. down (d)
                    II. charm (c)
                    III. bottom (b)
            - have a property called color
                - Color is something like electric charge
                - All quarks can be found in any one of three colors.
                    - red
                    - green
                    - blue
                - Color in this context has nothing to do with human vision or visible light
                - Only quarks and gluons are colored
            - are always bound to other quarks (by the strong force)
        - Leptons (l)…
            - have spin ½
            - come in one of six flavors
                - the three heavy leptons

I. electron (e)
II. muon (μ, mu)
III. tau (τ, tau)

- each with a charge of -1 e
- can be found free or bound to other charged fermions (by the electromagnetic force)

- and three corresponding neutrinos
  I. electron neutrino (ν_e, nu sub e)
  II. muon neutrino (ν_μ, nu sub mu)
  III. tau neutrino (ν_τ, nu sub tau)
  - all of them are electrically neutral
  - only interact with themselves and other particles via the weak force
  - are exceptionally lightweight

- The composite fermions arranged in order of increasing complexity are
  - Hadrons
    - Mesons
      - are quark-antiquark pairs
      - have spin 0 or 1 making them bosons
      - have charge 0 e or ±1 e
      - are color neutral
      - include exotic particles like the pion (π), eta (η), rho (ρ), etc.
      - Somewhere between 91–124 different mesons have been identified.
    - Baryons
      - are quark triplets
      - have spin ½ or 1½ making them fermions
      - have charge +2 e, +1 e, 0 e, -1 e
      - are color neutral
      - subgroups
        - nucleons: protons and neutrons
        - hyperons: exotic particles like the lambda (Λ), sigma (Σ), omega (Ω), etc.
      - Somewhere between 86–193 different baryons have been identified.
  - Nuclei
    - are groups of protons and neutrons
    - have a positive integral amount of elementary charge
    - are color neutral
  - Atoms
    - are nuclei with bound electrons (one electron for every

proton)
        - are electrically neutral
        - are color neutral
    - Molecules
        - are atoms sharing electrons
- Bosons
    - Bosons…
        - obey Bose-Einstein statistics
        - have integral spin quantum numbers (±0, ±1, ±2,…)
    - Vector bosons, also known as gauge bosons…
        - have spin 1
        - belong to one of three types each associated with a fundamental force
            - The photon (γ, gamma)
                - carries the electromagnetic force between particles with charge
                - has an infinite range
                - is massless
                - exerts a force that is moderately strong relative to the other fundamental forces
                - has no charge or color
                - is described by the theory of quantum electrodynamics (QED)
                - is discussed in more detail in a another section of this book
            - Gluons (g)
                - carry the strong force between particles with color (only quarks and gluons)
                - have a short range (~ 10^{-15} m, about the diameter of a nucleon)
                - are massless
                - exert a force which is very strong relative to the other fundamental forces
                - come in one of eight color combinations, but carry no charge
                - are described by the theory of quantum chromodynamics (QCD)
                - are discussed in more detail in a another section of this book
            - The intermediate vector bosons (W^+, W^-, Z^0), also known as the weak bosons
                - carry the weak force between certain particles with

flavor

- have an extremely short range (~ 10^{-18} m, smaller than any known object)
- have mass
- exert a force that is moderately weak relative to the other fundamental forces
- come in charged and uncharged varieties, but are not colored
  - W^+ has a charge of +1e
  - W^- has a charge of $-1e$
  - Z^0 has no charge
- are described by electroweak theory (EWT), which unites electromagnetism with weak interactions
- are discussed in more detail in a another section of this book

- Scalar bosons…
  - have spin 0
    - The higgs boson (H)
      - mediates the higgs mechanism
      - gives mass to all particles with mass (including itself)
      - has mass
- Hypothetical tensor bosons beyond the standard model
  - would have spin 2
    - The graviton (G)
      - would carry the gravitational force between particles with mass-energy
      - would have infinite range
      - would be massless
      - would be extremely weak
      - may one day be described by a theory of quantum gravitation or a theory of everything