12.6 The Standard Model of Elementary Particles

In science, some advances happen when old ideas generate new thinking. Other innovations occur because new ideas force the old ones to be discarded. In this section, you will learn why it was necessary to replace the Rutherford model of the atom with the Bohr model. You will discover how a deeper examination of the atom revealed that matter is made up of much more than just electrons, protons, and neutrons. You will learn about the concepts of matter and antimatter as described in one model of particle physics. Finally, the information in this section may cause you to wonder when it will be possible to describe our vast universe with a single unified theory of physics, or theory of everything.

Understanding the Atom

In 1909, physicist Ernest Rutherford and his students, Hans Geiger and Ernest Marsden, set out to learn more about the inner structure of atoms. During experiments, they aimed high-speed, positively charged particles at a thin sheet of gold foil. Rutherford and his team expected most of the particles to pass through the foil. Instead, they discovered that a small number of particles were deflected. Rutherford realized that this result meant that all the positive charge in an atom must be concentrated in a very small volume.

Rutherford suggested that the atom is like a miniature solar system, with electrons orbiting the nucleus just as planets orbit the Sun. This is called the planetary model of the atom. The electrons in the planetary model are not stationary. The electrons must move in orbits to avoid "falling" into the nucleus as a result of the electric force. The model also proposed that they could move in any orbit.

The charge carried by a proton is $+e$, and the charge carried by an electron is $-e$. Therefore, the total charge carried by a hydrogen atom, which contains one electron and a nucleus consisting of a single proton, is zero (**Figure 1**). The total charge of neutral atoms of all other elements is also zero. Therefore, the number of protons in the nucleus must be equal to the number of electrons in the neutral atom. This number, called the atomic number of the element, is denoted by Z.

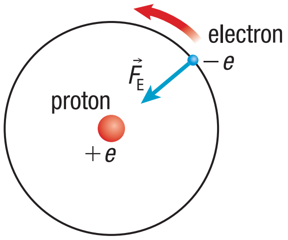

Figure 1 According to Rutherford's planetary model of the atom, electrons orbit the nucleus under the influence of the electric force. In a hydrogen atom, an electron with charge $-e$ orbits a proton with charge $+e$.

Nearly all atomic nuclei contain protons and neutrons. Protons are positively charged particles, so according to Coulomb's law, two or more protons collected in a tiny space the size of an atomic nucleus should repel each other and fly apart. Researchers now know that protons experience an additional force—what physicists call the strong force—that holds them together.

The neutron is a particle with a zero net electric charge. Protons are attracted to neutrons by this additional force. Since the neutrons do not have electric charge, they do not repel the protons or each other through the Coulomb force. Neutrons help make nuclei more stable by contributing to the strong force without a repulsive Coulomb force.

Problems with the Planetary Model

Calculations with the planetary model initially attempted to use Newtonian mechanics to describe the atom. However, some fundamental problems with this model were soon apparent. The biggest problem is the stability of an electron orbit.

Maxwell's classical theory of electromagnetism predicts that an electron emits electromagnetic radiation when it orbits a proton. The radiation carries away energy. If the electron in a hydrogen atom loses energy in this way, Newtonian mechanics predicts that it will spiral inward to the nucleus (**Figure 2**). According to classical physics, an atom in Rutherford's model is, by nature, unstable. If this model were correct, all atoms would collapse, which is not the case. Physicists were unable to modify the planetary model to make the atoms stable.

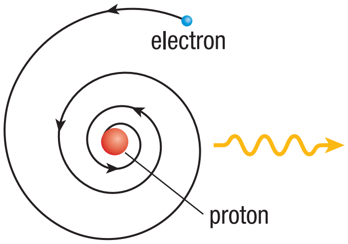

Figure 2 The problem with the planetary model of the atom is that the radiation emitted by an orbiting electron predicted by Maxwell's theory would result in the electron losing energy and spiralling into the nucleus.

The Bohr Model of the Atom

Shortly after Rutherford published his model of the atom, a young Danish physicist named Niels Bohr began to study the problems associated with the planetary model. Bohr proposed a quantum-mechanical approach to the motion of electrons within the atom. He was inspired by the Planck–Einstein introduction of quanta into the theory of electromagnetic radiation. As a result, he proposed a theory about the motion of electrons within atoms. Bohr's theory went against the well-established classical laws of mechanics and electromagnetism.

