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Chapter 1 : physics - Dictionary Definition : blog.quintoapp.com

Volume V explores motion inside matter: discover how chemistry, biology, material properties, the solid state, stars, nuclear reactors and particle physics follow from the quantum of action. The adventure leads from molecular motors in muscles to the colour of gems, from the working of nerves to the processes that make volcanoes erupt.

For the purposes of this discussion, it is convenient to divide the various types of ionizing radiation into two major categories: In the first group are the radiations that are normally viewed as α . At the most fundamental level, matter is composed of elementary particles, known as quarks and leptons the class of elementary particles that includes electrons. Quarks combine into protons and neutrons and, along with electrons, form atoms of the elements of the periodic table, such as hydrogen, oxygen, and iron. Atoms may combine further into molecules such as the water molecule, H_2O . Large groups of atoms or molecules in turn form the bulk matter of everyday life. Depending on temperature and other conditions, matter may appear in any of several states. At ordinary temperatures, for instance, gold is a solid, water is a liquid, and nitrogen is a gas, as defined by certain characteristics: These states can be further categorized into subgroups. Solids, for example, may be divided into those with crystalline or amorphous structures or into metallic, ionic, covalent, or molecular solids, on the basis of the kinds of bonds that hold together the constituent atoms. Less-clearly defined states of matter include plasmas, which are ionized gases at very high temperatures; foams, which combine aspects of liquids and solids; and clusters, which are assemblies of small numbers of atoms or molecules that display both atomic-level and bulklike properties. The mass of a body is a measure of this resistance to change; it is enormously harder to set in motion a massive ocean liner than it is to push a bicycle. Another universal property is gravitational mass, whereby every physical entity in the universe acts so as to attract every other one, as first stated by Newton and later refined into a new conceptual form by Albert Einstein. This transformation occurs, for instance, during nuclear fission, in which the nucleus of a heavy element such as uranium splits into two fragments of smaller total mass, with the mass difference released as energy. In the quantum view, elementary particles behave both like tiny balls and like waves that spread out in space—a seeming paradox that has yet to be fully resolved. Its detailed nature has yet to be determined. On the other hand, through the contemporary search for a unified field theory, which would place three of the four types of interactions between elementary particles—the strong force, the weak force, and the electromagnetic force, excluding only gravity within a single conceptual framework, physicists may be on the verge of explaining the origin of mass. Although a fully satisfactory grand unified theory (GUT) has yet to be derived, one component, the electroweak theory of Sheldon Glashow, Abdus Salam, and Steven Weinberg who shared the Nobel Prize for Physics for this work predicted that an elementary subatomic particle known as the Higgs boson imparts mass to all known elementary particles. After years of experiments using the most powerful particle accelerators available, scientists finally announced in the likely discovery of the Higgs boson. For detailed treatments of the properties, states, and behaviour of bulk matter, see solid, liquid, and gas as well as specific forms and types such as crystal and metal. Learn More in these related Britannica articles:

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Chapter 2 : Physics: Definition and Branches | Owlcation

The present introduction to quantum physics arose from a threefold aim I have pursued since to present the basics of motion in a way that is simple, up to date and captivating. In order to be simple, the text focuses on concepts, while keeping mathematics to the necessary minimum.

I believe the answer to this question is a resounding "Yes! But first, what is Quantum Mechanics? Things on a very small scale behave like nothing that you have any direct experience about. They do not behave like waves, they do not behave like particles, they do not behave like clouds, or billiard balls, or weights on springs, or like anything that you have ever seen. Even the experts do not understand it the way they would like to. We know how large objects will act, but things on a small scale just do not act that way. So we have to learn about them in a sort of abstract or imaginative fashion and not by connection with our direct experience. First, no satisfactory, generally accepted conceptual interpretation of Quantum Mechanics has ever been found, despite eighty years of intense debate and discussion of the subject. Any useful insight on this mystery, from whatever source, would be quite welcome. Second, the science of Quantum Mechanics is itself important in our technological society. Advances in semiconductors, computers, communications, lasers, medical diagnostic equipment, and many other things depend heavily on its application. It is definitely something we need to understand. Third, the question of the conceptual implications of Quantum Mechanics has never been given serious treatment in a biblical context. Christians have usually focused on issues like Evolution versus Creation, or on cosmology the age and origin of the Universe, etc. Indeed, these seem to be questions that could naturally and reasonably involve the Bible. If the Bible can somehow be legitimately applied in these fields, then we have much new territory to explore. Surely we will learn something important. Fortunately, the Bible offers an important principle about perceiving the invisible: The things which are seen were not made of things which are visible. It is based on evidence from actual, observable facts. The methodology used by Christians is thus very similar to that used by physicists. Christians are also given an important clue about the Universe we live in: Additionally, we look for simplicity and elegance. God even invites mankind to study his works: Stand and consider the wonders of God. Do you know how God establishes them? When you roll a marble across your desk, you are seeing an example of spatial motion. It has a starting point, an end point, and a trajectory that connects the two. But if you could impart temporal motion to an object, instead of spatial motion, what sort of picture would you see then? Temporal motion, by definition, is not motion in or through space. Hence, from the spatial standpoint, and from our common way of thinking, it is necessarily some sort of "motionless motion. Motion from one point in coordinate time to another point in coordinate time would be "trajectory-less" and infinite in extent as seen from the spatial standpoint. Does anything act like that? Physicists are quite familiar with them. They call them "force fields. That is, the force, or "motion" if we want to interpret the effect that way, is spherically distributed. It is motion that is "towards", but not towards any particular direction. It is also infinite in extent at least out to the quantization limit. And, in and of itself, the effect has no path, no trajectory. It fits our strange description of temporal motion. What does that have to do with Quantum Mechanics? Well, space and time are quantized. That means that atoms can approach each other no closer than one unit of space. With the spatial component of the motion fixed at one unit, any further motion must be in coordinate time. And that means temporal motion again. Which again means motion with no trajectory and which is infinite in extent. These are recognizable features of the mathematics of Quantum Mechanics. The mathematics for Quantum Mechanics have "infinite reach. Forces, velocities, and trajectories are generally not very useful in Quantum Mechanics. Instead, potentials and total energy are the quantities that are most useful expressed in the so-called "Hamiltonian". And these are clearly non-path, non-trajectory constructs. So the picture that evolves is this: Newtonian Mechanics describes spatial motion. Quantum Mechanics describes temporal motion. Put the two together and all the mysteries, paradoxes, and conceptual difficulties that bother physicists can be made to disappear. Here is a short list of what I think can be

