

# Fundamental Forces Cheat Sheet

Version 3.0

Fundamental Forces	Details
strong nuclear force	or strong interaction; the most powerful force at short distances; holds <b>protons and neutrons</b> together in the atomic nucleus, and holds <b>quarks</b> together in <b>hadrons</b> ; mediated by <b>gluons</b> ; described by <b>quantum chromodynamics (QCD)</b> , which concerns <b>color charge</b>
weak nuclear force	or weak interaction; responsible for <b>beta decay</b> ; mediated by <b>W and Z bosons</b> ; unified with the electromagnetic force as the electroweak force by <b>Glashow, Salam, and Weinberg</b>
gravity	weakest fundamental force; hypothetically mediated by gravitons; causes acceleration of <b>9.8 meters per second squared</b> (meters per second per second) on Earth; in <b>general relativity</b> , is accounted for by the curvature of spacetime; gravitational waves have been detected by <b>LIGO</b> ; subject of an inverse-square law created by Newton called his <b>Universal Law</b> of it
electromagnetism	or electromagnetic force or electromagnetic interaction; mediated by <b>photons</b> ; unified with the weak force as the electroweak force by <b>Glashow, Salam, and Weinberg</b> ; governed by <b>Maxwell's equations</b>

Theories and Models	Details
Grand Unified Theory	or GUT; theories that unify the strong, weak, and electromagnetic forces; first GUT was proposed by <b>Georgi and Glashow</b>
Quantum Chromodynamics	or QCD; a part of the <b>Standard Model</b> that assigns <b>color charges</b> to gluons and quarks
Standard Model	a theory that classifies the <b>elementary particles</b> , including quarks, leptons, and <b>gauge bosons</b> and accounts for all fundamental forces except gravity
Theory of Everything	or TOE; theories that unify all four fundamental forces by unifying a GUT with gravity

Particles	Details
bosons	particles that obey <b>Bose-Einstein</b> statistics; have integer spin and do not obey Pauli exclusion, which means that multiple bosons can occupy the same quantum state at a time; <b>gauge bosons</b> mediate fundamental forces (see above)
gluons	a type of boson that mediates the <b>strong interaction</b> ; in <b>QCD</b> , can have eight types based on <b>color charges</b> that include combinations of <b>red, blue, and green</b> with <b>anti-red, anti-blue, and anti-green</b>
hadrons	particles made up of <b>quarks</b> ; classified as <b>baryons</b> like protons and neutrons, which have an odd number of valence quarks, and <b>mesons</b> , which are made up of one quark and one antiquark
leptons	elementary particles with half-integer spin that mediate the <b>electroweak force</b> ; have no color charge; includes <b>electrons, muons, and tau leptons</b>
photons	a type of boson that mediates the <b>electromagnetic interaction</b> ; have <b>wave-particle duality</b> , meaning that they can act like both a wave and a particle; have <b>no mass</b> ; a photon's energy equals <b>Planck's constant times frequency</b>
quarks	elementary particles with half-integer spin that participate in the <b>strong interaction</b> ; have six <b>flavors: up and down, charm and strange, top and bottom</b> ; make up <b>hadrons</b>
W and Z bosons	types of boson that mediate the <b>weak interaction</b> ; W bosons have <b>W+</b> and <b>W-</b> types