Quantum Matter Elements and Particles

←Quantum

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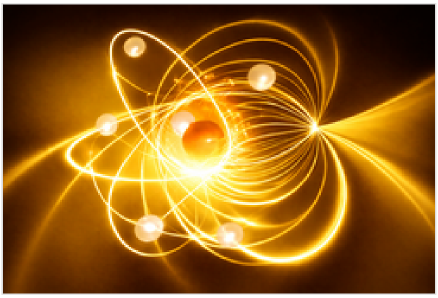
Subject classification: this is a physics resource.

Type classification: this is a quiz resource.

Type classification: this resource is a learning project.

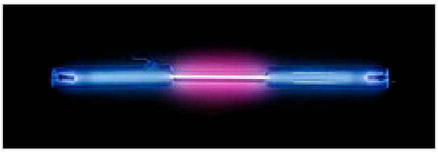
This page offers a guide to the different types of matter in the universe. From chemical elements to fundamental particles. It gives an overview of atoms, subatomic particles, and composite particles. The building blocks of matter and how they combine to form everything. It shows chemical elements and its arrangement in the periodic table.[1] Describes the Standard Model, and list the fundamental particles and the forces they have.[2] Composite particles like protons, neutrons, and mesons show how quarks form larger structures.[3] Visual aids, tables, and formulas help illustrate particle types and their relationships. This resource is intended for students, educators, and anyone curious about the structure of matter.



Artistic impression of an atom 5

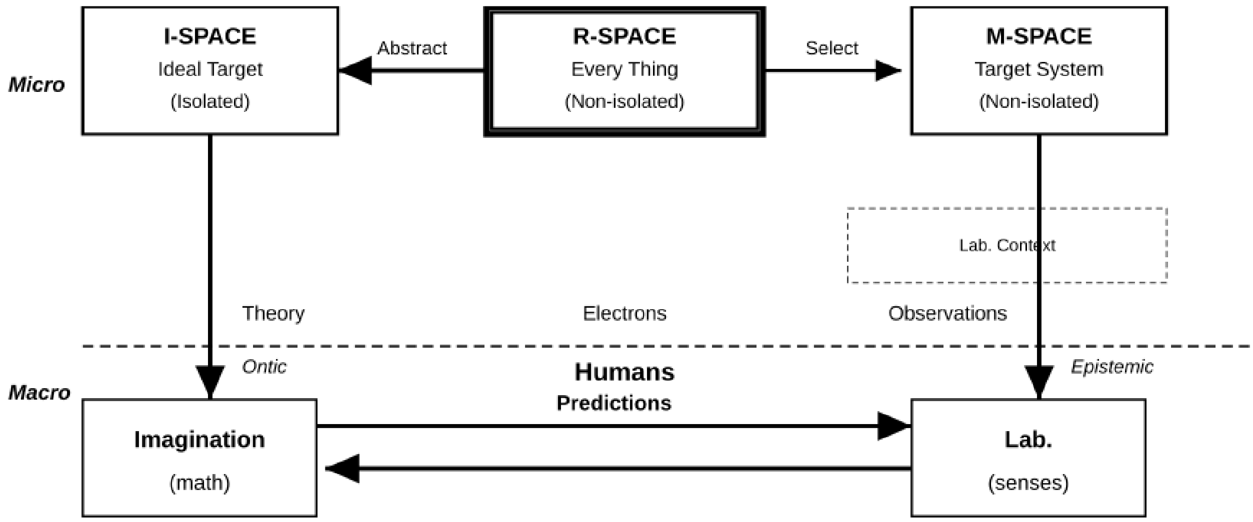
How many different Elements and Particles Exist?

The universe is made of tiny building blocks, known as particles. These particles combine to form atoms, molecules, and matter. Elements contain only one type of atom. There are 118 known chemical elements, each with properties and atomic structure.[1] Atoms are made of subatomic particles: protons, neutrons, and electrons.[4] Protons and neutrons are made of quarks, which are matter particles.[3] The Standard Model of physics includes all known fundamental particles and the forces between them.[2] Composite particles, such as hadrons and mesons, are formed from combinations of quarks.[3] By studying these particles scientists find the structure, behavior, and evolution of the universe.