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explained: Two photons originating in the same event will separate in coordinate space, but not in coordinate time. An action imposed on one photon, will instantaneously produce a complementary action on the other photon, even though that photon might be light years distant spatially from the other. A single photon has a single spatial location and a single temporal location. These effects combine to produce the "matter wave" interference pattern of Quantum Mechanics. The nature of gravitation: Gravitation is clearly a temporal motion. A little thought will also show why it is an accelerated non-directional motion a characteristic that causes us humans to be pressed against the Earth irrespective of our location upon it. Why the gamma correction factor is used in Special Relativity: Solving the gamma equation for c , instead of for gamma, shows that temporal motion has an inverse and Pythagorean relationship with spatial motion. Now if all that can be achieved with the concept of linear temporal motion, we should ask, "What could be achieved with the concept of rotational temporal motion? I hope other investigators, Christian or not, will pursue the implications. Can the practice of biblical Christian principles be helpful in understanding the conceptual implications of Quantum Mechanics? The answer is clearly, Yes! The Bible, of course, says nothing directly about physics or Quantum Mechanics. But it does say plenty about perceiving the invisible, about the Universe being accessible and understandable, about correct and careful reasoning, and about sorting through contradictory and confusing information. Christians become highly practiced in these methods and, as "mature men with minds trained by practice to distinguish between good and bad," they will find these skills useful in physics too. It is just as God has said: The Feynman Lectures on Physics. JB Alexander Jones, ed. Garden City, New York; London: The New King James Version. For a forum discussion about concepts similar to those in this paper visit:

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Chapter 3 : What does physics mean?

However, quantum mechanics, the underlying physical rules that govern the fundamental behavior of matter and light at the atomic scale, state that nothing can quite be completely at rest. For the first time, a team of Caltech researchers and collaborators has found a way to observe—and control—this quantum motion of an object that is large.

Continue reading to explore each of these branches in depth. This branch of physics deals mostly with matter and energy. Often, physics which date before are considered classical physics, whereas physics which date after are considered modern physics. In classical physics, energy and matter are considered separate entities. Acoustics, optics, classical mechanics, and electromagnetics are traditionally branches within classical physics. Moreover, any theory of physics that is considered null and void in modern physics automatically falls under the realm of classical physics. What Are the Three Laws of Physics? They are considered the basis of classical mechanics. When we speak of bodies, we are not speaking of actual human bodies although human bodies can be included in this definition, but of any piece of matter upon which a force may act. A body remains at rest or in uniform motion in a straight line unless acted upon by a force. When a force acts on a body due to another body, then an equal and opposite force acts simultaneously on that body. Modern Physics Modern physics is a branch of physics that is mainly concerned with the theory of relativity and quantum mechanics. Albert Einstein and Max Plank were the pioneers of modern physics as the first scientists to introduce the theory of relativity and quantum mechanics, respectively. In modern physics, energy and matter are not considered as separate entities. Rather, they are considered different forms of each other. The two pillars of modern physics are as follows. What Is the Theory of Relativity? As a result of this discovery, Einstein was able to confirm that space and time are interwoven in a single continuum known as space-time. As such, events that occur at the same time for one observer could occur at different times for another. Discovered by Max Plank in , quantum theory is the theoretical basis of modern physics that explains the nature and behaviour of matter and energy on the atomic and subatomic level. The nature and behaviour of matter and energy at that level is sometimes referred to as quantum physics and quantum mechanics. Plank discovered that energy exists in individual units in the same way that matter does, rather than just as a constant electromagnetic wave. Thus, energy was quantifiable. Nuclear Physics Nuclear physics is a branch of physics that deals with the constituents, structure, behaviour and interactions of atomic nuclei. This branch of physics should not be confused with atomic physics, which studies the atom as a whole, including its electrons. According to the Microsoft Encarta encyclopedia, nuclear physics is defined as: It is used in power generation, nuclear weapons, medicines, magnetic resonance, imaging, industrial and agricultural isotopes, and more. Who Discovered Nuclear Physics? The history of nuclear physics as a distinct field from atomic physics begins with the discovery of radioactivity by Henri Becquerel in . The discovery of the electron one year later indicated that the atom had an internal structure. With this, studies began on the nuclei of atoms, thus nuclear physics was born. Nuclear physicists examine only the nucleus, not the atom as a whole. Atomic Physics Atomic physics is a branch of physics that deals with the composition of the atom apart from the nucleus. It is mainly concerned with the arrangement and behaviour of electrons in the shells around the nucleus. Thus, atomic physics mostly examines electrons, ions, and neutral atoms. One of the earliest steps towards atomic physics was recognizing that all matter is comprised of atoms. The true beginning of atomic physics is marked by the discovery of spectral lines and the attempt to explain them. This resulted in an entirely new understanding of the structure of atoms and how they behave. Geophysics Geophysics is a branch of physics that deals with the study of the Earth. It is mainly concerned with the shape, structure and composition of the Earth, but geophysicists also study gravitational force, magnetic fields, earthquakes, magma, and more. Geophysics was only recognized as a separate discipline in the 19th century, but its origins date back to ancient times. The first magnetic compasses were made from All of these discoveries can be included in the field of geophysics, which is defined as: Biophysics According to the Microsoft Encarta encyclopedia,

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biophysics is defined as: Poll Physics is the study of:

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Chapter 4 : Physics | science | blog.quintoapp.com

Motion applies to objects, bodies, and matter particles, to radiation, radiation fields and radiation particles, and to space, its curvature and space-time. One can also speak of motion of shapes and boundaries.