Bohr proposed that an electron in an atom can have only certain orbits with particular values for the radius of each orbit. This was in contrast to the Rutherford model, in which an electron could orbit at any radius. The Bohr model requires that a whole-number multiple of electron wavelengths equal the circumference of an orbit. If this condition is not met, then the Bohr model does not allow the orbit. The special values of the orbital radius meant that the electron could only have special values of potential energy and kinetic energy. The total energy could take on only certain discrete, quantized values. Each value of energy corresponds to what is now called an energy level.

Investigation **12.6.1**

Laser Simulation (page 657)
Try the simulation of how a laser works in Investigation 12.6.1 to get a better understanding of energy levels as well as how quantum mechanics is applied in technologies.

According to Bohr, when an electron is in an allowed orbit, it does not radiate energy. An electron will emit a single photon when it moves from a higher energy level to a lower energy level. Bohr proposed that an atom could only absorb energy if that energy were equal to the energy difference between the lower state and a higher one.

Bohr's model was partially successful. It provided a physical model of the hydrogen atom. The model matched the internal energy levels to the levels observed in a hydrogen spectrum. At the same time, the model accounted for the stability of the hydrogen atom. Bohr's model, however, was incomplete. When applied to atoms with many electrons, the model broke down.

An explanation for the Bohr model came from de Broglie's matter waves, which were developed 10 years after Bohr's work. As mentioned above, the electrons in a given energy level have special values of kinetic energy. Therefore, those electrons have certain values of momentum. It follows that they have only certain wavelengths (Section 12.3).

Using de Broglie's model, the allowed electron orbits in hydrogen correspond exactly to those orbits in which electron waves form circular standing waves around the nucleus (**Figure 3**).

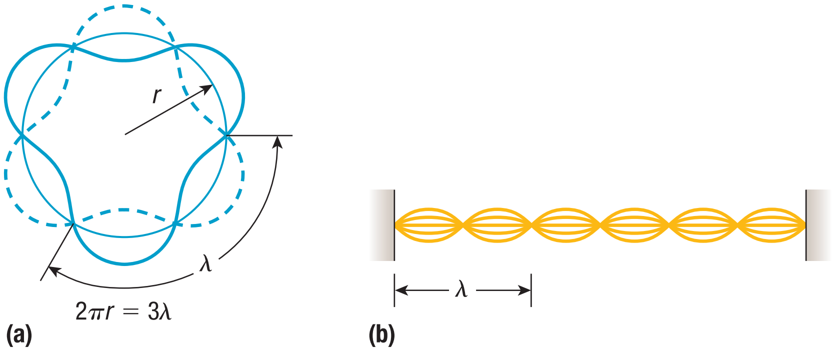

Figure 3 (a) The standing-wave pattern for an electron wave in a stable orbit of hydrogen requires that the orbital circumference equal a whole number of wavelengths. (b) The standing-wave pattern for a string fixed at both ends requires that the distance between supports equal a whole number of wavelengths.

Tutorial 1 examines the connection between electron standing waves and electron orbits in the Bohr model.

Tutorial 1 Standing Wave Orbits in the Bohr Model

Sample Problem 1: Electron Standing Waves around a Hydrogen Nucleus

The number of wavelengths in a standing wave represents the electron's energy level. **Figure 4(a)** shows two electron standing waves around a hydrogen nucleus. **Figure 4(b)** shows a single electron standing wave.

(a) Determine the energy level for each standing wave in Figure 4(a).

(b) Analyze Figure 4(b), and determine the energy level.

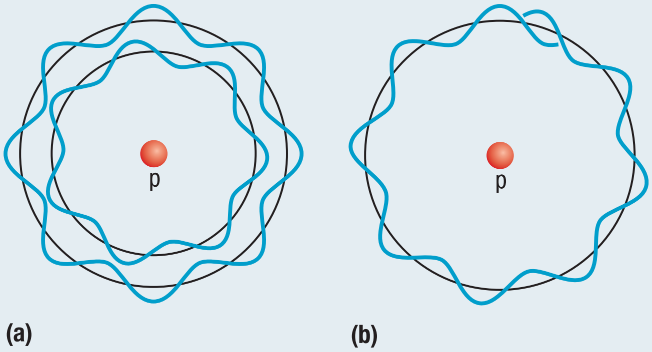

Figure 4

Solution

(a) The number of standing waves in each level represents the energy level. Count the number of wavelengths in each standing wave.