Hydrogen in its plasma state is the most abundant ordinary matter in the universe.

The following diagram illustrates the tri-partite metaphysical scheme for analyzing parts of material nature.



This diagram also illustrates the power of visualization to communicate information between human minds, especially about objects and relationships. There is limited use of language (only verbal 'tags'), no mathematics while the figures could be any shape or color.

1. Overview

Level	Count	Description
Chemical elements	118	Periodic table atoms[1]
Fundamental particles	31–32	Standard Model building blocks[2]
Common subatomic particles	Dozens	Electrons, protons, neutrons, etc.[4]
Composite particles	400+	Hadrons, mesons, exotic states[3]

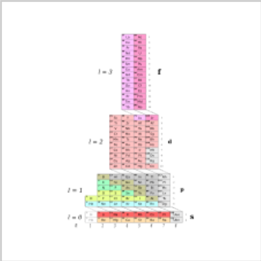
2. Chemical Elements (Periodic Table)

There are 118 confirmed elements.[1]

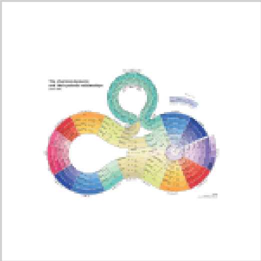
Periodic table

	1	2															3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																															He
2	Li	Be																									B	C	N	O	F	Ne
3	Na	Mg																									Al	Si	P	S	Cl	Ar
4	K	Ca															Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr															Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

s-block f-block d-block p-block



ADOMAH (long)

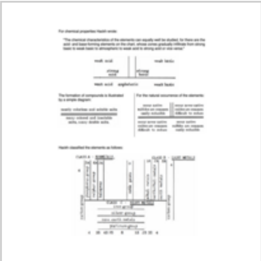


Curled ribbon (continuous)

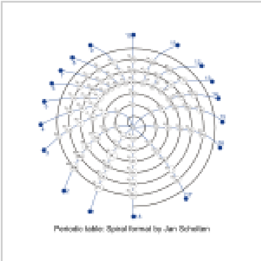
Four loops (continuous)

Partially disordered (unclassified)

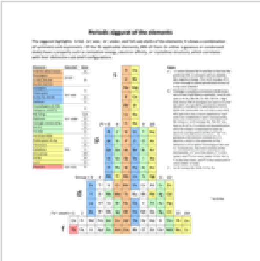
Short (9/11 columns)



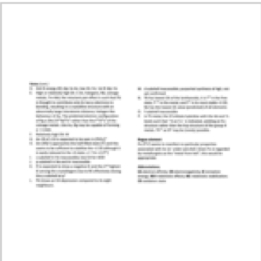
Short (9/11 columns) notes



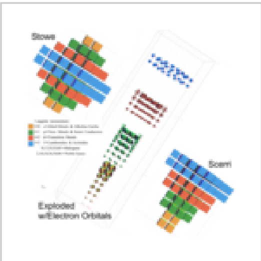
Spiral



Ziggurat (unclassified)



Ziggurat notes



4D Stowe-Scerri (spatial)

2.1 All known elements

Hydrogen, Helium, Lithium, Beryllium, Boron, Carbon, Nitrogen, Oxygen, Fluorine, Neon, Sodium, Magnesium, Aluminum, Silicon, Phosphorus, Sulfur, Chlorine, Argon, Potassium, Calcium, Scandium, Titanium, Vanadium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Gallium, Germanium, Arsenic, Selenium, Bromine, Krypton, Rubidium, Strontium, Yttrium, Zirconium, Niobium, Molybdenum, Technetium, Ruthenium, Rhodium, Palladium, Silver, Cadmium, Indium, Tin, Antimony, Tellurium, Iodine, Xenon, Cesium, Barium, Lanthanides, Hafnium, Tantalum, Tungsten, Rhenium, Osmium, Iridium, Platinum, Gold, Mercury, Thallium, Lead, Bismuth, Polonium, Astatine, Radon, Francium, Radium, Actinides, Rutherfordium, Dubnium, Seaborgium, Bohrium, Hassium, Meitnerium, Darmstadtium, Roentgenium, Copernicium, Nihonium, Flerovium, Moscovium, Livermorium, Tennessine, Oganesson[1]