The Motion of Matter Motion and its forms. The world is in constant motion. It has no "days-off". It never gets tired. The billions of stars that we admire on a clear night and that seem motionless to the naked eye are moving at colossal speeds. Every star is a sun with its own ring of planets. The stars and the satellites circling round them also revolve on their own axis and participate in the turning of the whole galaxy around its axis. Moreover, various parts of the galaxy have different cycles. Our galaxy moves in relation to other galaxies. And there is no end to these whimsical courses of the universal round about. At a certain stage in their evolution some stars explode and flare up like huge cosmic fireworks. Our Sun is a blazing fiery hurricane. Its whole surface is in a state of bubbling, erupting agitation. Colossal fiery waves pass over the turbulent solar surface. Huge fountains of flame—the protuberances—spurt to heights of hundreds of thousands of kilometres. The gigantic streams of internal heat that come to the surface are poured forth into space in the form of radiation. Many thinkers have perceptively noted the astonishing activity of matter, its tremendous internal energy. Apparently they have more in common than is visible to the eye. Motion is the mode of existence of matter. To be means to be in motion. The world is integrating and disintegrating. It never attains ultimate perfection. Like matter, motion is uncreatable and indestructible. It is not introduced from outside but is included in matter, which is not inert but active. Motion is self-motion in the sense that the tendency, the impulse to change of state is inherent in matter itself: The forms and kinds of motion are manifold. They are connected with the levels of the structural organisation of matter. The basic forms are motion of elementary particles, appearance and interaction of atoms and molecules, the chaotic displacement of particles in the form of heat motion, the mechanical motion of macroscopic bodies, the biological motion with all its diverse manifestations, the life of human society and, finally, a quite conceivable metasocial form of motion in the shape of extremely intricate connections between various civilisations on a cosmic scale. Every form of motion has its "vehicle"—substratum. Thus elementary particles are the material vehicles of the diverse processes of intermutations. The elements of the atomic nucleus are the material vehicles of the nuclear form of motion, the elements of the atom, of intra-atomic form of motion, the elements of molecules and molecular compounds, of the chemical form of motion, and so on up to the social form of motion, which is the highest of all known forms. The motion of any thing occurs only in relation to that of another. The motion of a separate body is an absurdity. Essentially motion is nothing but the interaction of things as a result of which they change. By the motion of a body we always mean its change of position in relation to a second body. It is, therefore, contrary to common sense to speak about the motion of only one body. This other object is known as the system of reference. Motion is intrinsically contradictory. It is a unity of change and stability, of disturbance and rest. Thus any change in structural elements, properties or relations takes place along side the conservation of certain other elements and every conservation takes place only through motion. In general, in the endless flux of ceaseless motion there are always moments of stability, expressed above all in conservation of the state of motion, and also in the form of equilibrium of phenomena and relative rest. No matter how much an object changes, it retains its own particular character for as long as it exists. A river does not cease to be a river because it flows. Flow is, in fact, the very thing that makes a river what it is. Possessing absolute rest means ceasing to exist. Everything in a state of relative rest is inevitably involved in some kind of motion and ultimately in the infinite forms of its manifestation in the universe. Rest always has only an apparent and relative character. Bodies may rest only in relation to a given system of reference, conventionally regarded as motionless. For example, we are motionless in relation to a given building and it is motionless in relation to the Earth. But we are continuously moving with the Earth and the Earth, together with its enviroing air ocean, is revolving on its own axis and around the Sun. The unity of matter and motion. Motion was not

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always regarded as an inseparable attribute of matter. In the history of philosophy and natural science there existed two opposite points of view: In order to set it in motion there had to be a "divine first push". In various sciences this doctrine took the form of notions of hidden forces, "minor ghosts" the life force, spirit, etc. This was a search for non-mechanical causes of various phenomena. The idealists maintained and still maintain that spirit is the active, creative principle, while matter is inert. The absolutising of energy was expressed in the conception of energism. The German scientist Wilhelm Ostwald believed that there was nothing in the world but energy. What did any person feel when he was struck with a stick? "the stick or the energy? Only energy," said Ostwald. And wherever people were accustomed to feeling and seeing matter, according to Ostwald, they were feeling and seeing only "pure energy". The discovery of the law of the conservation and transformation of energy and the successes of thermodynamics as applied to numerous natural phenomena encouraged thinkers to turn "pure" energy into an absolute, the ultimate content of everything that exists. But pure energy is an abstraction. Energy is one of the characteristics of the intensity of the interaction of material objects; energy is motion, which is impossible without a material vehicle, just as thought is impossible without a thinking brain or blueness without something that is blue. In the process of scientific research one often has to single out the energetic aspect of processes and disregard their vehicles. This is a justifiable abstraction. While the real structure of elementary particles, for example, is unknown one has to confine oneself to an energetic description of interconversion processes. But this absolutisation leads to energy, as a quantity surviving in all these processes, being sometimes interpreted as indestructible, as a stable substance from which elementary particles, as it were, are "made". Sometimes photons are identified with "pure energy". The discovery of light pressure showed that photons light are infinitely small accumulations of matter possessing not only energy but also mass. The law connecting the mass and energy of material objects is sometimes interpreted in the spirit of energism. Erroneously identifying mass with matter, the energists assume that matter may turn into a concentration of pure energy. It is well known, however, that mass is not matter, but only one of its properties. Matter cannot change into any of its properties: Mass is the measure of such properties of matter as inertia and gravitation, while energy is the measure of its motion. So the mass-energy law reflects and proves the inseparability of the properties of matter and motion. Motion has both a spatial and temporal character.

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Chapter 5 : The Adventure of Physics - Vol. IV: The Quantum of Change - Open Textbook Library

Matter: Definition & the Five States of Matter Any object or particle that is in motion has kinetic energy based on its mass and speed. In the new matter, called a Kitaev quantum spin.