The inner energy level is 7, and the outer energy level is 8.

(b) The Bohr model requires that a whole-number multiple of electron wavelengths equal the orbital circumference.

In Figure 4(b), the standing wave does not join with itself for this particular wavelength. So, this wavelength is not allowed in the Bohr model. Therefore, no energy level exists.

Practice

1. **Figure 5** shows two allowed orbits of an electron in a hydrogen atom. Copy this diagram into your notebook. Draw all allowed orbits for energy levels between the two shown. K/U T/I C

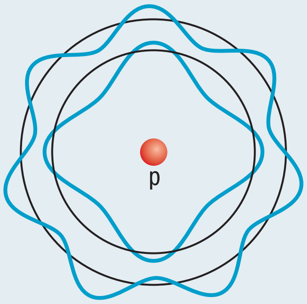

Figure 5

2. Draw the first three energy levels of a Bohr atom. K/U T/I C

Twenty-First-Century Physics and Antimatter

Rutherford's discovery of the atomic nucleus raised the question, "How is the nucleus itself put together?" The nucleus is not complicated: it is composed of just two different building blocks, protons and neutrons. The next level in the progression of understanding the atomic and subatomic world is the inner workings of the atomic nucleus and how protons, neutrons, and other subatomic particles are put together. CAREER LINK

Matter and Antimatter

One of the early developers of quantum physics was P.A.M. Dirac. He formulated a theory of quantum mechanics in the early 1930s. This theory combined the quantum theory of Schrödinger and Heisenberg with the postulates of special relativity. Dirac's theory predicted the existence of a completely new particle. This particle has the same mass and electric charge as the electron but the opposite sign of charge. This particle, called a positron, was later discovered in cosmic ray radiation, high-energy charged particles that strike Earth from all directions in space.

Positrons are written with the symbol e^+ to distinguish them from the electron, e^-. The electron carries a negative charge, and the positron carries a positive charge. The positron is an example of antimatter. **Antimatter** is any particle of matter that has the same mass and opposite charge as a corresponding particle of ordinary matter. Anti-protons and anti-neutrons are two more examples of antimatter.

antimatter a form of matter in which each particle has the same mass and an opposite charge as its counterpart in ordinary matter

Although the neutron and anti-neutron are both neutral, they are different particles. The reason, as you will read below, is that neutrons and anti-neutrons are actually made up of smaller particles called quarks that do have electric charges. The neutron is made up of a certain combination of quarks, and the anti-neutron is made up of the corresponding combination of anti-quarks.

Particles such as electrons, positrons, and protons undergo reactions, much like the reactions involving nuclei. When describing these reactions, we denote each of these particles by a symbol. Protons are denoted as p and neutrons as n; the corresponding anti-particles are denoted with the same letter but with an overbar. **Table 1** on the next page lists the mass and electric charge of the electron, proton, and neutron along with the values for their corresponding anti-particles.

Table 1 Some Properties of Electrons, Protons, Neutrons, and Their Anti-particles

Particle	Symbol	Mass (kg)	Mass (MeV/c^2)	Charge
electron	e^-	9.109×10^{-31}	0.511	-1
positron	e^+	9.109×10^{-31}	0.511	$+1$
proton	p	1.673×10^{-27}	938	$+1$
anti-proton	$\overline{p}$	1.673×10^{-27}	938	-1
neutron	n	1.675×10^{-27}	940	0
anti-neutron	$\overline{n}$	1.675×10^{-27}	940	0

Anti-particles give researchers a chance to see special relativity at work at the microscopic level. For example, when an electron encounters its anti-particle, the positron, the two undergo a reaction that destroys both particles. This reaction is written as

$$e^- + e^+ \rightarrow \gamma + \gamma$$

where the symbol γ (Greek letter gamma) represents one high-energy photon called a gamma ray. This process states that an electron plus a positron react to form two photons. The event needs to satisfy the law of conservation of energy. The total energy before the reaction of the original electron and positron must equal the final energy of the two photons. The total initial energy includes the kinetic energies of the electron and positron plus their rest energies. According to special relativity, the rest energy of an electron with rest mass m_e is $m_e c^2$. The positron also has rest mass m_e, so it has the same rest energy. When you know the initial kinetic energies of the particles, you can measure the energies of the two photons emitted in this event to determine the rest energies of the electron and positron and check the predictions of special relativity.