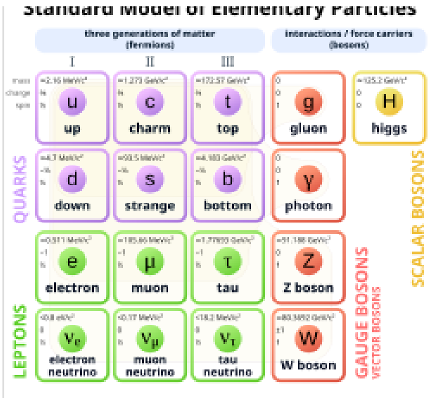
In 1985, Alan Chodos [13] proposed that neutrinos can have a tachyonic nature.[14] The possibility of standard model particles moving at faster-than-light speeds can be modeled using Lorentz invariance violating terms, for example in the Standard-Model Extension.[15][16] In this framework, neutrinos experience Lorentz-violating oscillations and can travel faster than light at high energies. This proposal was strongly criticized.[17]

Common subatomic particles

Particle	Type	Notes
Electron	Lepton	Fundamental[5]
Proton	Baryon	Composed of quarks[6]
Neutron	Baryon	Composed of quarks[7]
Photon	Boson	Force carrier (electromagnetism)[8]
Neutrinos	Lepton	Three flavors[9]
Muon	Lepton	Heavier electron[10]
Tau	Lepton	Heaviest lepton[11]
Quarks	Fermion	Six flavours (u, d, s, c, t, b)[12]

$\mathbf{A}$	Vector notation	G	Conductance or Gain
χ	Dispersive frequency shift	h	Planck constant
Δ	Tunneling rate or Detuning	I	Electrical current
δ	Dirac or Kronecker delta function	J	Inductance
ϵ	Energy asymmetry	K	Number of Cooper pairs
η	Efficiency	p	Probability or Probability density
Γ	Rate	r	Measurement result
$\hbar$	Reduced Planck constant	R_q	Resistance quantum
κ	Generalized eigenvalue or Cavity escape rate	S	Noise spectral density or Scattering matrix
λ	Eigenvalue or Wavelength or Coupling constant	T	Duration of time
μ	Magnetic moment	V	Voltage or Potential
ω	Frequency	W	Wiener random variable
Φ	Magnetic flux	x, y, z	Bloch coordinates
ϕ	Phase	y	Spherical harmonic
Φ_0	Magnetic flux quantum	Z	Impedance or Partition function
Π	Projection operator	$\bar{A}$	Average of A
ψ	Quantum state	$\mathcal{H}$	Stochastic Hamiltonian
τ_0	Correlation time	$\mathcal{L}$	Lindbladian or Lagrangian density
τ_m	Characteristic measurement time	M	Purity
T	Temperature	N	Wigner-Smith time delay matrix
ξ	Langevin random variable	Q	Accumulated charge
$*$	Complex conjugate	R	Signal-to-noise ratio
$\dagger$	Hermitian conjugate	S	Stochastic action
A	Amplitude	$\mathcal{T}$	Time-ordering operator or Transmission
$\mathbf{B}$	Magnetic field	Ω	Kraus (or measurement) operator
β	Inverse temperature or Bhattacharyya coefficient or Concurrence	$\hat{\rho}$	Density operator
c	Speed of light in a vacuum	$\hat{\sigma}$	Unnormalized density operator or Pauli operator
D	Displacement operator or Bhattacharyya distance	$\hat{a}$	Time-reversal operator
d	Degree of decoherence	$a, b, \hat{e}$	Bosonic annihilation operators
dW	Wiener increment	$\hat{H}$	Hamiltonian operator
E	POVM element or Electric field	l	Lindblad operator
e	Electron charge or Euler's number	$\hat{U}$	Unitary operator
E_c	Charging energy	$\hat{X}, \hat{P}$	Quadrature operators
E_F	Fermi energy	$\hat{O}$	Operator or Observable
E_J	Josephson energy		

