PHYSICA

NOTAE

data/physica

AGENDA

CONVERT DOC TO STANDARD STYLES

Reading. Vide Bibliographiam. Scan SN for latest developments (at least article noted in bibliography; ideally, all back issues, either directly or through indexes.)

You need to develop a better idea of the relationships between the various groupings of laws. A more complete enumeration of the basic laws of physics and its various major specialties is needed for this.

NOTAE

MISC.

SN 10/28/17.31, 9/16/17.7: Massless photons can momentarily convert into one electron + one positron, particles which, unlike photons, have mass and charge.

PHYSICS: GENERAL

On Physical Laws in General

"For every symmetry of physics…there is a conservation law." Pagels, *Code*, p. 328; elucidated in *PS*, pp. 188–9 (following from preceding discussion of symmetry).

Principle of Least Action

Tom Siegfried, *SN* 10/28/17.28. Principle of Least Action (mcv: what it sounds like; v. W s.v.), "in many ways more fundamental than some physical laws"; "many other facts of physics can be derived from it". Topic: importance of understand the math behind the physics.

LAWS OF CLASSICAL PHYSICS

Mach, *Sci. Mech*., p. 226: "The merits of Newton with respect to our subject are twofold. First, he greatly extended the range of mechanical physics by his discovery of universal gravitation. Second, he completed the formal enunciation of the mechanical principles now generally accepted. Since his time no essentially new principle has been stated. All that has been accomplished in mechanics since his day, has been a deductive, formal, and mathematical development of mechanics on the basis of Newton's laws."

Laws of Motion

(Laws of classical mechanics. Newton's formulations are from *Principia*, Bk. I)

NEWTON'S LAWS

1. [Law of Inertia]

(Newton) Lex I: Corpus omne perseverare in statu suo quiescendi vel movendi uniformiter in directum, nisi quatenus a viribus impressis cogitur statum illum mutare. (Every body continues in its state of rest or of uniform motion in a right line unless (nisi quatenus) it is compelled to change that state by forces impressed upon it.)

(*RHDII*) A body remains at rest or in motion with a constant velocity unless an external force acts on the body.

Comment: Referred to by Mach, *Sci. Mech.* p. 169, as "the so-called law of inertia". Cf. laws of conservation of linear and angular momentum, under Other Laws, infra. The standard English translation disregards "quatenus"—perhaps because it is redundant and thus perhaps confusing, containing as it does part of the substance of the second law.

2. [proportion of change to imposed force]

(Newton) Lex II: Mutationem motus proportionalem esse vi motrici impress[ae], et fieri secundum lineam rectam qua vis illa imprimitur. (The change in motion is proportional to the motive force impressed and is made in the direction of the right line in which that force is impressed.)

(*RHDII*) The sum of the forces acting on a body is equal to the product of the mass of the body and the acceleration produced by the forces, with motion in the direction of the resultant of the forces.

3. ("law of action and reaction", or "Newton's law of motion" [RHDII])

(Newton) Lex III: Actioni contrariam semper et æqualem esse reactionem: sive corporum duorum actiones in se mutuo semper esse æquales et in partes contrarias dirigi. (To every action there is always opposed an equal reaction; or, the mutual actions of two bodies upon each other are always equal and directed to contrary parts.)

(*RHDII*) For every force acting on a body, the body exerts a force having equal magnitude and the opposite direction along the same line of action as the original force.

OTHER LAWS OF MOTION

Law of Conservation of Linear Momentum

(*RHDII* s.v.) The linear momentum of a system has constant magnitude and direction if the system is subject to no external force.

Comment: It appears from Mach, *Sci. Mech.* p. 169, that physics recognizes no fundamental distinction between linear and angular momentum. The laws of their conservation are perhaps minor corollaries of the first and second laws of motion.

Law of Conservation of Angular Momentum

(*RHDII* s.v.) The total angular momentum of a system has constant magnitude and direction if the system is subject to no external force.

Comment: See Law of Conservation of Linear Momentum

Laws of Thermodynamics

(*RHDII* s.v. Law of thermodynamics: "Any of three principles [i.e., those cited below] variously stated in equivalent forms.") MCV: Perhaps better seen as laws of energy, rather than of heat.

Thermodynamics describes macroscopic properties of matter (the aggregate behavior of large numbers of molecules). "What is remarkable is that with a rather small number of … macroscopic variables [whose behavior is described by the laws of thermodynamics] we can give a complete description of how the bulk properties of matter change." (Pagels, *Code*, p. 120.)

The laws of thermodynamics are derived from the laws of classical physics (Pagels, *Code*, p. 127). (But the second law, at least, is not derivable from "the classical laws of motion" alone, since these laws are time-neutral and entropy is not.) On the importance of the laws of thermodynamics to cosmology, and especially for a clearing of the air with respect to the concept of entropy, v. *PS*, pp. 229–37 (main passage reproduced infra, s.v. Second Law.)

SN158.234ff seems to imply that the laws of thermodynamics are held to be general for both quantum and classical physics; the article describes a proposed exception to the 2nd Law in certain cases for quantum mechanics: the notion of such an exception is highly controversial (though not unthinkable), and is described as "appalling" even by the team that proposed it.

1. Law of Conservation of Energy

Energy cannot be created or destroyed, only converted from one form to another.

(*RHDII* s.v.) In a system that does not undergo any force from outside the system, the amount of energy is constant, irrespective of changes in its form.

(*RHDII* s.v. Law of thermodynamics) The change of energy of a thermodynamic system is equal to the heat transferred minus the work done.

Julius von Mayer, Germany, 11842; James Joule, England, 11843.

Note: In general physics, for which mass and energy are convertible rather than "separately conserved", this law is superseded by those of the convertibility and conservation of mass and energy. (Pagels, *Code*, p. 37.) But the traditional statement of the law is still apparently current (e.g., SN158.234).

*SN*158.235: "Even the sacred first law's conservation of energy breaks down in the quantum realm, albeit in a limited way…, because Heisenberg's uncertainty principle allows energy momentarily to appear from nothing, although it must be quickly paid back."

2. [entropy]

Heat cannot of itself pass from a colder to a warmer body.

mcv: [[[[possibility: Entropy as unstructured, uniform stasis with no further possibility of decay into less energetic state, still less of being structured into a state that can do work ***unless more energy is pumped into the system. (2nd law refers to closed systems only.) Negentropy is structure capable of doing work, i.e., of expending energy.]]]]

(*RHDII* s.v. Law of thermodynamics) No cyclic process is possible in which heat is absorbed from a reservoir at a single temperature and converted completely into mechanical work.

(Pagels, *Code*, p. 123.) For any closed system, the entropy always increases. (A system will always change from a less probable configuration to a more probable configuration.) —direction

(*Enc. Phil.*, s.v. Entropy.) The entropy of an isolated system never diminishes. [**Within an isolated system, every reversible change will leave entropy unaltered; every irreversible change will increase entropy.]

Rudoph Clausius, Germany, 11850.

