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Chapter 1 : Important Dates and Discoveries - The Physics of the Universe

The State of Physics at the End of the 20th Century: In Honor of Peter Carruthers Hardcover - March 1, by Fred Cooper (Editor), Ina Sarcevic (Editor), Chung-I Tan (Editor), Geoffrey West (Editor) & 1 more.

Sir Isaac Newton â€" The late 17th and early 18th centuries saw the achievements of the greatest figure of the Scientific revolution: Cambridge University physicist and mathematician Sir Isaac Newton , considered by many to be the greatest and most influential scientist who ever lived. Newton, a fellow of the Royal Society of England , combined his own discoveries in mechanics and astronomy to earlier ones to create a single system for describing the workings of the universe. Newton formulated three laws of motion and the law of universal gravitation , the latter of which could be used to explain the behavior not only of falling bodies on the earth but also planets and other celestial bodies. To arrive at his results, Newton invented one form of an entirely new branch of mathematics: Newton was able to refute the Cartesian mechanical tradition that all motions should be explained with respect to the immediate force exerted by corpuscles. Using his three laws of motion and law of universal gravitation, Newton removed the idea that objects followed paths determined by natural shapes and instead demonstrated that not only regularly observed paths, but all the future motions of any body could be deduced mathematically based on knowledge of their existing motion, their mass , and the forces acting upon them. However, observed celestial motions did not precisely conform to a Newtonian treatment, and Newton, who was also deeply interested in theology , imagined that God intervened to ensure the continued stability of the solar system. Beginning around , a bitter rift opened between the Continental and British philosophical traditions, which were stoked by heated, ongoing, and viciously personal disputes between the followers of Newton and Leibniz concerning priority over the analytical techniques of calculus , which each had developed independently. Initially, the Cartesian and Leibnizian traditions prevailed on the Continent leading to the dominance of the Leibnizian calculus notation everywhere except Britain. Newton himself remained privately disturbed at the lack of a philosophical understanding of gravitation while insisting in his writings that none was necessary to infer its reality. While Newton explained light as being composed of tiny particles, a rival theory of light which explained its behavior in terms of waves was presented in by Christiaan Huygens. Newton also formulated an empirical law of cooling , studied the speed of sound , investigated power series , demonstrated the generalised binomial theorem and developed a method for approximating the roots of a function. By bringing together all the ideas set forth during the Scientific revolution, Newton effectively established the foundation for modern society in mathematics and science. Other achievements[edit] Other branches of physics also received attention during the period of the Scientific revolution. William Gilbert , court physician to Queen Elizabeth I , published an important work on magnetism in , describing how the earth itself behaves like a giant magnet. Robert Boyle â€"91 studied the behavior of gases enclosed in a chamber and formulated the gas law named for him ; he also contributed to physiology and to the founding of modern chemistry. Another important factor in the scientific revolution was the rise of learned societies and academies in various countries. The earliest of these were in Italy and Germany and were short-lived. The former was a private institution in London and included such scientists as John Wallis , William Brouncker , Thomas Sydenham , John Mayow , and Christopher Wren who contributed not only to architecture but also to astronomy and anatomy ; the latter, in Paris, was a government institution and included as a foreign member the Dutchman Huygens. In the 18th century, important royal academies were established at Berlin and at St. The societies and academies provided the principal opportunities for the publication and discussion of scientific results during and after the scientific revolution. In , James Bernoulli showed that the cycloid is the solution to the tautochrone problem; and the following year, in , Johann Bernoulli showed that a chain freely suspended from two points will form a catenary , the curve with the lowest possible center of gravity available to any chain hung between two fixed points. He then showed, in , that the cycloid is the solution to the brachistochrone problem. Using this pump, Boyle and Hooke noticed the