The Standard Model

Studies of nuclear and particle physics began in the early 1900s, when Rutherford and other physicists conducted atomic experiments. Various particles were aimed at atoms and nuclei, revealing that nuclei are composed of protons and neutrons. For a brief period, scientists thought that electrons, protons, and neutrons were the fundamental particles from which all matter is composed. That simple model did not last long. Many other particles were discovered in cosmic ray studies, in collision experiments, and in nuclear decay processes. Protons and neutrons are themselves composed of particles called **quarks**. According to current understanding, quarks are fundamental point particles whose charge can be either $\frac{2}{3}e$ or $-\frac{1}{3}e$. Particles composed of quarks—such as protons, neutrons, and their anti-particles—form a family of particles called **hadrons**. Not all particles are members of the hadron family, however. **Leptons**, another family of particles that includes electrons and positrons, are believed to be elementary, indivisible particles. The behaviour of hadrons and leptons is described by the standard model of elementary particles. The **standard model** is the current theory of fundamental particles and the forces that are present in their interactions.

quark an elementary particle that makes up protons, neutrons, and other hadrons

hadrons a class of particles that contains the neutron, the proton, and the pion; composed of combinations of quarks and anti-quarks

leptons a class of particles that includes the electron, the muon, the tauon, and the three types of neutrinos; not composed of smaller particles

standard model the modern theory of fundamental particles and their interactions

Quarks Bind Together to Form Hadrons

There are six different kinds—or flavours, as they are also referred to in particle physics—of quarks, called up (denoted by the symbol u), down (d), charm (c), strange (s), top (t), and bottom (b). These names do not refer to any physical properties of the quarks. Rather, they are whimsical names made up by physicists. Each of these quarks has a corresponding anti-quark, denoted by $\overline{u}$, $\overline{d}$, and so on. **Table 2** lists some properties of quarks.

Table 2 Types of Quarks and Their Properties

Type of quark (flavour)	Symbol	Quark charge (e)	Mass	Anti-quark	Anti-quark charge (e)
up	u	$+\frac{2}{3}$	1.7 –3.1 MeV	$\bar{u}$	$-\frac{2}{3}$
down	d	$-\frac{1}{3}$	4.1 –5.7 MeV	$\bar{d}$	$+\frac{1}{3}$
charm	c	$+\frac{2}{3}$	1.18 –1.34 GeV	$\bar{c}$	$-\frac{2}{3}$
strange	s	$-\frac{1}{3}$	80 –130 MeV	$\bar{s}$	$+\frac{1}{3}$
top	t	$+\frac{2}{3}$	172.9 GeV	$\bar{t}$	$-\frac{2}{3}$
bottom	b	$-\frac{1}{3}$	4.13–4.37 GeV	$\bar{b}$	$+\frac{1}{3}$

Quarks were first discovered in collision experiments involving protons. When a high-energy electron collides with a proton, the way that the electron scatters (that is, its outgoing direction and energy) gives information about how mass and charge are distributed inside the proton. This is similar to Rutherford's experiment, which showed how positively charged particles scattered from an atom, indicating that it has a massive nucleus at its centre.

Hadrons composed of three quarks are called baryons (**Figure 6**). Protons and neutrons are both baryons. Collision experiments with protons show that there are three point-like particles inside each proton. **Table 3** lists the quark composition of the proton: two up quarks and one down quark (uud). The total charge on the proton is the sum of the charges of the constituent quarks. Table 3 lists a few other baryons as well. Dozens of other baryons have been observed and their component quarks identified.