Comments: *Enc. Phil.*, s.v. Entropy: "The idea [of entropy] first arose as a part of the theory of heat, but a similar notion can be associated with probability distributions of any kind." The Second Law "determines the **direction in which thermodynamic processes occur and expresses the fact that, although energy can never be lost, it may become unavailable for doing mechanical work." "The less energy available for physical work, the higher the entropy of the system." (The article contains much valuable info on entropy and its implications.)

"Information is a form of energy." (SN158.235).

SN158.234: "The law requires that some energy must flow from one heat source to something else at a lower temperature"; [and that heat discharge must be to a lower temperature area, not to a hotter one].

PS pp. 236–7: "Galaxies form and stars burn, thus dumping photons into space and adding to the preexisting gas of photons. These processes increase the total entropy of the universe. But the remarkable fact is that the increase in the total entropy of the universe, from all these processes integrated over the entire lifetime of all the galaxies and stars, is only one ten-thousandth of the entropy already in the background photons—a tiny fraction. For all intents and purposes, the entire entropy of the universe today is in the photon gas and has remained effectively constant since the big bang. Entropy is essentially a conserved quantity in our universe. Not so long ago scientists spoke of the "heat death" of the universe. In the 1930s the physicist James Jeans, reflecting the views of most of his colleagues, remarked: 'For, independently of all astronomical considerations, the general physical principle known as the second law of thermodynamics predicts that there can be but one end to the universe—a "heat death" in which the total energy of the universe is uniformly distributed, and all the substance of the universe is at the same temperature. This temperature is so low as to make life impossible.' Physicists like Jeans who realized the universe was subject to the second law of thermodynamics were not wrong about the heat death. But they did not know in the 1930s about the existence of the photon gas at 3 K. We now know that the "heat death" of the universe *happened long ago*—with the big bang that created the photon gas. Almost the entire entropy of the universe is in that photon gas. All the stars burning out can contribute but a tiny fraction to the total entropy that is already here."

https://www.sciencenews.org/article/scientists-peek-inside-mind-maxwells-demon

Scientists peek inside the mind of Maxwell's demon: Memory tests uphold the second law of thermodynamics by Emily Conover. 7:00am, July 17, 2017

(extracts from web version, slightly different:)

Since 1867, when the demon was proposed by physicist James Clerk Maxwell, scientists wondered whether such a creature could violate the second law, a sacred tenet of physics. It declares that the entropy, or disorder, of a closed system cannot decrease over time.

Maxwell suggested that a nefarious tiny being could shuttle around molecules to decrease entropy — for example, by putting all the fast-moving molecules on one side of a box containing a gas and the slower ones on the other side. Such an improbable reconfiguration would break the second law, allowing the demon to illegally siphon off energy.

A century later, a solution to this dilemma was found: The demon must record information about the molecules in order to manipulate them, and that information has physical relevance. Storing that information in its "brain" increases the entropy of the demon, compensating for the entropy decrease the demon produces. As the demon extracts energy, it must delete the contents of its memory in order to store new information and manipulate other molecules. That deletion, physicist Rolf Landauer determined in 1961, costs energy and releases entropy, with the result that the demon's energy harvest is negated.

* * *

While the rules of thermodynamics were originally understood only for large systems like steam engines, scientists now hope understanding how the rules translate to small scales could one day lead to designs for more efficient quantum machines. (cf. SN: 3/19/16, p. 18: https://www.sciencenews.org/article/ultrasmall-engines-bend-second-law-thermodynamics?mode=magazine&context=193431)

3. [absolute zero unattainable]

The entropy of ordered solids reaches zero at the absolute zero of temperature.

(*RHDII* s.v. Law of thermodynamics) It is impossible to reduce the temperature of a system to absolute zero in a finite number of operations.

Walter Nernst, Germany, 1918.

Laws of Electromagnetism

Formulated by Maxwell, they unified electricity and magnetism, previously seen as separate forces. (Pagels, *Code*, pp. 121, 332).

Other Laws of Classical Physics

Law of Conservation of Mass (Law of Conservation of Matter)

(*RHDII*) In a closed system subject to no external forces, the mass is constant irrespective of changes in its form. (The principle that matter cannot be created or destroyed.)

Comment: A law of macrocosmic physics, in which the convertibility of mass and energy is not a factor. In general physics, for which mass and energy are convertible rather than "separately conserved", this law is superseded by those of the convertibility and conservation of mass and energy. (Pagels, *Code*, p. 37.)

Ideal Gas Laws

(W: "Most gases behave like ideal gases at moderate pressures and temperatures.")

1: Boyle-Mariotte law: A gas will compress in proportion to the pressure to which it is subject. (The product of pressure and volume is constant for each gas: $PV = k$, k is a[n arbitrary] constant) (W, citing one Levine: "The absolute pressure exerted by a given mass of an ideal gas is inversely proportional to the volume it occupies if the temperature and amount of gas remain unchanged within a closed system." Or, "For a fixed amount of an ideal gas kept at a fixed temperature, pressure and volume are inversely proportional.")

2: Gay-Lussac equation: The volume of a gas will expand in direct proportion to the amount of heat added, and contract in direct proportion to the amount of heat subtracted. (W: "The pressure of a gas of fixed mass and fixed volume is directly proportional to the gas's absolute temperature.")

3: Charles's Law (Law of Volumes): W: "When the pressure on a sample of a dry gas is held constant, the Kelvin temperature and the volume will be directly related."

Boyle's law, Charles's law, and Gay-Lussac's law are summed up as the "combined gas law".

Combined Gas Law: W: "The ratio between the pressure-volume product and the temperature of a system remains constant."

Avogadro's Law: W: "Equal volumes of all gases, at the same temperature and pressure, have the same number of molecules."

The Combined Gas Law in combination with Avogadro's law can be generalized by the Ideal Gas Law.

Ideal Gas Law: W: "The ideal gas law is the equation of state of a hypothetical ideal gas." Often written:

$$PV = nRT$$

where:
P is the pressure of the gas
V is the volume of the gas
n is the amount of substance of gas (in moles)
R is the ideal, or universal, gas constant, equal to the product of the Boltzmann constant and the Avogadro constant.
T is the temperature of the gas

FUNDAMENTAL LAWS & PRINCIPLES OF GENERAL PHYSICS

Special relativity and the quantum theory, "taken together, provide the conceptual framework of almost all of physics and are the basis of our ideas about material reality." (Pagels, *Code*, p. 265ff, esp. 271–2; cf. *PS*, pp. 174–5.)

Laws

Law of Convertibility of Matter and Energy

Mass and energy are convertible in the proportion $E=mc^2$.

(Classification as fundamental per MCV. Status as law, phrasing and title per MCV.) Cf. Pagels, *Code*, p. 268. Mass is a form of bound energy. [Anything] with energy has an "effective mass" (Pagels, *Code*, p. 47), hence, e.g., light waves are bent by gravity.

Law of Conservation of Mass and Energy

In a closed system subject to no external forces, the aggregate of mass and energy is constant irrespective of changes in form.

(Classification as fundamental per MCV. Status as law, phrasing and title per MCV; phrasing after *RHD* expression of conservation laws.)