Mechanics Mechanics is generally taken to mean the study of the motion of objects or their lack of motion under the action of given forces. Classical mechanics is sometimes considered a branch of applied mathematics. It consists of kinematics , the description of motion, and dynamics , the study of the action of forces in producing either motion or static equilibrium the latter constituting the science of statics. The 20th-century subjects of quantum mechanics, crucial to treating the structure of matter, subatomic particles , superfluidity , superconductivity , neutron stars , and other major phenomena, and relativistic mechanics , important when speeds approach that of light, are forms of mechanics that will be discussed later in this section. Thus in the first approximation even objects as large as the Earth and the Sun are treated as pointlike. In rigid-body dynamics , the extension of bodies and their mass distributions are considered as well, but they are imagined to be incapable of deformation. The mechanics of deformable solids is elasticity ; hydrostatics and hydrodynamics treat, respectively, fluids at rest and in motion. The three laws of motion set forth by Isaac Newton form the foundation of classical mechanics, together with the recognition that forces are directed quantities vectors and combine accordingly. The first law, also called the law of inertia , states that, unless acted upon by an external force , an object at rest remains at rest, or if in motion, it continues to move in a straight line with constant speed. Uniform motion therefore does not require a cause. Accordingly, mechanics concentrates not on motion as such but on the change in the state of motion of an object that results from the net force acting upon it. Taken together, these mechanical laws in principle permit the determination of the future motions of a set of particles, providing their state of motion is known at some instant, as well as the forces that act between them and upon them from the outside. From this deterministic character of the laws of classical mechanics, profound and probably incorrect philosophical conclusions have been drawn in the past and even applied to human history. Lying at the most basic level of physics, the laws of mechanics are characterized by certain symmetry properties, as exemplified in the aforementioned symmetry between action and reaction forces. Other symmetries, such as the invariance i. The symmetry properties of the theory can be shown to have as mathematical consequences basic principles known as conservation laws , which assert the constancy in time of the values of certain physical quantities under prescribed conditions. The conserved quantities are the most important ones in physics; included among them are mass and energy in relativity theory, mass and energy are equivalent and are conserved together , momentum , angular momentum , and electric charge. The study of gravitation This field of inquiry has in the past been placed within classical mechanics for historical reasons, because both fields were brought to a high state of perfection by Newton and also because of its universal character. No further principles are required to understand the principal aspects of rocketry and space flight although, of course, a formidable technology is needed to carry them out. By measuring the transmission of laser signals between the spacecraft essentially a giant Michelson interferometer in space , scientists hope to detect and accurately measure gravity waves. The modern theory of gravitation was formulated by Albert Einstein and is called the general theory of relativity. Completed in , the theory was valued for many years mainly for its mathematical beauty and for correctly predicting a small number of phenomena, such as the gravitational bending of light around a massive object. Only in recent years, however, has it become a vital subject for both theoretical and experimental research. Curved space-timeThe four dimensional space-time continuum itself is distorted in the vicinity of any mass, with the amount of distortion depending on the mass and the distance from the mass. The study of heat , thermodynamics, and statistical mechanics Heat is a form of internal energy associated with the random motion of the molecular constituents of matter or with radiation. Temperature is an average of a part of the internal energy present in a body it does not include the energy of molecular binding or of molecular rotation. An isolated body eventually reaches

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uniform temperature, a state known as thermal equilibrium, as do two or more bodies placed in contact. The formal study of states of matter at or near thermal equilibrium is called thermodynamics; it is capable of analyzing a large variety of thermal systems without considering their detailed microstructures.

First law The first law of thermodynamics is the energy conservation principle of mechanics. **Second law** The second law of thermodynamics asserts that heat will not flow from a place of lower temperature to one where it is higher without the intervention of an external device. The concept of entropy involves the measurement of the state of disorder of the particles making up a system. For example, if tossing a coin many times results in a random-appearing sequence of heads and tails, the result has a higher entropy than if heads and tails tend to appear in clusters. Another formulation of the second law is that the entropy of an isolated system never decreases with time. **Third law** The third law of thermodynamics states that the entropy at the absolute zero of temperature is zero, corresponding to the most ordered possible state.

Statistical mechanics The science of statistical mechanics derives bulk properties of systems from the mechanical properties of their molecular constituents, assuming molecular chaos and applying the laws of probability. Regarding each possible configuration of the particles as equally likely, the chaotic state the state of maximum entropy is so enormously more likely than ordered states that an isolated system will evolve to it, as stated in the second law of thermodynamics. Such reasoning, placed in mathematically precise form, is typical of statistical mechanics, which is capable of deriving the laws of thermodynamics but goes beyond them in describing fluctuations. An example of a fluctuation phenomenon is the random motion of small particles suspended in a fluid, known as Brownian motion. Left Random motion of a Brownian particle; right random discrepancy between the molecular pressures on different surfaces of the particle that cause motion.

Quantum statistical mechanics plays a major role in many other modern fields of science, as, for example, in plasma physics the study of fully ionized gases, in solid-state physics, and in the study of stellar structure. Particles with electric charge interact by an electric force, while charged particles in motion produce and respond to magnetic forces as well. Many subatomic particles, including the electrically charged electron and proton and the electrically neutral neutron, behave like elementary magnets. On the other hand, in spite of systematic searches undertaken, no magnetic monopoles, which would be the magnetic analogues of electric charges, have ever been found. The field concept plays a central role in the classical formulation of electromagnetism, as well as in many other areas of classical and contemporary physics. The field describing the electric force between a pair of charged particles works in the following manner: Classical electromagnetism is summarized by the laws of action of electric and magnetic fields upon electric charges and upon magnets and by four remarkable equations formulated in the latter part of the 19th century by the Scottish physicist James Clerk Maxwell. The latter equations describe the manner in which electric charges and currents produce electric and magnetic fields, as well as the manner in which changing magnetic fields produce electric fields, and vice versa. The light to which the human eye is sensitive is but one small segment of an electromagnetic spectrum that extends from long-wavelength radio waves to short-wavelength gamma rays and includes X-rays, microwaves, and infrared or heat radiation. Radio waves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays are all types of electromagnetic radiation. Radio waves have the longest wavelength, and gamma rays have the shortest wavelength.

Optics Because light consists of electromagnetic waves, the propagation of light can be regarded as merely a branch of electromagnetism. However, it is usually dealt with as a separate subject called optics: More recently, there has developed a new and vital branch, quantum optics, which is concerned with the theory and application of the laser, a device that produces an intense coherent beam of unidirectional radiation useful for many applications. Spectrum of white light by a diffraction grating. With a prism, the red end of the spectrum is more compressed than the violet end. The formation of images by lenses, microscopes, telescopes, and other optical devices is described by ray optics, which assumes that the passage of light can be represented by straight lines, that is, rays. The subtler effects attributable to the wave property of visible light, however, require the explanations of physical optics. One basic wave effect is interference, whereby two waves present in a region of space combine at certain points to yield an enhanced resultant effect. Another

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wave effect is diffraction , which causes light to spread into regions of the geometric shadow and causes the image produced by any optical device to be fuzzy to a degree dependent on the wavelength of the light. Optical instruments such as the interferometer and the diffraction grating can be used for measuring the wavelength of light precisely about micrometres and for measuring distances to a small fraction of that length.