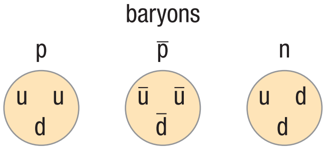

Figure 6 Baryons and anti-baryons are composed of three quarks. The three particles represented here are the proton (p), the anti-proton ($\bar{p}$), and the neutron (n).

Table 3 Properties of Some Baryons

Particle	Symbol	Constituent quarks	Lifetime (s)	Mass (MeV/c^2)
proton	p	uud	stable	938
neutron	n	udd	890	940
sigma plus	Σ^+	uus	0.8×10^{-10}	1189
sigma zero	Σ^0	uds	6.0×10^{-20}	1193
sigma minus	Σ^-	dds	1.5×10^{-10}	1197
xi minus	Ξ^-	dss	1.6×10^{-10}	1321

Note: There are many other baryons composed of other combinations of three quarks and anti-quarks.

A quark and an anti-quark can also combine to form a particle. Hadrons composed of just two quarks are called mesons (**Figure 7**), and a few are listed in **Table 4**.

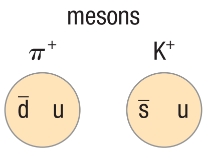

Figure 7 Mesons are composed of one quark and one anti-quark. These mesons are called pions (π^+) and kaons (K$^+$).

Table 4 Properties of Some Mesons

Particle	Symbol	Constituent quarks	Lifetime (s)	Mass (MeV/c^2)
pion (pi plus)	π^+	$u\bar{d}$	2.6×10^{-8}	140
pi zero*	π^0	$d\bar{d}/u\bar{u}$	8.4×10^{-17}	135
kaon (K plus)	K$^+$	$u\bar{s}$	1.2×10^{-8}	494
kaon (K minus)	K$^-$	$s\bar{u}$	1.2×10^{-8}	494
phi	ϕ	$s\bar{s}$	1.6×10^{-22}	1020

Note: There are many other mesons, which are composed of other combinations of quarks and anti-quarks.

* The π^0 is a quantum-mechanical combination of the $d\bar{d}$ and $u\bar{u}$ quark states.

All hadrons are composed of quarks, so the interactions between quarks determine the properties of hadrons and how they relate to one another. The two most important hadrons are the proton and the neutron, so the behaviour of quarks also determines the properties of nuclei. Quarks are charged, so they act on each other through the electric (Coulomb) force. They also interact through the strong force mentioned earlier. Quarks bind together to form protons and neutrons (nucleons), and the strong force is responsible for holding protons and neutrons together to make nuclei.

Leptons

Particle physicists think that leptons, like quarks, are not composed of any smaller particle. **Table 5** shows the six fundamental leptons plus their corresponding anti-particles. These particles group naturally into three pairs: the electron and the electron neutrino, the muon and the muon neutrino, and the tau and the tau neutrino. The muon and the tau are not stable. Electrons are stable, but the behaviour of neutrinos is more complicated. Recent experiments indicate that as neutrinos travel through space, they change from one to another of the three types of neutrinos listed in Table 5, an effect called neutrino oscillation.

Table 5 Leptons and Their Properties

Particle	Symbol	Lepton charge	Mass/c^2	Anti-lepton	Anti-lepton charge
electron	e$^-$	–1	0.511 MeV	e$^+$	1
electron neutrino	ν_e	0	0.05 eV < m < 2 eV	$\bar{\nu}_e$	0
muon	μ^-	–1	106 MeV	μ^+	1
muon neutrino	ν_μ	0	< 0.19 MeV	$\bar{\nu}_\mu$	0
tau	τ^-	–1	1780 MeV	τ^+	1
tau neutrino	ν_τ	0	< 18 MeV	$\bar{\nu}_\tau$	0

Another interesting property of neutrinos is that they have extremely small masses. Particle physicists have only approximations for the masses of neutrinos. However, to give you an idea of their mass, the best experiments to date give an approximate mass for the electron neutrino as less than 100 000 times the mass of an electron.