The probabilistic nature of quantum reality in fact allows for loopholes in this law. (Pagels, *Code*, p. 275.) Particle/anti-particle pairs are continuously and spontaneously being created, normally annihilating themselves immediately. But it is possible for some of these particles to remain in what is for practical purposes real existence. This spontaneous creation of particles is the phenomenon referred to as a quantum fluctuation in the void. Its likelihood increases for less massive particles, since the required fluctuation is more likely the less mass/energy is involved.

Note: The energy may be potential energy; e.g., when you lift a stone against gravity, the stone retains potential energy, which becomes kinetic when you let go.

"An electron-volt is the particle physicists' unit of energy and mass." Conover, SN 3/17/18.

Law of Gravitation

(*RHDII*) Any two masses attract each other with a force equal to a constant ([the] constant of gravitation) multiplied by the product of the two masses and divided by the square of the distance between them.

(Newton) The whole force with which one [perfect sphere] attracts the other will be inversely proportional to the square of the distance of the centers. (*Questions on Natural Philosophy*, Hafner p. 105, correlated with passage in *Principia* not in Hafner ed.)

(Classification as fundamental per MCV.)

Note: Gravitation is mediated by gravitational energy, which has all the characteristics of other types of energy, including convertibility with mass (SN 10/30/99, 156.277) and mediation by particles. String theories involving extra dimensions challenge the inverse square relation [in quantum situations]; they postulate that gravitons, unlike other particles, are affected by and can exist in, certain of these other dimensions. This would account for the weakness of the gravitational interaction: much of its energy diffuses into dimensions that do not affect other particles. (SN 2/19/00, 157.122ff.)

Law of Conservation of Charge

(*RHDII*) The total electric charge of a system is constant.

Cf. Pagels, *Code*, p. 244. Classification as fundamental per MCV. Developed by Benjamin Franklin, 1750s.

Quantum Physics

Some aspects of the theory of relativity

On special and general relativity, v. *PS*, pp. 301ff. Special relativity theory requires that the "laws of physics have the same form for observers with uniform motion relative to each other". General relativity requires that the laws be invariant regardless of relative motion. [This implies that the effects of intrinsic gravity and those of acceleration are indistinguishable], which would further imply that quanta of gravity exist for an accelerated observer but not for one at rest. (mcv: Relativity perhaps points to a purely pragmatic understanding of extension and time—our exceptional difficulty with the concept is the result of the immense difference between our pragmata and those of the quantum particles that dominated the scene when the space-time structure was very different.)

Space and time are unified by the theory of relativity. There is no absolute, universal time.

PS p. 142: "In Newtonian kinematics, the laws of transformation for space and time measurements are separate; the time transformation is independent of the position and relative velocity of two inertial observers. Thus time can be taken to have a universal, "absolute" significance for all inertial observers. But in Einstein's kinematics, space and time measurements become intimately interrelated; time is not absolute but is relative to a particular inertial observer. Einstein, reasoning from two general postulates—that absolute uniform motion of an inertial observer is undetectable and that the speed of light is an absolute constant—correctly deduced the new laws of space-time transformations. But it was Hermann Minkowski, a mathematician, who pointed out their geometrical interpretation. Minkowski showed that if one did not view the three space dimensions and the one time dimension as separate entities, but instead joined them together into a four-dimensional space-time, then Einstein's new transformations could simply be seen to correspond to rotations performed in this four-dimensional space-time. This was an enormous simplification, creating a new perspective on space and time. As Minkowski commented in 1908, 'Henceforth space by itself and time by itself are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.'" This leads to the issue of the "shape of the universe" (v. esp. *PS*, pp. 147ff).

What is seen as the gravitational force is the manifestation of the geometry of space-time. This is "the central conclusion of general relativity." (How does this tie in with the idea of gravity as mediated by particles? Answer (partial): The particles are *quanta*; the gravitational field is quantized. But v. *PS*, pp. 301ff: This relation of gravity to space-time doesn't tie in with the Standard Model, a reflection of the fact that gravity has not been integrated into that model.)

The speed of light, referred to in discussions of physics, is the speed of light in a vacuum. In refractive media, it can happen that certain particles can travel faster than light (phjotons) can in that medium.

Ontology; Field Theory

With quantum physics, a pragmatic ontology replaces naively realistic notions of matter: fundamental entities are not sensed, as "stuff", through the biological senses, but known through their effects. *Code* p. 266: Relativistic quantum field theory implied that to understand atomic particles one has to go beyond the old idea of matter as a "material stuff" that can be known through our senses to descriptions of particles in terms of how they transform when subject to various interactions. It is how material objects respond when acted upon that tells us what they are."

*SN*158.235: "Classical physics portrays fundamental particles, such as atoms and electrons, as tiny billiard balls. Quantum mechanics, on the other hand, also represents them as waves. According to that wave nature, elementary particles extend across space and interact with each other through the overlapping of their crests and troughs. The extended interaction, known as quantum coherence, gives quantum systems their remarkable character. It permits electrons to flow without resistance through superconductors and superfluid helium to mysteriously climb out of a cup of its own accord.... [There is] another even stranger type of interaction, known as entanglement, also takes place. Entangled particles share a single quantum state, so that whatever happens to one immediately affects the other, even if they are widely separated" (*SN* 11/20/99, p. 334).

All that exists is made up of quarks, leptons, and gluons. The interactions of these quanta determine the nature of all that exists. (Cf the "central dogmas" of Pagels, infra, and of Weinberg as cited in *Code*, p. 269.)

****Particles with identical quantum characteristics are absolutely identical: the principle of identity applies rigorously to them. (mcv: except in their realtiosn to other pragmata.) From the fact that they are therefore interchangeable in equations follow important consequences, which Pagels elucidates in *Code*, pp. 280ff.

Material particles can be understood as the quanta of various fields. (Weinberg, apud Pagels, *Code*, p. 269; on fields, v.q. *PS*, pp. 185ff.) "The intensity of a field at a point in space is interpreted as the statistical probability for finding its associated quanta." This is "the most important consequence of relativistic field theory." "The underlying reality is the set of fields, but its manifestation is particles." (Pagels, *Code*, p. 270.) Field and particle are complementary concepts, like particle and wave. (Pagels speaks of "wave fields oscillating in space".)

Heisenberg, Pauli, Pascual Jorden, and Eugene Wigner showed in the late 20s "that each different field—the electromagnetic field, the electron field, and so on—had an associated particle. particles were manifestations of a 'quantized' field. This was a basic idea of modern field theory, which banished forever the old idea that particles and fields were separate entities. Fields were the fundamental entities, but they were manifested in the world as particles. (*PS*, p. 175.) (MCV: Perhaps think of the quantization of a field in terms of resolution?) "The world according to this view [i.e., that of field theory] is a vast arena of interacting fields manifested as quantum particles flying about and interacting with one another." (*PS*, p. 191.)

"Fields are actually defined by how they transform the various symmetry operations." (*PS*, p. 189.) The characteristics of a particle (mass, spin, charge, etc.) can be predicated of a field. E.g., the electron field has a charge of -1, a spin of ½, etc., just like the electron. (*PS*, pp. 189, 190.)