Atomic and chemical physics One of the great achievements of the 20th century was the establishment of the validity of the atomic hypothesis , first proposed in ancient times, that matter is made up of relatively few kinds of small, identical parts—namely, atoms. However, unlike the indivisible atom of Democritus and other ancients, the atom, as it is conceived today, can be separated into constituent electrons and nucleus. Atoms combine to form molecules , whose structure is studied by chemistry and physical chemistry ; they also form other types of compounds , such as crystals , studied in the field of condensed-matter physics. Such disciplines study the most important attributes of matter not excluding biologic matter that are encountered in normal experience—namely, those that depend almost entirely on the outer parts of the electronic structure of atoms. Only the mass of the atomic nucleus and its charge, which is equal to the total charge of the electrons in the neutral atom, affect the chemical and physical properties of matter.

Millikan oil-drop experiment Between and the American physicist Robert Millikan conducted a series of oil-drop experiments. By comparing applied electric force with changes in the motion of the oil drops, he was able to determine the electric charge on each drop. He found that all of the drops had charges that were simple multiples of a single number, the fundamental charge of the electron. Although there are some analogies between the solar system and the atom due to the fact that the strengths of gravitational and electrostatic forces both fall off as the inverse square of the distance, the classical forms of electromagnetism and mechanics fail when applied to tiny, rapidly moving atomic constituents. Atomic structure is comprehensible only on the basis of quantum mechanics, and its finer details require as well the use of quantum electrodynamics QED. Atomic properties are inferred mostly by the use of indirect experiments. Of greatest importance has been spectroscopy , which is concerned with the measurement and interpretation of the electromagnetic radiations either emitted or absorbed by materials. These radiations have a distinctive character, which quantum mechanics relates quantitatively to the structures that produce and absorb them. It is truly remarkable that these structures are in principle, and often in practice, amenable to precise calculation in terms of a few basic physical constants:

Condensed-matter physics This field, which treats the thermal, elastic, electrical, magnetic, and optical properties of solid and liquid substances, grew at an explosive rate in the second half of the 20th century and scored numerous important scientific and technical achievements, including the transistor. Among solid materials , the greatest theoretical advances have been in the study of crystalline materials whose simple repetitive geometric arrays of atoms are multiple-particle systems that allow treatment by quantum mechanics. Because the atoms in a solid are coordinated with each other over large distances, the theory must go beyond that appropriate for atoms and molecules. Thus conductors , such as metals , contain some so-called free electrons, or valence electrons , which are responsible for the electrical and most of the thermal conductivity of the material and which belong collectively to the whole solid rather than to individual atoms. Semiconductors and insulators , either crystalline or amorphous , are other materials studied in this field of physics. Brattain, and William B. Other aspects of condensed matter involve the properties of the ordinary liquid state, of liquid crystals, and, at temperatures near absolute zero , of the so-called quantum liquids. The latter exhibit a property known as superfluidity completely frictionless flow , which is an example of macroscopic quantum phenomena. Such phenomena are also exemplified by superconductivity completely resistance-less flow of electricity , a low-temperature property of certain metallic and ceramic materials. Besides their significance to technology, macroscopic liquid and solid quantum states are important in astrophysical theories of stellar structure in, for example, neutron stars.

Nuclear physics This branch of physics deals with the structure of the atomic nucleus and the radiation from unstable nuclei. About 10, times smaller than the atom, the constituent particles of the nucleus, protons and neutrons, attract one another so strongly by the nuclear forces that nuclear energies are approximately 1., times larger than typical atomic energies. Quantum theory is needed for understanding

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nuclear structure. Particle tracks from the collision of an accelerated nucleus of a niobium atom with another niobium nucleus. The single line on the left is the track of the incoming projectile nucleus, and the other tracks are fragments from the collision. Courtesy of the Department of Physics and Astronomy, Michigan State University Like excited atoms, unstable radioactive nuclei either naturally occurring or artificially produced can emit electromagnetic radiation. The energetic nuclear photons are called gamma rays. Radioactive nuclei also emit other particles: A principal research tool of nuclear physics involves the use of beams of particles e . Recoiling particles and any resultant nuclear fragments are detected, and their directions and energies are analyzed to reveal details of nuclear structure and to learn more about the strong force. A much weaker nuclear force, the so-called weak interaction, is responsible for the emission of beta rays. Nuclear collision experiments use beams of higher-energy particles, including those of unstable particles called mesons produced by primary nuclear collisions in accelerators dubbed meson factories. Exchange of mesons between protons and neutrons is directly responsible for the strong force. For the mechanism underlying mesons, see below Fundamental forces and fields. In radioactivity and in collisions leading to nuclear breakup, the chemical identity of the nuclear target is altered whenever there is a change in the nuclear charge.

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Chapter 6 : What is antimatter? - Scientific American

Quantum mechanics is the body of scientific laws that describe the wacky behavior of photons, electrons and the other particles that make up the universe. Quantum mechanics is the branch of.