pressure-volume correlation for a gas: In that time, air was assumed to be a system of motionless particles, and not interpreted as a system of moving molecules. The concept of thermal motion came two centuries later. This tool gave Gay-Lussac the opportunity to derive his law , which led shortly later to the ideal gas law. Later designs implemented a steam release valve to keep the machine from exploding. By watching the valve rhythmically move up and down, Papin conceived of the idea of a piston and cylinder engine. He did not however follow through with his design. Although these early engines were crude and inefficient, they attracted the attention of the leading scientists of the time. Hence, prior to and the invention of the Savery Engine , horses were used to power pulleys, attached to buckets, which lifted water out of flooded salt mines in England. In the years to follow, more variations of steam engines were built, such as the Newcomen Engine , and later the Watt Engine. In time, these early engines would eventually be utilized in place of horses. Thus, each engine began to be associated with a certain amount of "horse power" depending upon how many horses it had replaced. In other words, large quantities of coal or wood had to be burned to yield only a small fraction of work output. Hence the need for a new science of engine dynamics was born. Alessandro Volta â€" During the 18th century, the mechanics founded by Newton was developed by several scientists as more mathematicians learned calculus and elaborated upon its initial formulation. The application of mathematical analysis to problems of motion was known as rational mechanics, or mixed mathematics and was later termed classical mechanics. Daniel Bernoulli â€" In , Brook Taylor derived the fundamental frequency of a stretched vibrating string in terms of its tension and mass per unit length by solving a differential equation. The Swiss mathematician Daniel Bernoulli â€" made important mathematical studies of the behavior of gases, anticipating the kinetic theory of gases developed more than a century later, and has been referred to as the first mathematical physicist. In , Bernoulli solved the differential equation for the vibrations of an elastic bar clamped at one end. Rational mechanics dealt primarily with the development of elaborate mathematical treatments of observed motions, using Newtonian principles as a basis, and emphasized improving the tractability of complex calculations and developing of legitimate means of analytical approximation. A representative contemporary textbook was published by Johann Baptiste Horvath. In , John Michell suggested that some objects might be so massive that not even light could escape from them. In , Leonhard Euler solved the ordinary differential equation for a forced harmonic oscillator and noticed the resonance phenomenon. In , Colin Maclaurin discovered his uniformly rotating self-gravitating spheroids. In , Benjamin Robins published his New Principles in Gunnery, establishing the science of aerodynamics. British work, carried on by mathematicians such as Taylor and Maclaurin, fell behind Continental developments as the century progressed. Meanwhile, work flourished at scientific academies on the Continent, led by such mathematicians as Bernoulli, Euler, Lagrange, Laplace, and Legendre. In , Pierre Louis Maupertuis applied minimum principles to mechanics. In , Euler solved the partial differential equation for the vibration of a rectangular drum. In , Euler examined the partial differential equation for the vibration of a circular drum and found one of the Bessel function solutions. In , John Smeaton published a paper on experiments relating power, work , momentum and kinetic energy , and supporting the conservation of energy. In , Antoine Lavoisier states the law of conservation of mass. Assuming that these concepts were real fluids, their flow could be traced through a mechanical apparatus or chemical reactions. This tradition of experimentation led to the development of new kinds of experimental apparatus, such as the Leyden Jar ; and new kinds of measuring instruments, such as the calorimeter , and improved versions of old ones, such as the thermometer. Franklin also showed that lightning is electricity in The accepted theory of heat in the 18th century viewed it as a kind of fluid, called caloric ; although this theory was later shown to be erroneous, a number of scientists adhering to it nevertheless made important discoveries useful in developing the modern theory, including Joseph Black â€"99 and Henry Cavendish â€" This mechanical theory gained support in from the cannon-boring experiments of Count Rumford Benjamin Thompson , who found a direct relationship between heat and mechanical energy. This impossibility only slowly disappeared as experimental practice became more widespread and more refined in the early years of the 19th century in places such as the newly established Royal Institution in London. At the

end of the century, the members of the French Academy of Sciences had attained clear dominance in the field. The Royal Society and the French Academy of Sciences were major centers for the performance and reporting of experimental work. Experiments in mechanics, optics, magnetism , static electricity , chemistry , and physiology were not clearly distinguished from each other during the 18th century, but significant differences in explanatory schemes and, thus, experiment design were emerging. Chemical experimenters, for instance, defied attempts to enforce a scheme of abstract Newtonian forces onto chemical affiliations, and instead focused on the isolation and classification of chemical substances and reactions. A year later, Thomas Young demonstrated the wave nature of lightâ€”which received strong experimental support from the work of Augustin-Jean Fresnel â€”and the principle of interference. In , Peter Ewart supported the idea of the conservation of energy in his paper On the measure of moving force. In , Michael Faraday built an electricity-powered motor, while Georg Ohm stated his law of electrical resistance in , expressing the relationship between voltage, current, and resistance in an electric circuit. A year later, botanist Robert Brown discovered Brownian motion: In , Gaspard Coriolis introduced the terms of work force times distance and kinetic energy with the meanings they have today. In , Carl Jacobi discovered his uniformly rotating self-gravitating ellipsoids the Jacobi ellipsoid.

Chapter 2 : the state of physics at the end of the 20th century | Download eBook PDF/EPUB

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A Century of Discoveries in Physics Given that is the th anniversary of the APS and the last year of the second millennium, it is worth enumerating the seven great physics achievements of the 20th century, achievements that have transformed the way that humanity views the universe: The concept of the atom had been hypothesized by Greeks two-and-half millennia ago. By the nineteenth century, the existence of atoms had been indirectly established. But the picture of the atom then was very different from that of today. In the nineteenth century, the atom was thought be a spherical blob of more-or-less uniform density. Nowadays, it is known that the atom possesses considerable structure: The name atom, which means "indivisible," has become a misnomer -- the atom is not the most fundamental building block since it is constructed out of smaller units. Furthermore, the nucleus is composed of protons and neutrons, both of which weigh almost times the weight of an electron. As their names imply, the proton is positively charged while the neutron is neutral, having no electric charge. By the way, it was only in two years before the founding of the American Physical Society that the existence of the electron was established; previously, electricity was thought to be the flow of a liquid rather than of microscopic particles. Thirty-five years ago, scientists believed that the basic constituents of matter were protons, neutrons and electrons. Since then, high-energy accelerators have revealed that protons and neutrons are made up of three quarks. Quarks are microscopic, point-like entities with electric charges that are one-third and two-thirds of the charge of the electron. In summary, scientists have been able to divide matter into ever increasingly smaller units. After a century of experiment and discover, an impressive detailed picture of the basic consituents of all matter has been acheived. No one can say when this "reductionism" will end -- perhaps, years from now in the year , new microscopic building blocks will have been discovered. To decide and then retreat. Uncertainty will certainly confuse the wise. One of the greatest scientific achievements of physics in the 20th century is the discovery of quantum mechanics. It governs the dynamics of microscopic objects such as atoms and electrons. In this tiny world, things behave differently from the macroscopic world where classical mechanics rules. One feature of quantum mechanics is uncertainty. The best metaphor for this is a cloud -- an electron in an atom is like a cloud with denser regions of the cloud representing places where the electron is most likely to be and less dense regions representing places where the electron is least likely to be. Another feature of quantum mechanics is discreteness. For example, an electron in an atom can only assume particular types of of motions, which are called states, and particular values for its energy, which are called energy levels. Quantum mechanics has important philosophical implications due to the uncertainty that it implies. Because the future is not determined, free will is possible. The microscopic quantum world is so different from the macroscopic classical world that it is difficult for most people to comprehend. To quote from The Bible According to Einstein: Click here to go to that section of the book. And, as for the rest of the Universe, know that it be vast and be beyond thy reach. Few people realize how much our picture of the universe has changed in years. At the end of the 19th century, the universe was thought to contain only hundreds of thousands of stars arranged in no particularly interesting patterns. The most distance stars were though to be about , light years away meaning that it would take light , years to travel from Earth to such distant stars; 1 light-year is about 10 trillion kilometers or 6 trillion miles. Furthermore, they have discovered that the universe contains many interesting structures. Galaxies are vast collections of stars grouped together in a relatively localized region of the universe. Most galaxies are pancake-shaped. Those with spiral arms are known as spiral galaxies. Others are ellipsoidal shaped, and still others are irregular in appearance. The galaxy in which the Sun and Earth reside is called the Milky Way, a name that arose because the other stars in this spiral galaxy create a band of whitish hue across the heavens, which can be observed with the naked eye on a particularly clear night sky. The two galaxies nearest to the Milky Way are