Fields corresponding to massless particles (e.g., electromagnetic and gravitational fields) act over long ranges. [[Massless particles travel at the speed of light.]] Fields corresponding to massive particles are short-range, acting only over atomic or nuclear distances.

Relation of quantum physics to macrophysics

SN 5/26/18.7: Macroscopic objects linked via quantum entanglement.

The "Central Dogmas of Relativistic Field Theory" (Pagels, *Code*, p. 271.)

1. The essential material reality is a set of fields.
2. The fields obey the principles of special relativity and quantum theory. (The importance of this as an axiom is shown in *PS*, Part 2, ch. 2.)
3. The intensity of a field at a point gives the probability for finding its associated quanta—the fundamental particles that are observed by experimentalists.
4. The fields interact and imply interactions of their associated quanta. These interactions are mediated by the quanta themselves.
5. There isn't anything else.

The four fundamental quantum interactions

There are only four fundamental quantum interactions. Each of these fundamental interactions is mediated by a gluon or class of gluons: the interacting particles are seen as interchanging gluons of the appropriate types. The strength of the interaction depends on the energy of the interacting particles. The fundamental interactions are, in order of increasing strength:

1. The gravitational interaction, mediated by gravitons. This is over 10^{27} times weaker than the electromagnetic interaction. It is readily manifest only where there are large concentrations of matter.
2. The weak interaction, mediated by weak (W and Z) gluons, which couple to the weak and flavor charges. Responsible for radioactivity and other types of decay of hadrons and leptons (sic Pagels; n.b. almost all of these are unstable). This interaction is manifest only over extremely small distances. Weak gluons are far more massive than gravitons and photons. Weak gluons cause hadron decay by changing the flavor of the quarks that make up the hadrons.
3. The electromagnetic interaction, mediated by photons. Effects include electromagnetic waves and the binding of electrons to the atomic nucleus. The field theory describing this interaction is called quantum electrodynamics.
4. The strong interaction (responsible for binding quarks inside hadrons), mediated by the eight types of colored gluons. The field theory describing this interaction is called quantum chromodynamics.

At higher energies than currently prevail in the universe, the distinctions between these interactions (or between the non-gravitational interactions at any rate: *Code*, p. 309) may vanish. (This condition is referred to as symmetry.) This implies the possibility of theoretically unifying the interactions. (V. *Code*, p. 263–4, 308–11; the basic situation seems to have changed little as of 2000.) Unified field theories exist that unify the electromagnetic, weak and strong interactions under a single theory. (The term "grand unified field theories" may refer to theories that unify any or all of the fundamental interactions.) Gravity is harder to bring into a unified field theory because it is so much less energetic than the other interactions, requiring theory for energies that much higher than those currently prevailing, and actual energies that much higher for experimental verification of these theories. The energies required are in the range of 10^{13}–10^{16} TeV; the highest energies currently attainable in accelerator collisions are approaching 1 TeV (*SN* 2/19/00, 157.122). But theories involving extra dimensions may allow for unification at lower energy levels, permitting tests of unified field theories for the non-gravitational interactions at levels of about 1 TeV (*SN*, loc. cit.). A field theory unifying all four of the fundamental interactions "would be the completion of physics as we know it now." (Pagels, *Code*, p. 332; he anticipates, however, that such a completion will open new horizons for questioning.) On GUTs, generally and specifically, v. *PS*, Part 3.

See Pagels, *Code*, pp. 251ff, for general detail and discussion of the fundamental quantum forces.

The Standard Model

See esp. *PS* Part 2, ch. 3; Part 3, ch. 3; and passim in *PS* and *Code*.

The Standard Model is a combination of special relativity and quantum field theory, explaining everything in terms of quarks, gluons, leptons, and their interactions. It does not integrate gravity, only the other fundamental interactions. Gravity poses many problems (*PS*, pp. 301ff; also supra on Theory of Relativity), which point to inadequacies in the Standard Model—the attempt to combine quantum theory with *general* relativity requires fundamental revisions in quantum theory. The Standard Model is considered basically adequate for describing the universe after the first [10^{-33}] seconds. But it is likely that understanding the origin of the universe will require a theory that integrates gravity.

The fact that the Standard Model, in conjunction with some other common notions, implies a singularity at the beginning of the universe is not proof of the singularity—it is likely an indication of inadequacies in the Standard Model. (*PS*, p. 244, and cf. 258ff.)

PARTICULA

"If I could remember the names of all these particles, I'd be a botanist." —Enrico Fermi

As into the the universe I did stare
I met a particle that wasn't there.
It wasn't there again today.
Oh, I wish it would go away.
—Tom Derderian, Winthrop Mass., on dark matter, in a letter to *SN*: 6/16/12, p. 31

General

On the classification of particles, v. *PS*, pp. 183ff.

"Quarks, leptons, and gluons and their organization are all there is in the universe." (*Code*, p. 251.) The fundamental attributes of particles (mass, spin, etc.) are not subject to the uncertainty principle.

Bowen, *The Telescope in the Ice*, 97, 98, written 2017: "There have been no fundamental advances in particle physics since [1984]. All the particles predicted by the standard model, except one, the Higgs boson, were discovered by [1984]." Since then, "the particle physics community has been searching desperately for experimental evidence of any kind of physics beyond the standard model." "As Gary Taubes, the author of *Nobel Dreams* wrote in 1986, 'If there is in fact no life in the desert, no new particles, then there will be no new evidence forthcoming with which to build better theories. Progress will be at an end. The standard model will remain standard for the duration.'"

Bowen *TTITI*, 292: "Supersymmetry, the extension to the standard model on which the particle physics community is pinning its greatest hopes, posits a heavy sister or brother particle for each of the particles in the standard model.... Several of the lightest of these hypothetical siblings happen to be the most promising candidates for the unseen cold dark matter." These latter are the WIMPS: wthout charge, unaffected by the strong nuclear force, affected only by the weak nuclear force and gravity. There is as yet no evidence for supersymmetry.

Only the proton, electron, photon, and neutrino are stable; the other particles eventually decay into these.

PS, p. 223: "The tendency in nature is for heavier particles, since they have the most mass energy, to release their energy by decaying into lighter particles with the energy of the original particle transformed into the energy of motion of the lighter particles." (On the postulation of proton decay by some GUTs, v. *PS*, Part 3; also pp. 221, 275ff.)

SN 4/28/18.24: A new, more accurate measurement of the fine-structure constant agrees "reasonably well" with previous measurements " and therefore confirms that the electron is probably not composed of smaller particles"

Dark matter/energy: SN 2/17/18: per Conover, "the universe is roughly 70 percent dark energy, 25 percent dark matter, and 5 percent matter, according to combined data from the Planck stallite, the Drake Energy Survey, and other observations."

Antimatter: For every (charged?) particle there can exist an antiparticle having the opposite charge. Collisions of a particle with its antiparticle annihilate the two, converting all their mass into energy.