For example, atomic and nuclear physics studies matter on the smallest scale at which chemical elements can be identified. The physics of elementary particles is on an even smaller scale since it is 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 particle accelerators. On this scale, ordinary, commonsense notions of space, time, matter, and energy are no longer valid. Classical mechanics approximates nature as continuous, while quantum theory is concerned with the discrete 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. The theory of relativity is concerned with the description of phenomena that take place in a frame of reference that is in motion with respect to an observer; the special theory of relativity is concerned with relative uniform motion in a straight line and the general theory of relativity with accelerated motion and its connection with gravitation. Both quantum theory and the theory of relativity find applications in all areas of modern physics. Loosely speaking, the laws of classical physics accurately describe systems whose important length scales are greater than the atomic scale and whose motions are much slower than the speed of light. Outside of this domain, observations do not match predictions provided by classical mechanics. Albert Einstein contributed the framework of special relativity, which replaced notions of absolute time and space with spacetime and allowed an accurate description of systems whose components have speeds approaching the speed of light. Later, quantum field theory unified quantum mechanics and special relativity. General relativity allowed for a dynamical, curved spacetime, with which highly massive systems and the large-scale structure of the universe can be well-described. General relativity has not yet been unified with the other fundamental descriptions; several candidate theories of quantum gravity are being developed. Mathematics and ontology are used in physics. Physics is used in chemistry and cosmology. Prerequisites Mathematics provides a compact and exact language used to describe the order in nature. This was noted and advocated by Pythagoras, [48] Plato, [49] Galileo, [50] and Newton. Physics uses mathematics [51] to organise and formulate experimental results. From those results, precise or estimated solutions are obtained, quantitative results from which new predictions can be made and experimentally confirmed or negated. The results from physics experiments are numerical data, with their units of measure and estimates of the errors in the measurements. Technologies based on mathematics, like computation have made computational physics an active area of research. The distinction between mathematics and physics is clear-cut, but not always obvious, especially in mathematical physics. Ontology is a prerequisite for physics, but not for mathematics. It means physics is ultimately concerned with descriptions of the real world, while mathematics is concerned with abstract patterns, even beyond the real world. Thus physics statements are synthetic, while mathematical statements are analytic. Mathematics contains hypotheses, while physics contains theories. Mathematics statements have to be only logically true, while predictions of physics statements must match observed and experimental data. The distinction is clear-cut, but not always obvious. For example, mathematical physics is the application of mathematics in physics. Its methods are mathematical, but its subject is physical. Every mathematical statement used for solving has a hard-to-find physical meaning. The final mathematical solution has an easier-to-find meaning, because it is what the solver is looking for. Physics is also called "the fundamental science" because the subject of study of all branches of natural science like chemistry, astronomy, geology, and biology are constrained by laws of physics, [53] similar to how chemistry is often called the central science because of its role in linking the physical sciences. Structures are formed because particles exert electrical forces on each other, properties include physical characteristics of given substances, and reactions are bound by laws of physics, like conservation of energy, mass, and charge. Physics is applied

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in industries like engineering and medicine. An applied physics curriculum usually contains a few classes in an applied discipline, like geology or electrical engineering. It usually differs from engineering in that an applied physicist may not be designing something in particular, but rather is using physics or conducting physics research with the aim of developing new technologies or solving a problem. The approach is similar to that of applied mathematics. Applied physicists use physics in scientific research. For instance, people working on accelerator physics might seek to build better particle detectors for research in theoretical physics. Physics is used heavily in engineering. For example, statics, a subfield of mechanics, is used in the building of bridges and other static structures. The understanding and use of acoustics results in sound control and better concert halls; similarly, the use of optics creates better optical devices. An understanding of physics makes for more realistic flight simulators, video games, and movies, and is often critical in forensic investigations. With the standard consensus that the laws of physics are universal and do not change with time, physics can be used to study things that would ordinarily be mired in uncertainty. It also allows for simulations in engineering which drastically speed up the development of a new technology. Research Scientific method Physicists use the scientific method to test the validity of a physical theory. By using a methodical approach to compare the implications of a theory with the conclusions drawn from its related experiments and observations, physicists are better able to test the validity of a theory in a logical, unbiased, and repeatable way. To that end, experiments are performed and observations are made in order to determine the validity or invalidity of the theory.

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Chapter 7 : The Adventure of Physics Vol. IV The Quantum of Change | Download book

Matter has many definitions, but the most common is that it is any substance which has mass and occupies space. All physical objects are composed of matter, in the form of atoms, which are in turn composed of protons, neutrons, and electrons. The idea that matter consisted of building blocks or.

Quantum mechanics is a set of principles describing physical reality at the atomic level of matter molecules and atoms and the subatomic particles electrons , protons , neutrons , and even smaller elementary particles such as quarks. These descriptions include the simultaneous wave-like and particle-like behavior of both matter and radiation energy as described in the wave-particle duality. In the quantum mechanics, due to the Heisenberg uncertainty principle , the complete state of a subatomic particle, such as its location and velocity, cannot be simultaneously determined. Many of these "imperceptible motions" are only perceivable with the help of special tools and careful observation. The larger scales of imperceptible motions are difficult for humans to perceive for two reasons: Universe[edit] Spacetime the fabric of the universe is expanding meaning everything in the universe is stretching like a rubber band. This motion is the most obscure as it is not physical motion as such, but rather a change in the very nature of the universe. Another reference frame is provided by the Cosmic microwave background. Thus, the solar system is moving. Earth[edit] The Earth is rotating or spinning around its axis. This is evidenced by day and night , at the equator the earth has an eastward velocity of 0. The fastest-moving plates are the oceanic plates, with the Cocos Plate advancing at a rate of 75 millimetres 3. At the other extreme, the slowest-moving plate is the Eurasian Plate , progressing at a typical rate of about 21 millimetres 0. Internal body[edit] The human heart is constantly contracting to move blood throughout the body. Through larger veins and arteries in the body, blood has been found to travel at approximately 0. Though considerable variation exists, and peak flows in the venae cavae have been found between 0. The most familiar would be the occurrence of peristalsis which is where digested food is forced throughout the digestive tract. Though different foods travel through the body at different rates, an average speed through the human small intestine is 3. The lymph fluid has been found to move through a lymph capillary of the skin at approximately 0. Cytoplasmic streaming is a way which cells move molecular substances throughout the cytoplasm , [16] various motor proteins work as molecular motors within a cell and move along the surface of various cellular substrates such as microtubules , and motor proteins are typically powered by the hydrolysis of adenosine triphosphate ATP , and convert chemical energy into mechanical work. Thus the molecules and atoms which make up the human body are vibrating, colliding, and moving. This motion can be detected as temperature; higher temperatures, which represent greater kinetic energy in the particles, feel warm to humans who sense the thermal energy transferring from the object being touched to their nerves. Similarly, when lower temperature objects are touched, the senses perceive the transfer of heat away from the body as feeling cold. This area is called the electron cloud. The speed of light or c is also the speed of all massless particles and associated fields in a vacuum, and it is the upper limit on the speed at which energy, matter, information or causation can travel; the speed of light is the limit of speed for all physical systems. In addition, the speed of light is an invariant quantity: This property makes the speed of light c a natural measurement unit for speed. Types of motion[edit] Simple harmonic motion e. Linear motion e. motion which follows a straight linear path, and whose displacement is exactly the same as its trajectory.

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Chapter 8 : The Motion of Matter

The table of contents of the Motion Mountain Physics Text, the free and entertaining physics book. The quantum description of matter and its motion: 5.