the Small and Large Magellanic Clouds -- they are irregularly shaped and observable from Earth only from the Southern Hemisphere. The third nearest galaxy at a distance of about 1,, light years is the famous Andromeda Galaxy. It was the first galaxy to be discovered and is spiral shaped. During the last three decades, astronomers have come to realize that 10 to galaxies often group together -- such a structure is called a galaxy cluster. There are also regions of the universe with relatively few if any galaxies -- these are known as giant voids. Thus, the large-scale structure of the universe consists of giant voids and galaxy clusters. Both are roughly ,, light years in size. This is about , times larger than the size that scientists thought it was in After a century of observation and discovery, we now have a reasonable picture of the universe and know our place in this immense world. But a man with an "Einsteinian brain" has a four-dimensional imagination and can picture a four-dimensional space. Special relativity, as developed by Albert Einstein at the beginning of the 20th century, determines the dynamics of things travelling at high speeds. The effects of special relativity are only noticeable for objects moving at a reasonable fraction of the speed of light , kilometers per second or , miles per second. Fast-moving bodies behave in ways that are completely counter-intuitive to us, who have formed our expectations based on daily, human experiences. For a list of some of the amazing, counter-intuitive consequences of special relativity , click here. The destruction of a small amount of mass produces an enormous amount of energy. This is the basis for atomic bombs. It is also the source of energy and light in a star including our star the Sun. One interesting consequence of special relativity is the unification of time and space into a four-dimensional world. Another great 20th century contribution of Albert Einstein is the general theory of relativity. It provides deep insights into the nature of gravity. An object moving in such a curved spacetime no longer moves at a constant speed in a constant direction -- it accelerates, just like a marble, when thrown onto the bed with the bowling ball, moves toward the bowling ball. Since, by definition, forces are things that create accelerations, the curvature of spacetime is seen to be the source of the gravitational force. Two interesting consequences of general relativity are the black hole and the expansion of the universe Click here to read a review of book The Inflationary Universe. In the 18th century, three fundamental forces were known: By the end of the 19th century, there were only two fundamental forces: In what is undoubtedly the greatest achievement in physics of the 19th century, the magnetic and electric forces were unified into one force, which is called electromagnetism. It turns all that all magnetic fields are created by the motion of charge, and charges, of courses, are the source of the electric force. In , scientists thought that there were only two fundamental forces: And since physicists had a complete understanding of these two forces, they thought that they knew all. But during the 20th century, two new fundamental interactions were discovered. They are subatomic, meaning that they act at scales much smaller than an atom and inside the nucleus. The strong nuclear force binds three quarks to form the proton and the neutron. It also holds together the protons and neutrons in a nucleus. The weak subnuclear force is responsible for certain radioactive decay of nuclei. Nowadays, it is often said that there are four fundamental forces, but, in fact, the pioneering work of Steven Weinberg, Sheldon Glashow and Abdus Salam has reduced the number back to three. In , they succeeded in unifying the weak force with electromagnetism. Thus, the fundamental forces are gravity, the electroweak interactions and the strong nuclear force. Thus as man in time moves forward, he shall look further back. In walking forward, he shall walk back. At the end of the 19th century, the age of the universe was thought to be several hundred million years. Today, it is estimated to be about 15 billion years. Scientists now know that the Earth is 4. In , the ideas of Darwin had begun to be accepted by a majority of people, but little was known about the evolutionary tree of life. Today, the relations between the different life forms of the past have been mapped out with impressive detail. In , hardly anything was known about the history of the universe. Nowadays, cosmologists have deduced a general picture of what transpired starting at seconds one trillionth of a second after the Big Bang beginning. For a list of some of the main events, click here. The universe started as an extremely hot concentration of mass and energy. As time advanced, the universe expanded, meaning that the fabric of space stretched. Through this stretching, material was dispersed and the universe cooled. Eventually, gravity took hold of higher concentrations of matter, causing them to collapse into galaxy clusters