Bowen, *The Telescope in the Ice*, 31: "Antimatter isn't quite exotic as it may sound. Abraham Pais points out that it is 'as much matter as matter is matter.'" mcv: It's merely a question of electrical charge. It just happens that the practical consequences of juxtaposing matter and antimatter are so drastic, from the POV of material observers.

Spin: All particles possess spin, which is quantized, occurring only in integer and half-integer magnitudes. Particles with integer spins and those with half-integer spins behave in importantly different ways. (*Code*, pp. 280–88; *PS*, p. 183.) Fundamental particles with integer spins are called bosons; those with half-integer spins are called fermions. Hadrons with integer spins are called mesons; those with half-integer spins are called baryons.

"Most fundamental quanta come in equal mixtures of right- and left-handed versions." (Code.) Handedness refers to the direction of spin: CW is right-handed, CCW is left-handed. The particle's axis of rotation is in the direction of forward motion.

Electron spin is the basis of the magnetic property of atoms. It is also the basis for the science of "spintronics", which seeks to harness the motion of electron spin in the same way that electronics harnesses the motion of electron charge. (Applied in quantum computing.)

Energy

Bowen, *TTITI* 72: "The standard unit of energy in particle physics is the electron-volt (eV), th amount of kinetic energy acquired by an electron when it is accelerated across a potential diffrence of one volt. ... It's a convenient unit for expressing the masses of elementary particles. The electron, for example, has a so-called rest mass (its mass-energy in its rest frame) of aboiut 510 eV." "An electron-volt is the particle physicists' unit of energy and mass." Conover, SN 3/17/18.

Miscellaneous particles, non-standard or classification TBD

Tachyons

Hypothetical particles, allowed for by the founding theory of particle classification, that travel faster than light.

Magnetic Monopoles

A new class of particles postulated by some GUTs. Discussed in *PS*, Pt. 3, ch. 2. (Note that electrons and protons are electric monopoles. "One may visualize the electric-field lines of force emerging from or converging on an electrically charged particle and beginning or ending there.") They would be isolated N or S magnetic poles. A monopole may have been detected in 1982, but the event was never repeated (*PS*, p. 289). Monopoles would be solitary but stable waves, unlike other fundamental particles, which are manifestations of a field. According to theory (or at least some theories) they have extension, and their mass is immense by quantum standards—in the neighborhood of 1 mcg, larger than some microorganisms.

Fundamental quantum particles (quarks, gluons, leptons): general

Fundamental particles with integer spins are called bosons; those with half-integer spins are called fermions.

Fermions are conserved—the number of fermions at the beginning of a reaction equals the number at the end. Baryons are not conserved.

"Identical bosons can occupy the same position in space, while identical fermions cannot. Identical bosons … prefer to condense in groups; identical fermions … exclud[e] one another." (This accounts for the exclusion principle of electrons.) (*PS*, p. 305.)

Quarks

"Quarks appear to be point particles without further structure." Pagels, *Code*, p. 206. "Quarks are point quantum particles similar to the electron." They are never found as free particles at currently attainable energies: the strong force (mediated by gluons) that binds them together into hadrons is too strong, and actually increases with distance, to the point where, before the energy is sufficient to uncouple them, that energy is transformed into matter (more quarks). (PS, p. 217.) (The strong force also decreases to zero as distance decreases.) (Quantum chromodynamics postulates that a "soup" of free quarks and gluons existed immediately following the Big Bang, and that such a soup could be recreated in high-energy collisions. This may have been done at CERN in February of 2000; the results await verification by higher-energy accelerators. *Economist*, 2/19/00, p. 79; SN 2/19/00, 157.117.)

SN 6/10/17.31, reply to letter, paraphrasing and quoting Emily Conover: "The three quarks within the proton are only apparent when the proton is probed with high-energy particles. At lower energies, particles 'see' the entire proton as one entity. 'In that case the proton just behaves like a sphere of positive charge.' she says."

Quarks have mass. All quarks have a spin of 1/2 (like leptons, including the electron). They are thus fermions, and exhibit the characteristics of fermions (see above). Unlike leptons, all quarks have fractional electrical charges. (This is not a problem for theory, because they are only found in groups that have inegral net charges. Conover, *SN* 3/17/18.)

There are six flavors of quark. (The term "flavor" became current at a time when the three quarks then known were called chocolate, vanilla, and strawberry.) Each (?) flavor has its corresponding antiquark. Each flavor of quark comes in three colors: R, B, Y. (Antiquarks can be thought of as coming in the three complementary colors.) Color can be spoken of as a type of charge possessed by a given quark. This charge is derived from the colored gluons (eight kinds) which mediate the strong force (*Code*, p. 261). Quarks interact predominantly with colored gluons, and to a lesser degree with other gluons. See Gluons for more on color.

name	symbol	spin	appx. mass (electron = 1)	electric charge (proton = 1)	comments
up	u	½	2	⅔	
[anti-up]	u¯	½	[2]	[–⅔]	
down	d	½	6	–⅓	
[anti-down]	d̄	½	[6]	[⅓]	
strange	s	½	200	–⅓	
[anti-strange]	s̄	½	[200]	[⅓]	
charm	c	½	3000*	⅔	
[anti-charm]	c̄	½	[3000*]	[–⅔]	
bottom (beauty)	b	½	9000	⅔	
top (truth)	t	½	?	–⅓	

*3000 per *Code*, p. 238; 1500 per *PS*, p. 215.

Leptons

All have a spin of ½ (like quarks). They are thus fermions, and exhibit the characteristics of fermions (see above). They resemble quarks in many ways, but can exist in a free state. Leptons are point particles. They react weakly with each other, whence the name (from Gk word meaning "light" or "swift"). They interact only with photons and the weak (W and Z) gluons; they do not interact with colored gluons.

The electron is the lightest of all electrically charged quanta. It is therefore absolutely stable, since there is no smaller particle that can carry away its charge. (As for the other leptons, the muon and tauon are highly unstable, and the neutrinos don't interact with much of anything.)

It is not clear that neutrinos have mass (*Code*, & v. infra). They react extremely weakly with other matter. They are frequent products of decay, and are so numerous that the question of whether or not they have even a very small mass bears significantly on the question of the amount of matter in the universe. There are three "flavors" of neutrino: electron neutrinos, associated with electrons, muon neutrinos with muons, and tau neutrinos with tauons. All neutrinos are left-handed. They interact very weakly with matter and with electromagnetic fields, and they generally pass right through anything in their way. V. *PS*, p. 251.

Neutrinos can change ("oscillate") from one flavor to another. This was discovered only in 1999 (SN 1/30/99 p. 76), and accounts for the missing neutrinos in solar output called for by theory; it also implies that neutrinos can make up "no more than about half the dark matter" (SN 159.388, 6/23/01). Such oscillations are ruled out by the Standard Model; quantum mechanics implies that such oscillation is possible only if neutrinos have mass, which they cannot have under the Standard Model. Conover, SN 3/17/18.15: "Neutrinos, which come in three different varieties and have three different masses, are extermely light." (Mass as yet unknown.)