This theory led to a surprising prediction: the equations that described the electron also described, and in fact required, the existence of another type of particle with exactly the same mass as the electron but with positive instead of negative electric charge. This particle, which is called the positron, is the antiparticle of the electron, and it was the first example of antimatter. A cloud chamber picture taken by Carl D. Anderson in 1932 showed a particle entering from below and passing through a lead plate. The direction of the curvature of the path, caused by a magnetic field, indicated that the particle was a positively charged one but with the same mass and other characteristics as an electron. Experiments today routinely produce large numbers of positrons. Each type of particle must have a corresponding antiparticle type. The mass of any antiparticle is identical to that of the particle. All the rest of its properties are also closely related but with the signs of all charges reversed. For example, a proton has a positive electric charge, but an antiproton has a negative electric charge. The existence of antimatter partners for all matter particles is now a well-verified phenomenon, with both partners for hundreds of such pairings observed. New discoveries lead to new language. In coining the term "antimatter," physicists in fact redefined the meaning of the word "matter." Any pair of matching particle and antiparticle can be produced anytime there is sufficient energy available to provide the necessary mass-energy. Similarly, anytime a particle meets its matching antiparticle, the two can annihilate each other—that is, they both disappear, leaving their energy transformed into some other form. There is no intrinsic difference between particles and antiparticles; they appear on essentially the same footing in all particle theories. This means that the laws of physics for antiparticles are almost identical to those for particles; any difference is a tiny effect. But there certainly is a dramatic difference in the numbers of these objects we find in the world around us; all the world is made of matter. Any antimatter we produce in the laboratory soon disappears because it meets up with matching matter particles and annihilates. Modern theories of particle physics and of the evolution of the universe suggest, or even require, that antimatter and matter were equally common in the earliest stages: so why is antimatter so uncommon today? The observed imbalance between matter and antimatter is a puzzle yet to be explained. Without it, the universe today would certainly be a much less interesting place, because there would be essentially no matter left around; annihilations would have converted everything into electromagnetic radiation by now. So clearly this imbalance is a key property of the world we know. Attempts to explain it are an active area of research today. In order to answer this question, we need to better understand that tiny part of the laws of physics that differ for matter and antimatter; without such a difference, there would be no way for an imbalance to occur. This distinction is the subject of study in a number of experiments around the world that focus on differences in the decays of particles called B-mesons and their antiparticle partners. These experiments will be done both at electron-positron collider facilities called B factories and at high-energy hadron colliders, because each type of facility offers different capabilities to contribute to the study of this detail of the laws of physics—a detail that is responsible for such an important property of the universe as the fact that there is anything there at all! Maria Spiropulu is a physics doctoral candidate at Harvard. People have asked "what is matter?" Democritus, the ancient Greek philosopher and mathematician, envisioned structure in the building blocks of everything and he called the basis for this structure an atom; he wrote, "nothing exists except atoms and empty space: As it turns out, though, atoms are not the fundamental constituents of matter. When we zoom closer into matter, by probing at smaller distances, the subatomic world unfolds. The closer we look, the stranger this world, the quantum world, actually behaves. We can not make a direct connection with it: But the quantum mechanics of this world does let us describe how atoms form molecules. It also enables us to depict the "motion" of certain particles inside atoms. Indeed, atoms are made of electrons that whiz around the fixed protons and neutrons in their nuclei, which are made of quarks. Based on the attributes

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of these particles, we assign them identification numbers, or quantum numbers. And by means of symmetries and conservation laws involving the quantum numbers of the particles, we can describe their interactions. Examples of such numbers are charge and intrinsic angular momentum, or spin. If a is any particle and this particle has no attributes other than linear and angular momentum which include energy and spin, then a is its own anti-particle--one of the constituents of antimatter. For example, the photon is its own anti-particle. If a particle has other attributes such as an electric charge Q , then the anti-particle has the opposite attributes or a charge of $-Q$. The proton and neutron have such attributes. In the case of the proton, its positive charge distinguishes it from the negatively charged anti-proton. The neutron--although electrically neutral--has a magnetic moment opposite that of the anti-neutron. Protons and neutrons have another quantum number called the baryon number, which also has the opposite sign in the corresponding anti-particles. The operation of changing particles with anti-particles is called Charge conjugation C . Particles and anti-particles have the exact same mass and equal, but opposite charges and magnetic moments; if they are unstable, they have the same lifetime. This period is called the Charge Conjugation-Parity-Time CPT invariance, which establishes the fact that if you interchange particles for anti-particles C , look in a three dimensional mirror P and reverse time T , you cannot tell the difference between the them. The most stringent tests of CPT to date are measurements of the ratio of the magnetic moments of the electron and positron to two parts in a trillion R. Schwinger, University of Washington, and measurements of charge per mass of the proton and antiproton--found to be 0. Antimatter came about as a solution to the fact that the equation describing a free particle in motion the relativistic relation between energy, momentum and mass has not only positive energy solutions, but negative ones as well! If this were true, nothing would stop a particle from falling down to infinite negative energy states, emitting an infinite amount of energy in the process--something which does not happen. In 1928, Paul Dirac postulated the existence of positively charged electrons. The result was an equation describing both matter and antimatter in terms of quantum fields. This work was a truly historic triumph, because it was experimentally confirmed and it inaugurated a new way of thinking about particles and fields. In 1932, Carl Anderson discovered the positron while measuring cosmic rays in a Wilson chamber experiment. And in 1985 at CERN, scientists synthesized anti-hydrogen atoms for the first time. When a particle and its anti-particle collide, they annihilate into energy, which is carried by "force messenger" particles that can subsequently decay into other particles. For example, when a proton and anti-proton annihilate at high energies, a top-anti-top quark pair can be created! An intriguing puzzle arises when we consider that the laws of physics treat matter and antimatter almost symmetrically. Why is it that the stars, dust and everything else we observe is made of matter? If the cosmos began with equal amounts of matter and antimatter, where is the antimatter? Even so, a rich program of searches for antimatter in cosmic radiation exists. We stated that there is an approximate symmetry between matter and antimatter. The small asymmetry is thought to be at least partly responsible for the fact that matter outlives antimatter in our universe. But antimatter has captured public interest mainly as fuel for the fictional starship Enterprise on Star Trek. In fact, NASA is paying attention to antimatter as a possible fuel for interstellar propulsion. At Penn State University, the Antimatter Space Propulsion group is addressing the challenge of using antimatter annihilation as source of energy for propulsion. See you on Mars? Answer originally posted October 18,

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Chapter 9 : Seeing Quantum Motion | Caltech

Physics: Physics, science that deals with the structure of matter and the interactions between the fundamental constituents of the observable universe. In the broadest sense, physics (from the Greek physikos) is concerned with all aspects of nature on both the macroscopic and submicroscopic levels.

