Introduction

Physics is the branch of science traditionally defined as the study of matter, energy, and the relation between the two. It was called natural philosophy until the late 19th century. Today, physics is subdivided into classical physics and modern physics.

Classical Physics

Classical physics includes the traditional branches that were recognized, and fairly well developed, before the beginning of the 20th century—mechanics, sound, optics, heat, and electricity and magnetism.

Mechanics

Mechanics is concerned with bodies acted on by forces and bodies in motion. It may be divided into statics and dynamics. Statics is the study of the forces on bodies at rest. Dynamics is the study of bodies in motion.

Dynamics is subdivided into kinematics and kinetics. Kinematics describes the motion of objects without consideration of the masses or forces that brought about the motion. In contrast, kinetics is concerned with the forces and interactions that produce or affect the motion.

Mechanics may also be divided into solid mechanics and fluid mechanics. The latter includes the branches of hydrostatics, hydrodynamics, aerodynamics, and pneumatics.

Sound

Sound is due to longitudinal pressure vibrations traveling through air, water, or some other medium. It can be explained in terms of the laws of mechanics. Ultrasonics is the study of sound waves of very high frequency, beyond the range of human hearing.

Optics

Optics deals with light and vision, chiefly the generation, propagation, and detection of electromagnetic radiation having wavelengths longer than X-rays and shorter than microwaves. Light outside the visible range exhibits all of the phenomena of visible light except visibility.

Optics is divided into geometric optics and physical optics. Geometric optics, or ray optics, describes light propagation in terms of rays. Physical optics, or wave optics, involves interference, diffraction, polarization, and other phenomena for which the ray approximation of geometric optics is not valid.

Heat

Heat is a form of energy, the internal energy possessed by the particles of which a substance is composed. Thermodynamics is the study of the relationships between heat, work, and energy.

Electricity and Magnetism

Electricity and magnetism have been studied as a single branch of physics since the connection between them was discovered in the early 19th century. An electric current gives rise to a magnetic field and a changing magnetic field induces an electric current. Electrostatics deals with electric charges at rest, electrodynamics with moving charges, and magnetostatics with magnetic poles at rest.

Modern Physics

Modern physics is concerned with the behavior of matter and energy under extreme conditions or on the very large or very small scale. The categories of modern physics include of atomic, nuclear, and molecular physics; elementary particle physics; cryogenics; solid-state physics; plasma physics; quantum theory; and relativity.

Atomic, Nuclear, and Molecular Physics

Atomic physics is the field of physics that studies atoms as an isolated system of electrons and an atomic nucleus.

Nuclear physics is concerned with the nucleus of the atom and the nucleus's fundamental particles—protons and neutrons.

Molecular physics is the study of the physical properties of molecules and of the chemical bonds between atoms that bind them.

Nanotechnology is an area of atomic and molecular physics that refers broadly to a field of applied science and technology whose unifying theme is the control of matter on an extremely small scale, normally 1 to 100 nanometers, and the fabrication of devices with critical dimensions that lie

within this size range.

Elementary Particle Physics

The physics of elementary particles is on an even smaller scale than atomic and nuclear physics, being concerned with the most basic units of matter. This branch of physics is also known as high-energy physics because of the extremely high energies necessary to produce many types of particles in large particle accelerators.

The two approaches to a uniform quantum field theory in theoretical physics are the Standard Model and String Theory.

Standard Model. The Standard Model is the name given to the theory of fundamental particles and how they interact. This theory includes strong interactions (quantum chromodynamics) and a combined theory of weak and electromagnetic interaction (electroweak theory).

Quantum chromodynamics (QCD) is a theory of the strong interaction (color force), which is a fundamental force describing the interactions of the quarks and gluons found in hadrons (such as protons and neutrons). QCD is a quantum field theory of a special kind called a non-abelian gauge theory. Gauge theories are a class of physical theories based on the idea that symmetry transformations can be performed locally as well as globally. It is called non-Abelian if the law of commutativity does not always hold.

The electroweak theories introduce W and Z bosons as the carrier particles of weak processes and photons as mediators to electromagnetic interactions.

The particles of the Standard Model are grouped into two classes—bosons (particles that transmit forces) and fermions (particles that make up matter). The bosons have particle spin that is either 0 or 1. The fermions have spin 1/2. The particles of the Standard Model are summarized in the following tables:

Name	Spin	Charge	Mass
Photon	1	0	0
Gluon	1	0	0
W^+	1	+1	80 GeV
W^-	1	-1	80 GeV
Z^0	1	0	91 GeV
Higgs	0	0	> 78 GeV

Particles that transmit force (bosons)
(Based on The Official String Theory Web Site, www.superstringtheory.com)

Name	Spin	Charge	Mass
Electron	1/2	-1	.0005 GeV
Muon	1/2	-1	0.10 Gev
Tau	1/2	-1	1.8 Gev
Electron neutrino	1/2	0	0?
Muon neutrino	1/2	0	<.00017 GeV
Tau neutrino	1/2	0	<.017 GeV
Up quark	1/2	2/3	0.005 GeV
Charm quark	1/2	2/3	1.4 GeV
Top quark	1/2	2/3	174 GeV
Down quark	1/2	-1/3	0.009 GeV
Strange quark	1/2	-1/3	0.17 GeV
Bottom quark	1/2	-1/3	4.4 GeV

Particles that make up matter (fermions)
(Based on The Official String Theory Web Site, www.superstringtheory.com)

The first six fermion particles (electron, muon, tau, electron neutrino, muon neutrino, tau neutrino) are known as leptons.