at larger scales and into stars at smaller scales. The process of star formation through gravitational collapse continues today, although at a slower rate. The evolution of the universe, earth and life is a great history story, a story that astonishes and enlightens, a story that cannot be told in a few paragraphs, but is told as a wonderful narration of amazing events in The Old Testament of The Bible According to Einstein. Present at the meeting in Atlanta, Georgia were more than 50 Nobel laureates! Meeting Summary Program highlights included symposia on unsolved problems in astrophysics, on the pattern formation in fluids, on the search for the ultimate structure of matter, on industrial research, on computers in physics, on the impact of science on technology, on environmental and medical physics, on lasers and semiconductors, on science policy for the new millennium, on improving physics education, on milestones in polymer physics, on the role of physics in national defense, and on the histories of nuclear physics, quantum mechanics, atomic physics, magnetism, relativity and particle physics. There were featured plenary talks entitled "Physics and the Information Revolution" and "Physics and the American Culture. In addition, researchers from all parts of the United States presented their latest scientific results in more than specialized, technical seminars. On the other end of the spectrum so to speak , there were public lectures on the physics of sports, of star trek and of music. Before an audience of more than spectators, theoretical physicist Stephen Hawking, the author of the best-seller A Brief History of Time , argued that the universe is a self-contained system without boundaries in a talk entitled "The Universe in a Nutshell.

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Chapter 3 : America at the End of the Twentieth Century

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Technology Triumphs, Morality Falters Successes Of The 20th Century The technological progress of the 20th century is a source of great pride for Americans, who place advancements in science and technology â€" especially the space program â€" at the top of the list of American achievements. A nearly unanimous public attributes U. Although agreement on the greatest failure of this era is less pronounced, when asked to judge the century, the public laments the use of force, a decline in morality and a breakdown in politics and governance. Overall, the single most-mentioned success is the space program. When asked to name the U. One-in-ten cite problems with politics and government. One-in-ten name a particular policy area e. Twenty-four years after the fall of Saigon, the shadow of Vietnam still looms large for America: The same number list it as the U. At this point, the Clinton-Lewinsky scandal also casts a historic pall for a striking minority. The public may be frustrated by how the system operates, but they like the design. The public also credits a century of national achievements to the resources that have sustained these accomplishments. A similar majority also gives credit to divine sources: Explanations that deal with specific religious values or the role of religion in American politics receive only lukewarm endorsement. Finally, the public is loathe to ascribe more than passing influence to accident: A Consensus View The overwhelming endorsement given to the building blocks of democracy and capitalism is shared by all Americans, regardless of age, race or gender. However, some groups express more enthusiasm than others. For example, although the Constitution receives resounding support as a key to American success, African Americans are slightly more temperate in their analysis: Of the three top reasons, some of the greatest differences between groups are in their evaluations of the free enterprise system, which draws relatively less support from blacks, women and Americans under age 35, although majorities of each group still label it a major reason. Black women are the least enthusiastic: Americans divide most sharply, however, on the credit they give divine intent. Women are also more supportive about the role of God: Again, African American women stand out: Seniors are especially enthusiastic about the importance of the two-party system and geographic isolation â€" two prominent theories of an earlier era. As the most ethnically and racially diverse age group, young adults express slightly more support for the importance of the cultural diversity of the American people as an explanation of national success. Seculars Stand Out Secular Americans, who do not affiliate with any religion, also differ from others in their evaluation of various reasons for American success in the 20th century. Instead, seculars give disproportionate credit to the cultural diversity of the American people:

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Chapter 4 : Einstein Nineteenth Century Physicist

This is a volume in honor of Professor Peter Carruthers on the occasion of his 61st birthday. It is a unique collection of papers by the world's leading experts, describing the most exciting developments in many areas of theoretical physics.

Timeline of the 20th century Map of the British Empire as of At its height, it was the largest empire in history. Nationalism became a major political issue in the world in the 20th century, acknowledged in international law along with the right of nations to self-determination , official decolonization in the mid-century, and related regional conflicts. The century saw a major shift in the way that many people lived, with changes in politics, ideology, economics, society, culture, science, technology, and medicine. The 20th century may have seen more technological and scientific progress than all the other centuries combined since the dawn of civilization. Terms like ideology , world war , genocide , and nuclear war entered common usage. Scientific discoveries, such as the theory of relativity and quantum physics , profoundly changed the foundational models of physical science, forcing scientists to realize that the universe was more complex than previously believed, and dashing the hopes or fears at the end of the 19th century that the last few details of scientific knowledge were about to be filled in. It was a century that started with horses , simple automobiles, and freighters but ended with high-speed rail , cruise ships , global commercial air travel and the Space Shuttle. These developments were made possible by the exploitation of fossil fuel resources, which offered energy in an easily portable form, but also caused concern about pollution and long-term impact on the environment. Humans explored space for the first time, taking their first footsteps on the Moon. Advancements in medical technology also improved the health of many people: Rapid technological advancements, however, also allowed warfare to reach unprecedented levels of destruction. World War II alone killed over 60 million people, while nuclear weapons gave humankind the means to annihilate itself in a short time. However, these same wars resulted in the destruction of the imperial system. For the first time in human history, empires and their wars of expansion and colonization ceased to be a factor in international affairs, resulting in a far more globalized and cooperative world. The last time major powers clashed openly was in , and since then, violence has seen an unprecedented decline. Summary[edit] Technological advancements during World War I changed the way war was fought, as new inventions such as tanks , chemical weapons , and aircraft modified tactics and strategy. In addition to annexing many of the colonial possessions of the vanquished states, the Triple Entente exacted punitive restitution payments from them, plunging Germany in particular into economic depression. Ukraine, early days of the Nazi invasion. Meanwhile, Japan had rapidly transformed itself into a technologically advanced industrial power and, along with Germany and Italy, formed the Axis powers. After some years of dramatic military success, Germany was defeated in , having been invaded by the Soviet Union and Poland from the East and by the United States, the United Kingdom, Canada , and France from the West. After the victory of the Allies in Europe, the war in Asia ended with the dropping of two atomic bombs on Japan by the US, the first nation to develop and use nuclear weapons. In total, World War II left some 60 million people dead. After the war, Germany was occupied and divided between the Western powers and the Soviet Union. East Germany and the rest of Eastern Europe became Soviet puppet states under communist rule. Western Europe was rebuilt with the aid of the American Marshall Plan , resulting in a major post-war economic boom , and many of the affected nations became close allies of the United States. Allies during the war, they soon became hostile to one another as their competing ideologies of communism and democratic capitalism proliferated in Europe, which became divided by the Iron Curtain and the Berlin Wall. The period was marked by a new arms race as the USSR became the second nation to develop nuclear weapons, which were produced by both sides in sufficient numbers to end most human life on the planet had a large-scale nuclear exchange ever occurred. Mutually assured destruction is credited by many historians as having prevented such an exchange, each side being unable to strike first at the other without ensuring an equally devastating retaliatory strike. Unable to engage