four known fundamental forces (electromagnetic, weak and strong interactions – excluding gravity) in the universe and classifying all known elementary particles. It was developed in stages throughout the latter half of the 20th century, through the work of many scientists worldwide.with the current formulation being finalized in the mid-1970s upon experimental confirmation of the existence of quarks. Since then, proof of the top quark (1995), the tau neutrino (2000), and the Higgs boson (2012) have added further credence to the Standard Model. In addition, the Standard Model has predicted various properties of weak neutral currents and the W and Z bosons with great accuracy.



Standard Model of elementary particles

Standard Model particles

Category	Particles	Count
Quarks	up, down, charm, strange, top, bottom	6[3]
Antiquarks	anti-up, anti-down, anti-charm, anti-strange, anti-top, anti-bottom	6[3]
Leptons	electron, muon, tau, neutrinos	6[4]
Antileptons	positron, anti-muon, anti-tau, anti-neutrinos	6[4]
Total fermions		24[3]
Bosons	photon, gluon, W+, W−, Z0, Higgs	6[2]
Gravity (theoretical)	graviton	1[2]
Total bosons		7[2]
Grand total		31–32[2]

4.1 Key Formulas

- Fermions: $6+6+6+6=24$[3]
- Standard Model total: $24+6+1=31$[2]
- Baryon structure: $3quarks$[3]
- Meson structure: $1quark+1antiquark$[3]

5. Composite Particles (Hadron Zoo)

Hadrons, mesons, exotic states

Type	Examples	Notes
Baryons	proton, neutron, Δ, Σ, Ξ, Ω	3 quarks [1]
Mesons	π, K, η, ρ	1 quark + 1 antiquark [2]
Exotic	tetraquarks, pentaquarks	4 or 5 quark states [3]
Resonances	many	short-lived states[4]

four valence quarks. A tetraquark state has long been suspected to be allowed by quantum chromodynamics,[18] the modern theory of strong interactions. A tetraquark state is an example of an exotic hadron that lies outside the conventional quark model classification. A number of different types of tetraquark have been observed.

Several tetraquark candidates have been reported by particle physics experiments in the 21st century. The quark contents of these states are almost all $q\bar{q}Q\bar{Q}$, where q represents a light (up, down or strange) quark, Q represents a heavy (charm or bottom) quark, and antiquarks are denoted with an overline. The existence and stability of tetraquark states with the $qq\overline{QQ}$ (or $\overline{qq}QQ$) have been discussed by theoretical physicists for a long time, however these are yet to be reported by experiments.[19]

A particle temporarily called X(3872), by the Belle experiment in Japan, was proposed to be a tetraquark candidate,[20] as originally theorized.[21] The name X is a temporary name, indicating that there are still some questions about its properties to be tested. The number following is the mass of the particle in MeV/c²

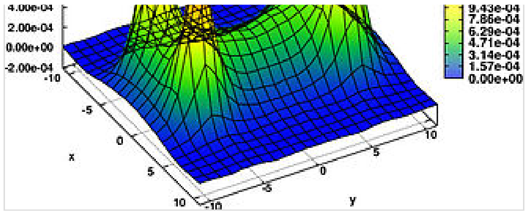
Baryon angular momentum quantum numbers for *L* = 0, 1, 2, 3