Table from Pagels, *Code*, p. 250; see also *PS*, p. 209ff:

name	symbol	spin	mass (electron = 1)	electric charge (in units of proton charge)	comments
electron	e^-	½	1	–1	See text. Mass = 0.51 million electron volts (*PS*, p. 189)
positron (anti-electron)		½	[1]	1	
muon	μ^-	½	207	–1	Highly unstable.
anti-muon		½	[207]	1	
tauon	τ^-	½	3491	–1	Highly unstable.
neutrinos					See text.
electron neutrino	ν_e	½	< 0.00012	0	
muon neutrino	ν_μ	½	< 1.1	0	
tauon neutrino	ν_τ	½	< 500	0	
anti-neutrinos					
anti-electron neutrino	$\bar{\nu}_e$				
anti-muon neutrino					
anti-tauon neutrino					

Gluons

Each of the four fundamental interactions is mediated by a gluon or class of gluons: the interacting particles are seen as interchanging gluons of the appropriate types. The strength of the interaction (the strength with which gluons latch onto the interacting particles) depends on the energy of the interacting particles. (On the fundamental interactions, see Fundamental Laws and Principles of General Physics. See Pagels, *Code*, pp. 251ff, for general detail and discussion of the fundamental quantum forces, and p. 300ff on the field theory of gluons; also PS, pp. 216ff.)

Photons are said to be stable, in apparent contrast to other gluons. Gluons cause quarks and leptons to stick together. While gluons are responsible for decay, gluons other than photons are themselves apparently subject to decay; Pagels (*Code*) does not discuss this.

Gluons (except for colored gluons: Pagels, *Code*, p. 303) can exist in a free state. They have integer spins, and are thus bosons, exhibiting the characteristics of bosons. (See above.)

"Today physicists believe that all four fundamental interactions…are based on gauge fields. The gluons of these interactions are the quanta associated with the gauge fields." (Pagels, *Code*, p. 299.) These are the "Yang-Mills" gauge fields

On color: "The basic idea of quantum chromodynamics is that each quark has a new kind of charge—a 'color' charge. [The colors are called red, blue, and yellow—the three primary colors.] Introducing these three extra color charges allowed physicists to postulate a new symmetry among the quarks—a color symmetry. This symmetry was similar to the rotational symmetry of a sphere in three-dimensional space—
each of the three spatial dimensions now corresponded to one of the three primary colors…. If the sphere was rotated, the different colors mixed, and perfect color symmetry meant that the three primary colors had to be mixed. An equal mixture of the three primary colors produces white…. Requiring such a color invariance thus implied that only those combinations of colored quarks were allowed that when mixed resulted in no color at all. These colorless combinations of colored quarks (anti-quarks are assumed to have the complements of the primary colors) correspond exactly to the observed hadrons." (Pagels, *Code*, pp. 302–3.) That is, the three primary colors (or the three complementary colors, may combine to form "white" (color charge = 0), or a color and its complementary may combine to form "gray" (color charge also = 0). These are the only combinations possible. (In both *Code* and *PS*, Pagels calls the "primary" colors R, B, and Y.)

Table, Pagels, *Code*, p. 262:

name	symbol	spin	electrical charge	mass	couples to	role in quantum interactions; comments
graviton					mass	Gravitational interaction. Interacts very weakly with other matter. Implied by theory, which also implies that they are undetectable by any feasible technology. They couple to mass according to Pagels (v. PS, pp. 301f); might weight be the more appropriate term?
Leptons interact only with these:						
photon	γ	1		0	electric charge	Electromagnetic interaction. Couple to electric charge.
weak gluons				v. high	weak & flavor charges	The weak interaction. V. PS, pp. 204, 216, 222f. Mass = 90+ proton mass.
	W^+	1	+1			
	W^-	1	–1			Can change a d quark into a u quark.
	Z°	1	0			
Quarks interact primarily with these:						
colored gluons (8 kinds)				0	colored charges	The strong interaction [or strong force] that. binds quarks into hadrons.

Misc.

?Higgs boson. 0 spin, very massive. (Cf. *PS*, p. 203, 224-5, 280; also articles in Bibliography.

Other gluons postulated by unified field theories (one requires 24 gluons), including 12 superheavy gluons responsible for theoretical proton decay. (*PS*, p. 227; and Part 3.)

Hădrons

"Hadrons interact with each other very strongly, reflecting the strong forces that bind the quarks inside of them." (*Code*, p. 241.) "Quantum chromodynamics describes how quarks bind together so tightly that they become permanently contained in tiny 'bags'. (*PS*, p. 208). These bags are the hadrons.

Hadrons are made up of quarks, in combinations having an integral total electric charge and a total color charge of zero. (*PS*, p. 219). That is, the three primary colors (or the three complementary colors, may combine to form "white" (color charge = 0), or a color and its complementary may combine to form "gray" (color charge also = 0). These are the only combinations possible. (In both *Code* and *PS*, Pagels calls the "primary" colors R, B, and Y.)

The varieties of hadrons are infinite: they are determined both by the types of quarks involved and by the orbital configurations of these quarks, for which the possibilities are infinite. In practice, only those hadrons involving the lowest energy orbital configurations (i.e., the most stable ones; cf. atoms) are much studied.

They are classified in terms of their spin. (V. *Code*, p. 222.) The spin of hadrons is quantized; it must be either a whole or half integer. Hadrons fall under two general types: mesons (with integer spins) and baryons (with half-integer spins). (The analogous division of the fundamental particles—quarks, leptons, and gluons— is into bosons, with integer spins, and fermions, with half-integer spins.) Each of these types has subfamilies of hadrons, with members all having the same spin. Pagels (*Code*) refers to an "eightfold way" classification of hadrons. This is never described in detail, but detailed partial examples are shown on p. 230.

The properties of hadrons include: mass, spin, electric charge, isotopic charge, strangeness charge. Hadrons have a finite spatial extension. In hadron collisions, electric, isotopic, and strangeness charges are conserved. This conservation reflects the conservation of the component quarks which determine charge. In collisions, these quarks may recombine to produce new hadrons.

General: Pagels, *Code*, p. 218, 219 ff.

[classification TBD]

kaon

lambda hyperon (= λ baryon?)

Mesons

Mesons have integer spins (0, 1, 2,…). They are combinations of a quark and an antiquark. (How come, e.g., the $\bar{b}$b pair of the ϒ meson don't annihilate each other?) The number of mesons is not conserved in collision—hadron collisions can create many mesons.

ρ meson

ϒ (upsilon): quark composition $\bar{b}\bar{b}$

<u>meson octet</u> (8 particles)

pion (π meson)	spin 0	holds together protons and neutrons in the nucleus (*Code*, p. 216–7). About one-seventh the mass of the neutron, and much shorter-lived.

Baryons

Baryons have half integer spins (1/2, 3/2,…). Baryons are combinations of three quarks; antibaryons are made of three antiquarks. The number of baryons minus the number of anti-baryons is conserved in particle interactions—the same number is left in the end as there was at the beginning. (*PS*, p. 249.)

Neutron: *SN* 3/4/17.13: "Outside of an atomic nucleus, neutrons survive only about 15 minutes on average. Thye quickly decay into a proton, an electron, and an antineutrino."