one another directly, the conflict played out in a series of proxy wars around the worldâ€”particularly in China , Korea , Vietnam , and Afghanistan â€”as the USSR sought to export communism while the US attempted to contain it. The technological competition between the two sides led to substantial investment in research and development which produced innovations that reached far beyond the battlefield, such as space exploration and the Internet. Albert Einstein is often regarded as the father of modern physics. In the latter half of the century, most of the European-colonized world in Africa and Asia gained independence in a process of decolonization. Meanwhile, globalization opened the door for several nations to exert a strong influence over many world affairs. Britain also continued to influence world culture , including the " British Invasion " into American music , leading many rock bands from other countries such as Swedish ABBA to sing in English. After the Soviet Union collapsed under internal pressure in , most of the communist governments it had supported around the world were dismantled â€”with the notable exceptions of China , North Korea , Cuba , Vietnam , and Laos â€”followed by awkward transitions into market economies. It enacted resolutions on such topics as the conduct of warfare, environmental protection, international sovereignty , and human rights. Peacekeeping forces consisting of troops provided by various countries, with various United Nations and other aid agencies, helped to relieve famine, disease, and poverty, and to suppress some local armed conflicts. Europe slowly united, economically and, in some ways, politically, to form the European Union , which consisted of 15 European countries by the end of the 20th century. In many countries, especially in Europe, the movement was channeled into politics through Green parties. Increasing awareness of global warming began in the s, commencing decades of social and political debate. The computer is a major technological advancement in this century. The nature of innovation and change[edit] Due to continuing industrialization and expanding trade, many significant changes of the century were, directly or indirectly, economic and technological in nature. Scientific research, engineering professionalization and technological developmentâ€”much of it motivated by the Cold War arms raceâ€”drove changes in everyday life. Martin Luther King, Jr. At the beginning of the century, strong discrimination based on race and sex was significant in general society. Although the Atlantic slave trade had ended in the 19th century, the fight for equality for non-white people in the white-dominated societies of North America , Europe, and South Africa continued. During the century, the social taboo of sexism fell. By the end of the 20th century, women had the same legal rights as men in many parts of the world, and racism had come to be seen as abhorrent. The world at the end of the 20th century[edit] Communications and information technology, transportation technology, and medical advances had radically altered daily lives. Europe appeared to be at a sustainable peace for the first time in recorded history. The people of the Indian subcontinent , a sixth of the world population at the end of the 20th century, had attained an indigenous independence for the first time in centuries. China, an ancient nation comprising a fifth of the world population, was finally open to the world , creating a new state after the near-complete destruction of the old cultural order. With the end of colonialism and the Cold War, nearly a billion people in Africa were left in new nation states after centuries of foreign domination. The world was undergoing its second major period of globalization ; the first, which started in the 18th century, having been terminated by World War I. Since the US was in a dominant position, a major part of the process was Americanization. Terrorism , dictatorship , and the spread of nuclear weapons were pressing global issues. The world was still blighted by small-scale wars and other violent conflicts, fueled by competition over resources and by ethnic conflicts. Despots such as Kim Jong-il of North Korea continued to lead their nations toward the development of nuclear weapons. Disease threatened to destabilize many regions of the world. Malaria and other diseases affected large populations. The virus was becoming an epidemic in southern Africa. World population increased from about 1. The number of people killed during the century by government actions was in the hundreds of millions. This includes deaths caused by wars, genocide, politicide and mass murders. The deaths from acts of war during the two world wars alone have been estimated at between 50 and 80 million[citation needed]. Political scientist Rudolph Rummel estimated ,, deaths caused by democide , which excludes those killed in war battles, civilians unintentionally killed in war and killings of rioting mobs. Most likely a

comparable number of civilians died of war-induced disease and other indirect effects. World War I led to the creation of many new countries , especially in Eastern Europe. At the time, it was said by many to be the " war to end all wars ". Industrial warfare greatly increased in its scale and complexity during the first half of the 20th century. Notable developments included chemical warfare , the introduction of military aviation and the widespread use of submarines. The introduction of nuclear warfare in the midth century marked the definite transition to modern warfare. Civil wars occurred in many nations.