Spin, *S*	Orbital angular momentum, *L*	Total angular momentum, *J*	Parity, *P*	Condensed notation, J^P
$\frac{1}{2}$	0	$\frac{1}{2}$	+	$\frac{1}{2}^+$
	1	$\frac{3}{2}, \frac{1}{2}$	−	$\frac{3}{2}^-, \frac{1}{2}^-$
	2	$\frac{5}{2}, \frac{3}{2}$	+	$\frac{5}{2}^+, \frac{3}{2}^+$
	3	$\frac{7}{2}, \frac{5}{2}$	−	$\frac{7}{2}^-, \frac{5}{2}^-$
$\frac{3}{2}$	0	$\frac{3}{2}$	+	$\frac{3}{2}^+$
	1	$\frac{5}{2}, \frac{3}{2}, \frac{1}{2}$	−	$\frac{5}{2}^-, \frac{3}{2}^-, \frac{1}{2}^-$
	2	$\frac{7}{2}, \frac{5}{2}, \frac{3}{2}, \frac{1}{2}$	+	$\frac{7}{2}^+, \frac{5}{2}^+, \frac{3}{2}^+, \frac{1}{2}^+$
	3	$\frac{9}{2}, \frac{7}{2}, \frac{5}{2}, \frac{3}{2}$	−	$\frac{9}{2}^-, \frac{7}{2}^-, \frac{5}{2}^-, \frac{3}{2}^-$

Meson angular momentum quantum numbers for *L* = 0, 1, 2, 3

S	*L*	P	*J*	J^P
0	0	−	0	0^-
	1	+	1	1^+
	2	−	2	2^-
	3	+	3	3^+
1	0	−	1	1^-
	1	+	2, 0	2^+, 0^+
	2	−	3, 1	3^-, 1^-
	3	+	4, 2	4^+, 2^+

A **pentaquark** is a subatomic particle, consisting of four quarks and one antiquark bound together. Evidence for the existence of pentaquarks has been found. As quarks have a baryon number of $+\frac{1}{3}$, and antiquarks of $-\frac{1}{3}$, the pentaquark would have a total baryon number of 1, and thus would be a baryon. Further, because it has five quarks instead of the usual three found in regular baryons (A.k.a. "triquarks"), it is classified as an exotic baryon. The name pentaquark was coined by Claude Gignoux *et al.* (1987)[23] and Harry J. Lipkin in 1987; however, the possibility of five-quark particles was identified as early as 1964 when Murray Gell-Mann first postulated the existence of quarks. Although predicted for decades, pentaquarks proved surprisingly difficult to discover and some physicists were beginning to suspect that an unknown law of nature prevented their production.



Colour flux tubes produced by four static quark and antiquark charges, computed in lattice QCD.[22] Confinement in quantum chromodynamics leads to the production of flux tubes connecting colour charges. The flux tubes act as attractive QCD string-like potentials.

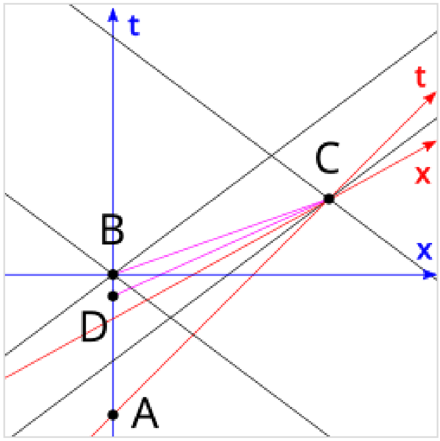
5.2 Tachyon

- This section is about hypothetical faster-than-light particles. For quantum fields with imaginary mass, see tachyonic fields.

A **tachyon** (or tachyonic particle) is a hypothetical type of particle that would move only at speeds faster than light. Modern physics, however, rules out the existence of such faster-than-light particles because they conflict with established physical laws. Relativity rules out speeds faster than light.[24][25] If tachyons were real, they might allow information to be transmitted faster than light, possibly even backward in time, That would violate causality and create logical contradictions such as the grandfather paradox.[26]

In theory, tachyons would behave weird: their speed would increase as their energy decreased, and bringing them down to the speed of light would require infinite energy, effectively making them the “inverse” of the usual $E = MC^2$ relationship. No experiment has ever produced reliable evidence for their existence.