<u>baryon octet</u> (*Code*, p. 229–30.)

name	symbol	composition	spin	electric charge (proton = 1)	isospin charge	strangeness charge	comments
proton		uud	½	1	½	0	
neutron		udd	½		–½	0	
	Λ	uds			0	–1	
	Σ°	uds			0	–1	
	Σ^{+}	uus			1	–1	
	Σ^{-}	dds			–1	–1	
	Ξ^{-}	dss			–½	–2	
	Ξ°	uss			½	–2	

strangeness charge	–³⁄₂	–1	–½	0	½	1	³⁄₂
–2			Ξ^{-} dss		Ξ° uss		
–1		Σ^{-} dds		Σ° uds / Λ uds		Σ^{+} uus	
0			neutron udd		proton uud		

isospin charge

<u>baryon decuplet</u> (*Code*, p. 230.)

name	symbol	composition	spin	electric charge (proton = 1)	isospin charge	strangeness charge	comments
	N^{*-}	ddd			–3/2	0	
	$N^{*\circ}$	udd			–1/2	0	
	N^{*+}	uud			1/2	0	
	N^{*++}	uuu			3/2	0	
	Σ^{*-}	dds			–1	–1	
	$\Sigma^{*\circ}$	uds			0	–1	
	Σ^{*+}	uus			1	–1	
	Ξ^{*-}	dss			–1/2	–2	
	$\Xi^{*\circ}$	uss			1/2	–2	
	Ω^{-}	sss			0	–3	

–3				Ω^{-} sss			
–2			Ξ^{*-} dss		$\Xi^{*\circ}$ uss		
–1		Σ^{*-} dds		$\Sigma^{*\circ}$ uds		Σ^{*+} uus	
0	N^{*-} ddd		$N^{*\circ}$ udd		N^{*+} uud		N^{*++} uuu
strangeness charge	–3/2	–1	–1/2	0	1/2	1	3/2
				isospin charge			

BIBLIOGRAPHIA

SIGLA

PS Pagels, *Perfect Symmetry*.

WORKS READ

<u>BOOKS</u>

Gribbin, John. *In Search of Schrödinger's Cat: Quantum Physics and Reality.* New York: Bantam Books, 1984.
Read long ago. Probably to re-read, but Pagels may have covered the same ground better in *Code*.

Mach, Ernst. *The Science of Mechanics: A Critical and Historical Account of Its Development.* Tr. Thomas J. McCormack, new introduction by Karl Menger. 6th ed, with revisions through the 9th German ed. La Salle, Ill.: Open Court, 1960. (First German ed. 1883.)
Have, in Chron.

Pagels, Heinz R. *The Cosmic Code: Quantum Physics as the Language of Nature.* New York: Simon & Schuster, 1982.

———. *Perfect Symmetry: The Search for the Beginning of Time.* New York: Simon & Schuster, 1985.

<u>PERIODICAL ARTICLES</u>

Science News articles (cited by volume and page number, date). Xeroxed articles are filed with notes.

"The Quantum Universe: A Zero-Point Fluctuation?" Dietrick E. Thomsen. v. 128, 8/3/85. Xeroxed.

1/30/99, p. 76. Discovery that neutrinos can change from one flavor to another.

"Revived collider seeks physics firsts." P.W. 155.399, 6/19/99. Xeroxed.

"Four ions mingle in quantum chorus." P.W. 157.255, 4/15/00. Xeroxed. Quantum entanglement, in which certain shared properties of particles continue to be shared when changed in one of the particles, even in distans, has been artificially induced by "correlating" the spins of four supercooled ions with laser beams, a process that promises applicability to larger numbers of particles.

"Cooled device unveils a quantum limit." J. Travis. 157.279, 5/6/00. Xeroxed. Confirmation of the existence of phonons, quanta described as "collective mechanical vibrations of atoms", which mediate heat flow; also related matters.

"Balloon sounds out early universe." R. Cowen. 157.276, 5/6/00. Xeroxed. Deductions about the early universe made possible by new degrees of precision in measurement of cosmic microwave background.

"Intergalactic magnetism runs deep and wide." P. Weiss. 157.294, 5/6/00. Xeroxed.

"Gravity gets measured to greater certainty." P. Weiss. 157.311, 5/13/00. Xeroxed. New precision in measurement of the gravitational constant, "which relates mass and distance to the strength of gravity in Newton's law."

"Most wanted particle appears, perhaps." P. Weiss. 158.196, 9/23/00. Xeroxed. Possible detection of the Higgs boson, the only still undetected particle of the "roughly two dozen" predicted by the standard model.

"Through the looking glass: reflections on a mirror universe." Ron Cowen. 158. 173–5, 9/9/00. Xeroxed. Hypothesis of mirror universe may be superior to that of dark matter as solution to various problems in physics. History, background information, theories that mirror universe may interact with ours, possible means of verifying theory suggested.

"Why is antimatter absent? Hunt heats up." 158.86, 8/5/00.

"Attractive atoms pick up repulsive habits." 158.102, 8/12/00. Weird properties being found in Bose-Einstein condensates, which have been created and studied in the lab since 1995.

"Bigger, Bigger… Biggest? Galaxy map reveals the limits of cosmic structure." 158.04, 8/12/00. Xeroxed. Superclusters seem to be the largest structures in the universe; this reinforces a widely held view of cosmic evolution, according to which slight variations in the primordial soup were amplified by the action of gravity over time, giving rise to the present cosmic structures.

"Breaking the law: Can quantum mechanics + thermodynamics = perpetual motion." 158.234ff, 10/7/00

"Force from empty space drives a machine." 159.86, 2/10/01. The Casimir force, a manifestation of interactions between virtual particles, has been used to operate a nanomachine. General info on the force; its implications (including potential applications, but also sticking as a limiting factor) for nanotechnology.

"Muon orbits may defy main physics theory." 159.102, 2/17/01.

"Frigid 'dynamite' assembles into superatom". 159.183, 3/24/01. New knowledge of Bose-Einstein condensates since 1995. "Physicists describe a Bose-Einstein condensate as a kind of superatom. Because atoms behave as waves as well as particles in a dilute, ultracold gas, they overlap and merge into a single entity with only one quantum state. Until now, Bose-Einstein condensates have contained atoms only in their lowest energy state, or ground state."

[reply to letter]. R. Cowen. 159.339, 2/2/01. Microwave Anisotropy Probe (MAP), to be launched 6/01, to revolutionize studies of cosmic microwave background.

"Starry data support revved-up cosmos". R. Cowen. 159.196, 3/31/01. "A Dark Force in the Universe". Ron Cowen. 159.218, 4/7/01 (xeroxed). Expansion of universe is accelerating, contrary to theory; "dark energy"posited as explanation.

"Sounds of the universe confirm Big Bang." R. Cowen. 159.261, 4/28/01. New, finer observations of CMB also support inflation theory, and provide information on the makeup of the early universe. These conclusions agree very well with other data.

"Physics bedrock cracks, sun shines in". P. Weiss. 159.388, 6/23/01. New discoveries about neutrinos (v.s.v., supra) show, inter alia, that they can make up no more than half the dark matter.