Leptons play important roles in certain reactions involving hadrons. For example, an isolated neutron (a neutron outside a nucleus) decays to form a proton, an electron, and an electron anti-neutrino:

$$\mathrm{n} \rightarrow \mathrm{p} + \mathrm{e}^- + \bar{\nu}_\mathrm{e}$$

Nuclear decay reactions also produce leptons. In fact, neutrinos were first observed in the 1950s in studies of the particles emitted inside a nuclear fission reactor. The nuclear fusion reactions that occur within the Sun provide a very large source of the neutrinos observed on Earth. Studying these solar neutrinos is one of the best ways to understand the nuclear reactions that take place inside the Sun.

Bosons: Force-Mediating Particles

The fundamental forces of nature are the ways in which individual particles interact with each other. Every interaction in the universe can be described using only three forces. (In general relativity, gravity is not a force.) These forces are the strong nuclear force, the weak nuclear force, and electromagnetism. The strong nuclear force holds the subatomic particles of the nucleus together. The weak nuclear force causes radioactive decay and starts the process of hydrogen fusion and other nuclear processes in stars. The electromagnetic force is responsible for the attraction and repulsion among electrical charges.

Quarks and leptons make up the building blocks of matter, and physicists classify these particles as **fermions**. In addition to fermions, the standard model includes another type of particle called a field particle, or boson. **Bosons** are responsible for transmitting the fundamental forces between the quarks and the leptons.

fermion a fundamental particle that forms matter

boson the particle responsible for transmitting electromagnetic, strong, and weak forces

The standard model describes particle interactions involved in three of the fundamental forces: electromagnetism, the strong nuclear force, and the weak nuclear force. The electromagnetic force is "mediated" (see next paragraph) by the photon, which means that photons transmit the electromagnetic force acting on charged particles. The strong nuclear force is mediated between quarks by particles called **gluons**. Eight different types of gluons exist, and the force exerted between two quarks depends on the type of each quark. The weak nuclear force is mediated by a family of three particles called the W^+, W^-, and Z bosons. Unlike the photon and gluons, which have zero mass, the W^+, W^-, and Z bosons have mass.

gluon a particle that mediates the strong nuclear force

In the language of particle physicists, bosons mediate the interactions between other particles. **Figure 8(a)** gives a classical picture of how the exchange of particles can lead to a force between two objects. Here the "objects" are two children playing catch. The child throwing the ball experiences a recoil force during the throw while the child catching the ball experiences a recoil force when she catches it. The ball plays the role of a photon in the electromagnetic force, and both the ball and the photon mediate a force between two objects (**Figure 8(b)**).

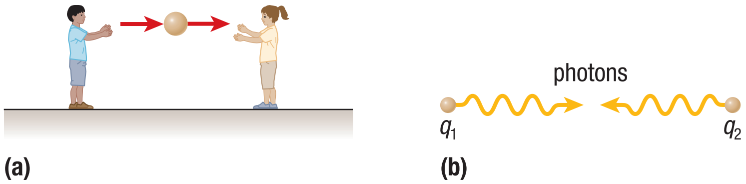

Figure 8 (a) When two children play catch, the ball "carries" a force from one to the other. Physicists describe the ball as being an object that mediates a force between the two children. (b) The force carried by photons is similar to the situation of two children playing catch. In the quantum-mechanical model, photons mediate (or carry) the electric force from one charge to another.

Table 6 and **Table 7** summarize the particles of the standard model. Some scientists think that all the fundamental forces in nature are mediated by elementary particles.

Table 6 Fermions, the Building Blocks of Matter, in the Standard Model

Leptons		Quarks	
Name	**Charge**	**Name**	**Charge**
electron	–1	up	$+\frac{2}{3}$
electron neutrino	0	down	$-\frac{1}{3}$
muon	–1	charm	$+\frac{2}{3}$
muon neutrino	0	strange	$-\frac{1}{3}$
tau	–1	top	$+\frac{2}{3}$
tau neutrino	0	bottom	$-\frac{1}{3}$

Table 7 Bosons, Carriers of Forces, in the Standard Model

Name	Force
photon	electromagnetic force
W^+, W^-, and Z bosons	weak nuclear force
gluons (eight different types)	strong nuclear force

Higgs boson the theoretical particle thought to play a role in giving mass to other particles

According to the standard model, another boson, the Higgs boson, exists. The **Higgs boson** is a hypothetical massive elementary particle. It plays a part in the mechanism that gives other fundamental particles their mass. Rigorous tests of the standard model have resulted in the observation of all quarks, all leptons, and four bosons, but not the Higgs boson. Researchers working with the particle accelerator called the Large Hadron Collider at the European Organization for Nuclear Research (CERN) plan to collide protons with enough energy that a Higgs boson may be created.