The name *tachyon* originates from a 1967 paper by Gerald Feinberg, who studied quantum-field excitations with an imaginary mass. Later research showed that these excitations do not correspond to real faster-than-light particles, though physicists still use the term “tachyon” in contexts such as tachyon condensation, where it refers to unstable or imaginary-mass fields rather than actual particles.
As noted by Albert Einstein, Richard C. Tolman, special relativity implies that faster-than-light particles, if they existed, could be used to communicate backwards in time.[27]

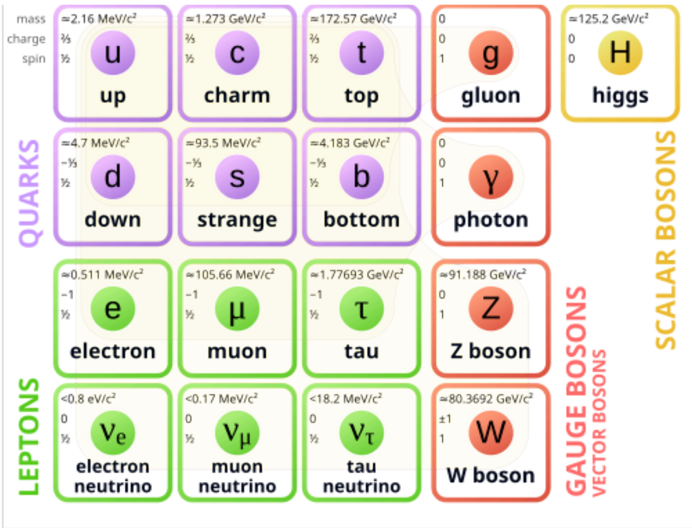


Spacetime diagram showing that moving faster than light implies time travel in the context of special relativity. A spaceship departs from Earth from A to C slower than light. At B, Earth emits a tachyon, which travels faster than light but forward in time in Earth's reference frame. It reaches the spaceship at C. The spaceship then sends another tachyon back to Earth from C to D. This tachyon also travels forward in time in the spaceship's reference frame. This effectively allows Earth to send a signal from B to D, back in time.

6. Graph Example

The Standard Model of particle physics is describing a part of the known fundamental forces (Weak and strong interactions electromagnetic– not including gravity in the universe and containing all known elementary particles.[2] Developed in the second half of the 20th century, by many scientists worldwide, with the current formulas finalized in the middle of 1970.

properties of weak currents and the W and Z bosons.[2]

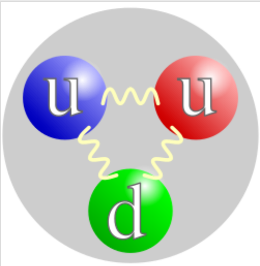
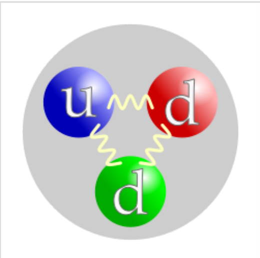


Standard Model is theoretically self-consistent and has some success in providing predictions, Some unexplained physical phenomena make it to fall short of being a complete theory of fundamental interactions. It does not explain why there is more matter than anti-matter. The full theory of gravitation as per general relativity, account for the universe's expansion as may be described by dark energy. This model not contains any viable dark matter particle that has all of the properties found from observational cosmology. It also does not has neutrino oscillations and their masses.[3]

The Standard Model is used by theoretical and experimental particle physicists. The Standard Model is basis of a quantum field theory, exhibiting lots of phenomena, including symmetry breaking, anomalies, and different behavior. It is a basis for more exotic models for hypothetical particles, Multidimensional scaling, and symmetries and supersymmetry, to see results at with the Standard Model, such neutrino oscillations and dark matter.[2]