The Higgs boson is the only particle predicted by the Standard Model that has not yet been detected.

The Standard Model accounts for three of the four fundamental forces (electromagnetic, strong nuclear, weak nuclear), but fails to account for the fourth (gravity).

String Theory. Theories in particle physics that treat subatomic particle as infinitesimal, one-dimensional string-like objects rather than dimensionless points in space-time are known as string theories. Different vibrations of the strings correspond to different particles.

One of the predictions of string theory is that at higher energy scales we should start to see evidence of a symmetry that gives every particle that transmits a force (a boson) a partner particle that makes up matter (a fermion), and vice versa. This symmetry between forces and matter is called supersymmetry.

Cryogenics

Cryogenics is the science and technology of phenomena and processes at very low temperatures, defined arbitrarily as below 150 K (−190°F). At these temperatures, quantum effects, such as superconductivity and superfluidity, occur.

Superconductivity is a phenomenon occurring in certain materials at

extremely low temperatures, characterized by the absence of electrical resistance and the exclusion of an interior magnetic field.

Superfluidity is a state of matter characterized by the complete absence of viscosity.

Solid-state physics

Solid-state physics is the study of rigid matter, or solids. It is the largest branch of condensed matter physics, which is the field of physics that deals with the macroscopic physical properties of matter.

The bulk of solid-state physics theory and research is focused on crystals, largely because the periodicity of atoms in a crystal facilitates mathematical modeling, and also because crystalline materials often have electrical, magnetic, optical, or mechanical properties that can be exploited for engineering purposes.

Plasma physics

Plasma physics is the study of the properties of plasma, which is is an electrically neutral, highly ionized gas composed of ions, electrons, and neutral particles. Because of its unique properties, it is considered to be a distinct state of matter (in addition to gas, liquid, and solid). The free electric charges make the plasma electrically conductive so that it responds strongly to electromagnetic fields.

Quantum Theory

Quantum theory is concerned with the discrete, rather than the continuous, nature of many phenomena at the atomic and subatomic level, and with the complementary aspects of particles and waves in the description of such phenomena. It is concerned with phenomena on such a small-scale that they cannot be described in classical terms, and it is formulated entirely in terms of statistical probabilities.

Uncertainty Principle. The Heisenberg uncertainty principle states that locating a particle in a small region of space makes the momentum of the particle uncertain; and conversely, that measuring the momentum of a particle precisely makes the position uncertain.

Since the position of an atom is measured with a photon, the reflected photon changes the momentum of the atom, and hence the actual momentum is uncertain. The amount of uncertainty can never be reduced below the limit set by the uncertainty principle, regardless of the experimental setup.

In quantum mechanics, the position and momentum of particles do not have precise values, but have probability distributions. There are no states in which a particle has both a definite position and a definite momentum. The narrower the probability distribution is in position, the wider it is in momentum.

Quantum electrodynamics (QED). QED is a relativistic quantum field theory of electrodynamics. QED mathematically describes all phenomena involving electrically charged particles interacting by means of exchange of photons.

Relativity

Relativity, as developed by Albert Einstein, is comprised of two parts—the special theory of relativity and the general theory of relativity.

Special Theory of Relativity. The special theory of relativity postulates that the speed of light is the same for all observers, regardless of their motion relative to the source of the light, and that all observers moving at constant speed should observe the same physical laws. The only way both of these can happen is if time intervals and/or lengths change according to the speed of the system relative to the observer's frame of reference. For example, an atomic clock traveling at high speed in a jet plane ticks more slowly than its stationary counterpart.

This theory is called special because it is limited to bodies moving in the absence of a gravitational field.

The discovery of the relativity of space and time led to an equally revolutionary insight—matter and energy are interrelated as given by $E = mc^2$, where m = mass and c = the speed of light.

General Theory of Relativity. The general theory of relativity unifies special relativity, Newton's law of universal gravitation, and the insight that gravitational acceleration can be described by the curvature of space and time.

1. Cryogenics, Microsoft Encarta Encyclopedia Online, http://encarta.msn.com/ encyclopedia_761563758/Cryogenics, 2007.
2. Physics, The Columbia Encyclopedia, Sixth Edition, www.bartleby.com/65/ph/physics-ent, 2001-2007.
3. Plasma (Physics), Microsoft Encarta Encyclopedia Online, http://ca.encarta.msn.com/ encyclopedia_761568690/Plasma_(physics), 2007.
4. Quantum Chromodynamics, Encyclopedia.com, www.encyclopedia.com/doc/1E1-quantumch.
5. Quantum Electrodynamics, Encyclopedia.com, www.encyclopedia.com/doc/1E1-quantumel.
6. Quantum Theory, Microsoft Encarta Encyclopedia Online, http://encarta.msn.com/ encyclopedia_761559884/Quantum_Theory, 2007.
7. Relativity, Microsoft Encarta Encyclopedia Online, http://encarta.msn.com/ encyclopedia_761558302_1____4/Relativity, 2007.
8. Solid-state Physics, Microsoft Encarta Encyclopedia Online, http://encarta.msn.com/ encyclopedia_761577376/Condensed-Matter_Physics, 2997.
9. Special Relativity, Wikipedia, http://en.wikipedia.org/wiki/Special_relativity.
10. String Theory, Wikipedia, http://en.wikipedia.org/wiki/String_theory.
11. The Standard Model, The Official String Theory Web Site, www.superstringtheory.com/ experm/exper2.
12. Uncertainty Principle, Wikipedia, http://en.wikipedia.org/wiki/Uncertainty_principle.