Chapter 6

The Standard Model Particles

6.1 Introduction

The Standard Model describes all known elementary particles and three of the four fundamental forces. Every particle belongs to either the fermion family, which makes up matter, or the boson family, which mediates the fundamental interactions.

6.2 Fermions: The Matter Particles

Fermions have spin 1/2 and obey the Pauli Exclusion Principle. They are divided into two groups: quarks and leptons. Six quarks and six leptons are known, arranged into three generations.

6.3 The Six Quarks

The quarks are Up, Down, Charm, Strange, Top, and Bottom. Each carries color charge and participates in the strong interaction. Quarks combine to form hadrons such as protons and neutrons.

6.4 The Six Leptons

The leptons are the electron, muon, tau, and their corresponding neutrinos. Charged leptons participate in electromagnetic and weak interactions, while neutrinos interact only through the weak force and gravity.

6.5 Three Generations

The particles are organized into three generations. The first generation forms ordinary matter. The second and third generations are heavier and unstable, decaying rapidly into first-generation particles.

6.6 Gauge Bosons

The four fundamental interactions are mediated by gauge bosons. The photon carries electromagnetism, eight gluons carry the strong interaction, and the W+, W–, and Z bosons carry the weak interaction.

6.7 The Higgs Boson

Discovered in 2012, the Higgs boson is associated with the Higgs field, whose nonzero vacuum expectation value breaks electroweak symmetry and gives mass to the W and Z bosons as well as the fundamental fermions.

6.8 Antiparticles

Every fermion has an antiparticle with the same mass and spin but opposite electric charge and other additive quantum numbers. Matter-antimatter annihilation converts mass into energy.

6.9 Particle Properties

Each elementary particle is characterized by a unique set of properties, including mass, electric charge, spin, weak isospin, hypercharge, color charge, baryon or lepton number, and generation.

6.10 The Standard Model at a Glance

The Standard Model successfully explains an enormous range of experimental observations. Although remarkably successful, it does not include gravity, explain dark matter, or account for the observed matter-antimatter asymmetry of the universe.

Summary of Standard Model Particles

Quarks: Up, Down, Charm, Strange, Top, Bottom
Leptons: Electron, Electron Neutrino, Muon, Muon Neutrino, Tau, Tau Neutrino
Gauge Bosons: Photon, Eight Gluons, W+, W–, Z■
Scalar Boson: Higgs Boson

Chapter Summary

The Standard Model classifies all known elementary particles into fermions and bosons. Fermions constitute matter, while bosons mediate the fundamental forces. Together they provide one of the most successful scientific descriptions of nature ever developed.