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Chapter 5 : History of physics - Wikipedia

The Physicists' Debates on Unification in Physics at the End of the 20th Century Jordi Cat Hist Stud Phys Biol Sci, Vol. 28 No. 2, ; (pp.) DOI: /

The following essay is reprinted with permission from The Conversation , an online publication covering the latest research. Though not the typical reaction, this discovery threatens to close a chapter of 20th century physics without a hint of how to start writing the next page. Until July last year, when physicists at the Large Hadron Collider LHC announced its discovery , the Higgs boson remained the last missing piece of the Standard Model of particle physics, a theory that describes all the particles that make up the world we live in with stunning accuracy. The Standard Model has passed every experimental test thrown at it with flying colors, and yet has some rather embarrassing holes. According to astronomical measurements, the matter described by the Standard Model that makes up the stars, planets and ultimately us, only accounts for a tiny fraction of the universe. We appear to be a thin layer of froth, floating on top of an invisible ocean of dark matter and dark energy, about which we know almost nothing. The theory predicts that, after the Big Bang, equal quantities of matter and antimatter should have obliterated each other, leaving an empty universe. Both of these are good scientific reasons to doubt that the Standard Model is the end of the story when it comes to the laws of physics. Aside from having a large number of different particles and forces, many of which seem surplus to requirement, it is also very precariously balanced. This spooky fine-tuning worries many physicists, leaving the universe looking as though it has been set up in just the right way for life to exist. A surprising discovery of the 20th century was the realization that empty space is far from empty. The conventional wisdom states that as the Higgs boson passes through the vacuum it interacts with this soup of virtual particles and this interaction drives its mass to an absolutely enormous value â€” potentially up to a hundred million billion times larger than the one measured at the LHC. Theorists have attempted to tame the unruly Higgs mass by proposing extensions of the Standard Model. These sparticles cancel out the effect of the virtual particles in the vacuum, reducing the Higgs mass to a reasonable value and eliminating the need for any unpleasant fine-tuning. Supersymmetry has other features that have made it popular with physicists. Perhaps its best selling point is that one of these sparticles provides a neat explanation for the mysterious dark matter that makes up about a quarter of the universe. Although discovering the Higgs boson may have been put forward as the main reason for building the 27km Large Hadron Collider LHC , what most physicists have really been waiting for is a sign of something new. So far however, the LHC has turned up nothing. The fact that nothing has been found has already ruled out many popular forms of supersymmetry. This has led some theorists to abandon naturalness altogether. This may sound like a technical difference, but the implications for the nature of our universe are profound. The argument is that we live in a fine-tuned universe because it happens to be one among an effectively infinite number of different universes, each with different laws of physics. However, if split-supersymmetry is right, the lack of new physics at the LHC could be indirect evidence for the existence of the very multiverse anticipated by string theory. All of this could be rather bad news for the LHC. If the battle for naturalness is lost, then there is no reason why new particles must appear in the next few years. Some physicists are campaigning for an even larger collider, four times longer and seven times more powerful than the LHC. We are at a critical juncture in particle physics. Perhaps after it restarts the LHC in , it will uncover new particles, naturalness will survive and particle physicists will stay in business. There are reasons to be optimistic. After all, we know that there must be something new that explains dark matter, and there remains a good chance that the LHC will find it. But perhaps, just perhaps, the LHC will find nothing. Though a worrying possibility for experimentalists, such a result could lead to a profound shift in our understanding of the universe, and our place in it. This article was originally published at The Conversation. Read the original article.

Chapter 6 : Successes Of The 20th Century | Pew Research Center

This 20th century in physics began with a rush of new insights and, happily, it is ending in much the same way. For example, our ability to understand, to probe, and to structure surfaces has opened up entirely new areas of catalysis and corrosion resistance, and an entirely new understanding of phenomena such as friction and adhesion.