7. Simple Explanation for Kids

Everything around us your toys, the air, even you, is made of tiny building blocks called **particles**.[4] At the smallest level, these particles combine in fun ways to form atoms, molecules, and more.[1]

 A very simple atom	This shows an atom with a nucleus in the center and electrons around it. Atoms are like LEGO bricks of the universe.
 Quark structure of a proton	A proton has three quarks: two "up" quarks (u) and one "down" quark (d). The colors of the quarks in the diagram help show that up and down quarks are different types. In real physics, quarks also have a property called “color charge” (red, green, blue) that keeps them stuck together.[3]
 Quark structure of a neutron	A neutron has one "up" quark and two "down" quarks. Again, the color coding shows the difference between the types of quarks, and each quark also has a color charge that helps hold the neutron together.[3]

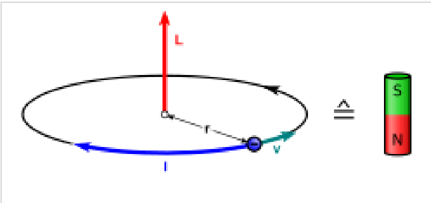
Here’s how to think about it:

- Atoms are like tiny LEGO bricks.
- Inside protons and neutrons are quarks, even smaller building blocks.[3]
- Quarks are glued together by the strong force.[3]
- Diagrams use colors to show different quark types (up vs down) and their “color charge” (red, green, blue).
- Protons and neutrons stick together in the nucleus, while electrons orbit around it.
- Molecules form when atoms join, making everything you see.
- Learning about these tiny pieces helps us understand why matter behaves the way it does and how the universe is built.

Particle	Field
Electron	electron field[4]
Up quark	up-quark field[3]
Photon	electromagnetic field[2]
Higgs boson	Higgs field[2]

8.1 Electron

The electron e^-, or β^- in nuclear reactions is a negatively charged subatomic particle and an elementary particle that, with up quarks and down quarks, forms ordinary matter.



Electron-orbital-magnetic-moment-simplified

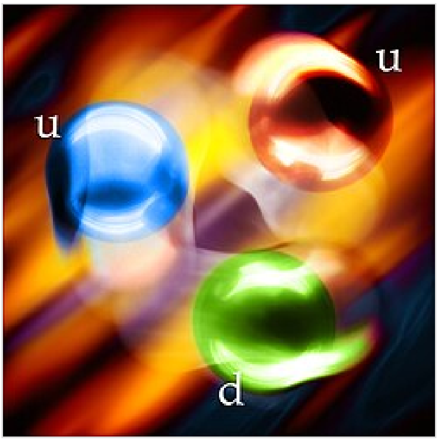
Electrons are very light and occupy orbitals around a atomic nucleus. Their arrangement defines an atom's chemical properties, with outer valence electron forming chemical bonds and driving chemical reactions, while inner electrons make up the atomic core.

In metals, delocalised electrons allow high electrical and thermal conductivity. In semiconductors, electron and hole numbers can be tuned by doping, temperature, voltage, or radiation, enabling electronics.

Free electrons in vacuums can be accelerated and focused for applications like cathode ray tubes, electron microscopes, electron beam welding, lithography, and particle accelerators producing synchrotron radiation.

8.2 Up quark

The up quark (symbol: u) is the lightest quark and one of the basic building blocks of matter. Together with the down quark, it makes up protons and neutrons:



Quark_wiki

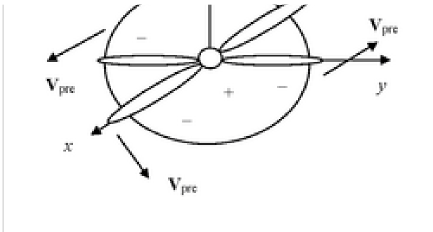
- A proton is two up quarks + one down quark: uud
- A neutron is one up quark + two down quarks: udd