A Theory of Everything

At a fundamental level, almost every concept that we understand about our universe comes from quantum mechanics or the theory of relativity, which includes special relativity (Chapter 11), and general relativity, the modern theory of gravity developed by Einstein in 1915.

theory of everything a theory that attempts to combine three fundamental forces (weak, strong, and electromagnetic) with gravity into a single theory

Quantum mechanics describes the world at a subatomic scale, and general relativity describes the world at the macroscopic scale. However, neither theory sufficiently describes both. It is widely believed that these two ideas must somehow be combined into a **theory of everything**, which would combine the ideas of quantum mechanics and the ideas of general relativity. Such a theory would answer some of the most complex questions imaginable, such as "How is it possible for the universe to exist at all?"

Discovering a theory of everything would be a great success for physics. The new theory would answer deep questions about the universe and reveal new secrets. It would also lead to new technologies that would impact society and our environment in major ways. Quantum mechanics itself began as a theory that mostly interested scientists, but it has now revolutionized our everyday life through computers, medical technology, nuclear power, and many more areas. It continues to change our lives through advances in quantum computing, quantum cryptography, and other new tools. We can only begin to imagine a theory of everything's potential impact on humanity.

12.6 Review

Summary

- Rutherford discovered the nucleus and proposed that electrons in an atom orbit the nucleus like a planetary system. Classical physics predicts that this system is not stable.
- The Bohr model of the atom proposes that electrons can only orbit the nucleus at certain allowed energy levels. These electrons transition between levels by emitting or absorbing photons whose energies are equal to the difference between the energy levels.
- Antimatter is a particle of matter that has the same mass and opposite charge as its corresponding particle of ordinary matter. The positron, for example, is the antimatter counterpart of the electron.
- All particles in the universe interact through the three fundamental forces of nature: the strong nuclear force, the weak nuclear force, and electromagnetism.
- The standard model is the current theory of particle physics, which predicts that nature consists of quarks, leptons, and bosons that interact through fundamental forces.
- Quarks combine to form hadrons, which include protons and neutrons. Leptons include electrons and neutrinos.
- Bosons mediate fundamental forces. The Higgs boson helps explain the origin of particle masses, but it has not yet been detected.
- A theory of everything attempts to explain and predict interactions in both the macroscopic and the quantum worlds by combining quantum mechanics and the theory of general relativity into one theory.

Questions

1. Explain why Rutherford's planetary model of the atom is inconsistent with classical physics and what we know about atoms. K/U C
2. In the progression of atomic models, describe the fundamental changes that were made between each new model. K/U T/I C
3. (a) Illustrate the constituent parts of a proton and a neutron.
   (b) Create a particle of your own using any combination of quarks.
   (c) Research your creation to see if it exists and what its properties are. 🌐 T/I C A
4. Describe the role that bosons play in the standard model. K/U
5. Compare and contrast
   (a) fermions with bosons
   (b) mesons with baryons
   (c) leptons with hadrons K/U C
6. Describe the standard model of elementary particles in terms of the characteristics of quarks, leptons, and bosons. Explain the possible limitations of the standard model. K/U
7. What are the implications of the discovery of the Higgs boson? K/U
8. In a few sentences, explain why scientists think that there must be a theory of everything that is yet to be discovered. Describe what scientists are expecting to explain with a theory of everything. K/U T/I C
9. Newton's law of gravitation is one example of a unification of physics principles. In what way does his law of gravity unify the motion of celestial objects with the motion of earthly objects? K/U T/I C
10. The standard model developed through the work of many researchers. Research the history of the standard model, and choose a scientist who you feel made one of the most important contributions to the development of the standard model. Describe the experiments that the scientist conducted or organized, or the theory that the scientist formulated. Describe the discovery that the scientist made, and how the discovery built on earlier discoveries and influenced later discoveries. 🌐 C A

🌐 WEB LINK