Contact Author American Gothic, a famed painting from the twentieth century that failed to define itself within the bounds of the largest art movements of the time. Source The twentieth century was one of particular worldwide upheaval, ranging from wars to economic downturns to radical political movements. No one can disagree that the years between and were years of extreme change for artists all over the world. These changes were boldly reflected in the works of avante-garde artists throughout the century. Classical art was being challenged more and more as waves of nationalism and imperialism spread over the world in the early half of the twentieth century. Artists explored extreme and varying themes in the years before and after World War I, and those same themes were revisited in the aftermath of World War II, creating an interesting parallel. This article is divided into two sections: Art Movements Timeline from Art Movements from Timeline created by Shanna Click on image for larger size. Bright vivid colors and somewhat abstract forms characterized Fauvism and Expressionism. Source Fauvism and Expressionism By the turn of the century, artists were rapidly making their departure from more classical works and were seeking to express themselves through different means. Fauvism was the short lived name for the longer-lasting art movement called Expressionism. From about to artists sought to explore emotions in new ways, employing the use of bright, vivid colors and emotional images and subjects. This movement is most well known for capturing the creations of such famous artists as Henri Matisse. The Fauvism movement eventually faded into the calmer, more thoughtful expressionistic art as Fauvism- which came from the word Fauves meaning wild beasts- lost popularity. The addition of geometric figures to expressionism style paintings characterized the Cubism movement. Source Cubism and Primitivism Pioneered by Pablo Picasso, Cubism sought to deepen the consideration that expressionist artists had created by rendering objects and ideas from different angles, seeking to break up and analyze things. Primitivism was similar by extension and was influenced by American colonization and exploration in the early s. This art movement was also rather short and reached its height in the years between and , extending and intermingling with the Futurism movement, although art scholars agree it had reached the end of its lifetime by Futurism Movement One of the lesser known art movements, the Futurism art movement did not produce any works of art that are still widely known by the world today. However, futurism was an important political tool used by artists in the years leading up to World War I. In fact, some scholars believe the unrest associated with the futurism movement may have served as propaganda for World War I. The movement advocated societal revolution and changes in the way art was made and produced. Largely an Italian movement, the Futurism movement featured growing unrest and unhappiness with the economic climate that was producing larger separations between the working and upper classes. Source Dada art By the end of World War I, artists were realizing that the Futurism movement was not the answer to their problems. World War I left artists across the world disillusioned, angry and bitter. Their art was irrational and their ideas were a radical departure from centuries of art forms. The Dada movement espoused strange and radical ideals as they explained in one of their many art manifestos: Dada spits on everything. Dada has no fixed ideas. Dada does not catch flies. Dada is bitterness laughing at everything that has been accomplished, sanctified Dada is never right No more painters, no more writers, no more religions, no more royalists, no more anarchists, no more socialists, no more politics, no more airplanes, no more urinals Like everything in life, Dada is useless, everything happens in a completely idiotic way We are incapable of treating seriously any subject whatsoever, let alone this subject: The art produced during the Dada movement was fascinating in the abstract principles and ideas it sought to portray. Often the artists of the Dada era sought to mock more classical and conventional artists, as Marcel Duchamp did when he submitted an old urinal to an art museum as a piece of work. Dada

was the final explosion of the Futurism movement and gave way to surrealism by Surrealism The anger after World War I gradually faded and was replaced by surrealism, a longer-lasting art movement that explored the human psyche. Pioneered by such artists as Salvador Dali, the surrealism movement followed in the footsteps of many leading psychologists of the day in discovering dreams and exploring what made reality real. Characterized by strange paintings and dream-like qualities, art of the Surrealism movement is fascinating to look at and study today and is reminiscent of some of our strangest dreams and ideas. Surrealism was the return to a calmer art movement that sought to dig deeper into human consciousness, emotion and preference instead of overturning it. This World War II American propaganda shows the use of art in garnering public support for the war effort. Source Propaganda Many art scholars argue that all art has its roots in propaganda or religious ideas. While this sweeping generalization is still debated today, it is obvious that some art is indeed used first and foremost as propaganda. The end of the surrealism movement was marked by the beginning of World War II in Europe and propaganda was the movement of the day, with artists requisitioned to contribute to the war efforts and produce works of art that would motivate their country into supporting the war effort. The idea was to create a "righteous anger". Some of the most famous works of World War II propaganda came from the United States, which entered the war a bit late and had to garner support. Rosie the Riveter, Uncle Sam and other famous faces decorated propaganda art until the end of Timeline of Art Movements from to Timeline made by shanna It concerned a specific set of ideas related to human existence, thought and ideas that were abstract and were generally unique to each individual. Existentialism in art was similar to expressionism and renewed the same sort of cynical ideas about human existence. Art focused on angst, despair, reason, failings and many complex, dark and difficult emotions. Many of the artists were atheists and centered around what one art history textbook calls the "absurdity of human existence" Gardner. Francis Bacon is a noted artist from this time period with his work simply called "Painting" that portrayed a gruesome slaughterhouse scene and symbolic meaning in the life of man. A splatter-paint image done in the style of Jackson Pollock. Source Abstract Expressionism In the late s, Abstract Expressionism sprang up with the idea of expressing a state of mind. Considered the birth of "modern art", artists who painted during the Abstract Expressionism movement wanted viewers to really reach deeply for understanding of an image. They wanted the ideas about the painting to be free of conventional thinking and believed that their images would have a unique, instinctive meaning for each viewer. Some of the famed artists during this time period were Jackson Pollock and Mark Rothko, using splatter-paint and other unusual methods to create abstract works of art. An image done in the style of Andy Warhol, who arguably extended and innovated the Pop Art movement. Source Pop Art A new brand of art called Pop Art emerged in the s as a surprising break-away from previous movements. Artists in the Pop Art movement felt that Abstract Expressionist art was alienating the audience and sought to use their art to communicate more effectively with the viewer. Roy Lichtenstein was the famed pioneer of this movement and used his art in a commercial way, expressing emotion and ideas in a very vividly appealing way that his audience could easily understand and relate to. The Pop Art movement is one of the most recognized movements of the twentieth century and as it morphed and expanded, famed artists like Andy Warhol became well known for their own similar brands of work. Superrealism Superrealism is in reality a very small movement that further interpreted the Pop Art movement in the s. However, superrealism produced works of art that were drastically different from pop art and past works. Artists during this movement brought a return to idealism and perfection in their art. Many artists during this time period created their works of art based off of photographs. A symbol of the s German Feminist movement and an example of art as propaganda. Source Neo-Expressionism and Feminism Superrealism crumbled beneath the powerful emotions that Neo-Expressionism and the Feminist movement sought to invoke with their works of art. Neo-expressionism was a return to the cynical artwork of the s and the Futurism movement but lacked the same angry feel. Instead, artists of this era wanted to produce a more careful, serious examination of emotion and expression. They wanted the viewer to be curious and think deeply instead of being enraged. With legislation like Title IX passed and other victories for the feminists, the

art movement gradually gave way to the s and Performance Art. Performance Art The last decade of the twentieth century featured art that was largely labeled as Performance Art. This art characterized the growing use of personal computers and art was used liberally in new video games, movies, and other technological advances. Art was being used for performances sake and to catch the eye and appeal of the buyer. Art was largely commercial in this last decade before the dawn of the twenty first century. Which was your favorite movement? Which was your favorite art movement?