It belongs to the first and lightest family of quarks. It has an electric charge of $+2/3, e$ (twice the charge of a down quark, but only 2/3 of an electron's charge) a very tiny mass, about $2.2, \mathrm{MeV}/c^2$ (roughly 1/2000 the mass of a proton). Like all quarks, it has spin $1/2$ (making it a fermion) and experiences all four fundamental forces: gravitation, electromagnetism, the weak force, and the strong nuclear force. Its antiparticle is the anti-up quark; it has the same properties except that its charge is $-2/3, e$ and a few other properties are reversed. The existence of the up quark (along with down and strange quarks) was proposed in 1964 by Murray Gell-Mann and George Zweig to explain observed patterns in subatomic particles. It was first directly observed in experiments at Stanford Linear Accelerator Center in 1968.

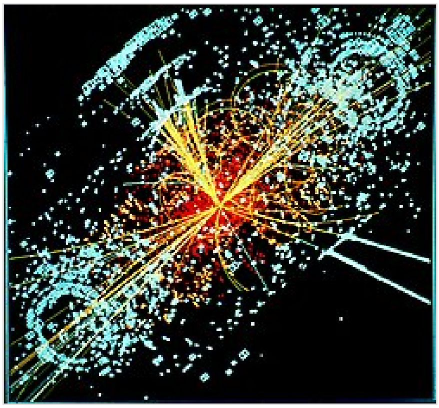
8.3 Photon

A photon (Greek φωτός), light is an elementary particle that is a quantum of the electromagnetic field, including electromagnetic radiation such as light and radio waves, and the force carrier for the electromagnetic force.

Photons are massless and can move only at one speed: the c, the speed of light in vacuum. The photon belongs to the class of boson particles.



Photon_model



CMS_Higgs-event

8.4 Higgs field

The Higgs field is an invisible field that permeates all of space, giving mass to elementary particles that interact with it. Particles gain mass by interacting with the field, much like a person moving through mud. The more a particle interacts with the Higgs field, the more mass it has. The existence of this field was confirmed by the discovery of the Higgs boson, which is an excitation or ripple in the field.

- **Mass:** The Higgs field is a medium that particles move through: Particles that interact strongly with the Higgs field are “slowed down” → they behave as if they have larger mass. Particles that interact weakly get small mass. Particles that do not interact at all (like photons) remain massless.This interaction is not friction; it’s a fundamental quantum interaction.
- **The Higgs boson:** Is a ripple (excitation) in the Higgs field. Discovered in 2012 at CERN. Its existence confirmed the mechanism that gives particles mass.
- **Mechanism:** The interaction between a particle and the field is what gives the particle its mass. It is a fundamental concept in the Standard Model of particle physics that explains why some particles have mass and others do not.

Gauge symmetries:

$U(1)$ Electromagnetism[2]

- $SU(2)$ Weak force[2]
- $SU(3)$ Strong force[2]

9. Summary Table

Category	Count	Notes
Chemical elements	118	Periodic table[1]
Fundamental particles	31–32	Standard Model[2]
Subatomic particles	Dozens	Commonly observed[4]
Composite particles	400+	Hadrons, mesons, exotic states[3]
Bosons	6 confirmed	Photon, gluon, W+, W−, Z0, Higgs[2]
Fermions	24	Quarks + leptons + antiparticles[3]

External links

- Particle Data Group – Particle Listings (https://pdg.lbl.gov) [3]
- CERN – Standard Model overview (https://home.cern/science/physics/standard-model) [2]
- IUPAC – Periodic Table of Elements (https://iupac.org/what-we-do/periodic-table-of-elements/) [1]

- Quantum
- Quantum A Matter Of Size
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- Quantum Noisy Qubits
- Quantum optics beam splitter experiments
- Quantum: The Secret of Cohesion: How Waves Hold Matter Together
- Quantum Ultra fast lasers
- Template:Quantum optics operators
- Physical Sciences

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11. Navigation Box

Levels of Matter
Chemical element · Atom · Subatomic particle · Quark · Lepton · Boson · Hadron · Standard Model