Uncertain Universe Electromagnetic Radiation a. The wavelength of the light determines its characteristics. For example, short wavelengths are high energy gamma-rays and x-rays, long wavelengths are radio waves. The whole range of wavelengths is called the electromagnetic spectrum. Planck noticed fatal flaw in our physics by demonstrating that the electron in orbit around the nucleus accelerates. Acceleration means a changing electric field the electron has charge, when means photons should be emitted. But, then the electron would lose energy and fall into the nucleus. To resolve this problem, Planck made a wild assumption that energy, at the sub-atomic level, can only be transferred in small units, called quanta. The word quantum derives from quantity and refers to a small packet of action or process, the smallest unit of either that can be associated with a single event in the microscopic world. Changes of energy, such as the transition of an electron from one orbit to another around the nucleus of an atom, is done in discrete quanta. Quanta are not divisible and the term quantum leap refers to the abrupt movement from one discrete energy level to another, with no smooth transition. Quantization limits the energy to be transferred to photons and resolves the UV catastrophe problem. The wave-like nature of light explains most of its properties: This dualism to the nature of light is best demonstrated by the photoelectric effect, where a weak UV light produces a current flow releases electrons but a strong red light does not release electrons no matter how intense the red light. Einstein explained the photoelectric effect by assuming that light exists in a particle-like state, packets of energy quanta called photons. There is no current flow for red light because the packets of energy carried by each individual red photons are too weak to knock the electrons off the atoms no matter how many red photons you beamed onto the cathode. But the individual UV photons were each strong enough to release the electron and cause a current flow. It is one of the strange, but fundamental, concepts in modern physics that light has both a wave and particle state but not at the same time, called wave-particle dualism. Perhaps one of the key questions when Einstein offered his photon description of light is, does an electron have wave-like properties? The response to this question arrived from the Ph. One way of thinking of a matter wave or a photon is to think of a wave packet. Normal waves look with this: A composition of several waves of different wavelength can produce a wave packet that looks like this: So a photon, or a free moving electron, can be thought of as a wave packet, having both wave-like properties and also the single position and size we associate with a particle. Does this mean an electron exists at all places in its trajectory? So energy is also connected to the wave property of matter. While de Broglie waves were difficult to accept after centuries of thinking of particles are solid things with definite size and positions, electron waves were confirmed in the laboratory by running electron beams through slits and demonstrating that interference patterns formed. How does the de Broglie idea fit into the macroscopic world? The length of the wave diminishes in proportion to the momentum of the object. So the greater the mass of the object involved, the shorter the waves. The wavelength of a person, for example, is only one millionth of a centimeter, much too short to be measured. The uncertainty principle, developed by W. Heisenberg, is a statement of the effects of wave-particle duality on the properties of subatomic objects. Consider the concept of momentum in the wave-like microscopic world. The momentum of wave is given by its wavelength. A wave packet like a photon or electron is a composite of many waves. Therefore, it must be made of many momentums. But how can an object have many momentums? Of course, once a measurement of the particle is made, a single momentum is observed. But, like fuzzy position, momentum before the observation is intrinsically uncertain. This is what is known as the uncertainty principle, that certain quantities, such as position, energy and time, are unknown, except by probabilities. In its purest form, the uncertainty principle states that accurate knowledge of complementarity pairs is impossible. For

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example, you can measure the location of an electron, but not its momentum energy at the same time. So, you can measure the position of an electron to some accuracy, but then its momentum will be inside a very large range of values. Likewise, you can measure the momentum precisely, but then its position is unknown. For example, the uncertainty in position of a thrown baseball is millimeters. The depth of the uncertainty principle is realized when we ask the question; is our knowledge of reality unlimited? The answer is no, because the uncertainty principle states that there is a built-in uncertainty, indeterminacy, unpredictability to Nature. An electron in orbit has no position to speak of, other than it is somewhere in its orbit. To deal with this problem, quantum physics developed the tool of the quantum wave function as a mathematical description of the superpositions associated with a quantum entity at any particular moment. The key point to the wave function is that the position of a particle is only expressed as a likelihood or probability until a measurement is made.

Antimatter The fact that quantum systems, such as electrons and protons, have indeterminate aspects means they exist as possibilities rather than actualities. This gives them the property of being things that might be or might happen, rather than things that are. This is in sharp contrast to Newtonian physics where things are or are not, there is no uncertainty except those imposed by poor data or limitations of the data gathering equipment. The superposition of possible positions for an electron can be demonstrated by the observed phenomenon called quantum tunneling. Notice that the only explanation for quantum tunneling is if the position of the electron is truly spread out, not just hidden or unmeasured. It raw uncertainty allows for the wave function to penetrate the barrier. This is genuine indeterminism, not simply an unknown quantity until someone measures it. It is important to note that the superposition of possibilities only occurs before the entity is observed. Once an observation is made a position is measured, a mass is determined, a velocity is detected then the superposition converts to an actual. Or, in quantum language, we say the wave function has collapsed. The collapse of the wave function by observation is a transition from the many to the one, from possibility to actuality. The identity and existence of a quantum entities are bound up with its overall environment this is called contextualism. Like homonyms, words that depend on the context in which they are used, quantum reality shifts its nature according to its surroundings. The power in the Bohr model was its ability to predict the spectra of light emitted by atoms. In particular, its ability to explain the spectral lines of atoms as the absorption and emission of photons by the electrons in quantized orbits. The field of quantum mechanics concerns the description of phenomenon on small scales where classical physics breaks down. The biggest difference between the classical and microscopic realm, is that the quantum world can be not be perceived directly, but rather through the use of instruments. And a key assumption to quantum physics is that quantum mechanical principles must reduce to Newtonian principles at the macroscopic level there is a continuity between quantum and Newtonian mechanics. Consider what a wave looks like around an orbit, as shown below. If the wavelength is longer or shorter, then the ends do not connect. Thus, de Broglie matter waves explain the Bohr atom such that on certain orbits can exist to match the natural wavelength of the electron. If an electron is in some sense a wave, then in order to fit into an orbit around a nucleus, the size of the orbit must correspond to a whole number of wavelengths.