"An illuminating journey: Reading cosmic history from the Big Bang's radiation." Ron Cowen. 159.394ff, 6/23/01. Traces of the evolving structures of the universe detected in the cosmic microwave background; these are much fainter than the variations in the CMB that date from the Big Bang.

"New probe reveals unfamiliar inner proton." P. Weiss. 159.277, 5/5/01. Use of electron-scattering to investigate structure of intact protons suggests it may not be as thought.

"Light's Debut: Good Morning, Starshine!" R. Cowen. 160.84, 8/11/01. Reports an apparent observation of quasar light from the "re-ionization" period (from 500 MY to 1 BY after the Big Bang), distinguished by absorption spectra predicted for this event.The four most distant quasars known were examined; the effect was found only in the most distant.

"Quantum queerness gets quick, compact." P.W. 160.73, 8/4/01. Advances in technology for creating Bose-Einstein condensates.

"Window opens into strange nuclei." P. Weiss. 160.116, 8/25/01. First mass creation of lambda particles, which incorporate strange quarks. The particles prove unstable; this result reinforces the belief that qaurks combine only in 2s and 3s, falsifying some theories that have quarks combining in larger groups.

"Atomic crowds tied by quantum thread." P. Weiss. 160.196, 9/29/01. First succesful quantum entanglement of large numbers of atoms.

"Mishap halts work at Japanese neutrino lab." B. harder. 160.327, 11/24/01. Super-Kamiokande neutrino detector crippled by an accident.

"When branes collide: stringing together a new theory for the origin of the universe." Ron Cowen. 160.184–86, 9/22/01. Very interesting new work. Alternative to Big Bang theory based on string theory and multidimensionality; recap of history of theory. Eliminates need for inflation, reduces all particles to single class of object, the string; postulation of a stringlike class of objects [with one more dimension than strings], called membranes, or "branes". "String theory is simply the only hope we have for a quantum theory of gravity." (George Guth.) Theory still highly controversial; possibility of testing it.

[Nobel prize in physics] 160.231, 10/13/01. Prize goes to makers of the first Bose-Einstein condensate. On the importance of the achievement.

"A cosmic crisis? Dark doings in the universe." 160.234–6, 10/13/01. Ron Cowen. New ideas on dark matter.

"Constant changes: If a constant of nature can vary, then so might the laws of physics." Peter Weiss. 160.2223, 10/6/01. An isolated astonomical observation suggests the possibility of a slight variation in an important physical constant. The excitment seems to me to be premature.

Other periodicals:

Sky & Telescope, 10/00:

"Finding Missing Baryons". P. 24. On dark matter and the types of matter that make it up. Much may be invisible intergalactic ionized hydrogen.

pp. 41–64: Several feature articles on gravitational waves, related relativity theory, and the history of the idea in 20th century physics, and on major advances being made in instruments designed to detect gravitational waves directly for the first time. Valuable general discussion of relativity theory.

New York Times, 4/30/01. On early Big bang, and cosmology. Downloaded.

National Geographic, 11/07.141ff. "Raising Heaven", Timothy Ferris. Brief, but gives lucid summary of a few important points on recent develoments in cosmological physics, and astrophyisical exploration with space-based instruments. Ferris is the author of *Coming of Age in the Milky Way*, *The Whole Shebang*, etc.

OTHER WORKS CITED

TO READ

See clippings. See also bibliographies in works read and cited, esp. Pagels, *Code*.

have

Blum, Harold F. *Time's Arrow and Evolution.* 3rd ed. Princeton, Princeton U.P., 1968.
Have, in Chron.

Boys, C.V. *Soap Bubbles and the Forces Which Mold Them.* Garden City, N.Y.: Doubleday, 1959.

Gribbin, John. *In Search of Schrödinger's Cat: Quantum Physics and Reality.* New York: Bantam Books, 1984.
Read long ago. Probably to re-read, but Pagels may have covered the same ground better in *Code*. Note later writing(s) of Gribben below.

Newton, Isaac. *Newton's Philosophy of Nature: Selections from His Writings.* Ed. and notes by H.S. Thayer, introduction by J.H. Randall. New York: Hafner, 1953.
Cited as Newton, Hafner.

Schrödinger, Erwin. *What is Life? and Other Scientific Essays.* Garden City, NY: Doubleday, 1956. Have, in Chron.

Whitrow, G.J. *The Natural Philosophy of Time.* New York: Harper & Row, 1961. Have, in Chron.

out there (new book info was not noted here before 9/1/01)

Chaisson, Eric J. *Cosmic Evolution*. Harvard U.P., 2001. SN160.143,9/1/01 (blurb). Unifying principles underlying development of all things.

Cole, K.C. *The Hole in the Universe: How Scientists Peered Over the Edge of Emptiness and Found Everything*. Harcourt, 2000. Cosmology and astrophysics, with the emphasis on nothing. SN160.306,11/17/01

Croswell, Ken. *The Universe at Midnight*. Free Press, 2001. Very up-to-date acct of recent developments in cosmology, including evidence for acceleration of expansion. (SN books.)

Ferris, Timothy. *Coming of Age in the Milky Way*, *The Whole Shebang*, etc.

Feynman, Richard. *Lectures on Physics.* Said to be a classic resource; see ad on back of SN, v. 159 (5/26/01).

Goldsmith, Donald. *The Runaway Universe*. Perseus, 2001. SN160.BC,9/1/01 (blurb). The expansion of the Universe appears to be accelerating. Said to be a revolutionary finding.

Gribbin, John. *The Birth of Time*. Yale U.P., 1999. SN160.BC,9/1/01 (blurb). On determining age of Universe. Hubble data reveal "that the Universe is older by at least one billion years than the oldest stars".
SIBL circ. 523.1 G

Hawking, Stephen. *A Brief History of Time*. (~1988)

———. *The Universe in a Nutshell*. Bantam, 2001. Sequel to the above, covering developments over the last 13 years, including string theory and branes.

———. "The Edge of Spacetime". *New Scientist*, 8/16/84. (In *Physica* clippings).

Livio, Mario. *The Accelerating Universe*. Wiley, 2000. SN160.BC,9/1/01 (blurb). On implications for science of the discovery that the expansion of the Universe is (may be) accelerating. (Cf. Goldsmith.)
SIBL circ. 523.1 L

Parsons, Paul. *The Big Bang: The Birth of Our Universe*. DK Publishing, Inc., 2001. Overview. (SN books.)

Rees, Martin. *Our Cosmic Habitat*. Princeton U.P., 2001. 205 pp., $22.50 HB.
On multiverse theory (of which Rees is a proponent), and other questions of scientific cosmology.

Science News. *Dimensions of Time*. Diversion Books, 2016. (ebook)
First section is on physics & cosmogony, much by Tom Siegfried, extremely interesting.

Smolin, Lee. *Quantum Gravity*. Basic Books, 2001. SN 9/1/01p130 (blurb). On current theories attempting to unify relativity and quantum physics: string theory, loop quantum gravity theory, black hole dynamics.

OTHER