Chapter 7 : Could the Higgs Nobel Be the End of Particle Physics? - Scientific American

A Century of Discoveries in Physics Given that is the th anniversary of the APS and the last year of the second millennium, it is worth enumerating the seven great physics achievements of the 20th century, achievements that have transformed the way that humanity views the universe.

Allan Bromley Science and its applications - which today we call technology - has from its very beginning been an important part of the American society. As we approach the close of the 20th century, it is entirely appropriate that we celebrate the role of our particular sector of this science and technology: What, then, is physics? The best definition I have encountered is that of my old friend, the late Edward Purcell. In he wrote, "Science is knowing. What man knows about inanimate nature is physics - or rather, the most lasting and universal things that he knows make up physics. Our measurements support that arrogance. Purcell goes on to say, "As he gains more knowledge, what would have appeared complicated or capricious can be seen as essentially simple and in a deep sense, orderly. This reflects the enormous impact that our ability to manipulate the atom and its component electrons has had on such diverse areas of modern civilization as communications, computation, energy, and medicine. In , Albert Einstein published his classic papers on Brownian motion, the photoelectric effect and special relativity, the latter providing us with one of the classic equations of all time: And in Ernest Rutherford discovered the atomic nucleus. The next two decades saw the emergence of quantum mechanics, culminating in , truly an annus mirablis in the physics of the time, with the discovery of positrons in cosmic rays; experimental confirmation of the relativity of time; the first electrostatic accelerator; and the first cyclotron. These activities ushered in a total seachange in the scientific and technical communities. Prior to World War II, basic research was directed toward the understanding of nature, while invention and technology were directed toward the mastery of nature, and the two proceeded on rather parallel and noncommunicating courses. What the wartime projects made very evident was that basic understanding could greatly facilitate the development of technology, and basic technology could facilitate whole new areas of basic research. The prewar activities that had frequently been called natural philosophy and invention, respectively, were irretrievably joined, and nowhere more so than in physics. This 20th century in physics began with a rush of new insights and, happily, it is ending in much the same way. For example, our ability to understand, to probe, and to structure surfaces has opened up entirely new areas of catalysis and corrosion resistance, and an entirely new understanding of phenomena such as friction and adhesion. Entire optical benches and chemical laboratories are now being fabricated on single chips with nanoscale rotary and linear motors powering the necessary motions. The development of new materials has had a major impact on our ability to develop human prosthetic devices to replace both bones and soft tissue. Our understanding of chaotic phenomena and their dependence on nonlinearities and initial conditions marks one of the major achievements of the 20th century in physics. Elementary particle physics and cosmology are slowly coming together to address some of the most fundamental questions in physics, because with ever more powerful accelerators, it becomes possible to recreate, if only for tiny fractions of a second, the conditions that were present within the first moments of the existence of our universe. Atomic and nuclear technology has found wide application in biology and medicine, and the interconnections are growing on almost a daily basis. In communications, single optical fiber bandwidths have been doubling every nine months and the actual in-the-field telephone company products now lag the research frontiers by only four years. The resulting communication and computation explosion has truly reduced our planet to a global village and changed the entire nature of our society. There are far too many other exciting developments at the frontiers of physics to attempt a complete list here. With regard to the future, there are ten open questions in physics that strike me as being of particular interest. How does mass originate? Does nonbaryonic dark matter exist, and if so, in what form? Why are we in a matter universe? What is the ultimate fate of our universe? What is the structure of quantum gravity? Are quarks and leptons truly elementary, or composite? Do the physical constants change with time? What are the

consequences of a nonzero neutrino mass? How does one build a quantum computer? And finally, is room temperature superconductivity possible? Lord Raleigh, then president of the British Association for the Advancement of Science, was asked years ago to give a review of physics in the 19th century as his presidential address. He began by noting that this was impossible, and I know only too well how he felt. But I would like to quote one of his closing comments: We physicists are among the most fortunate of humans; we have been privileged to engage in that greatest adventure of discovery at a time when technology has allowed us to push outward the frontiers of knowledge at unprecedented rates. And in so doing, we have also bettered the lives of humans everywhere. Physics, as the most fundamental of the sciences, will always remain a vital part of this great adventure.

Chapter 8 : Digital History

If the twentieth century was the century of novel physics, the nineteenth century was the century of novel mathematics. Geometry had always been central to science, but it was languishing. Newton's mathematical techniques in his Principia of would have been immediately intelligible to Euclid himself.

Digital History ID The 20th century was a century of revolutions. We usually think of revolutions in terms of banners and barricades, and the 20th century certainly witnessed social and political upheavals, including the Russian and Chinese Revolutions. Revolutions in technology, science, and medicine utterly transformed the way people lived. The scientific revolution is perhaps the most obvious development. During the s, physics and medicine radically changed our view of the world. The discovery of X-rays, radioactivity, sub-atomic particles, relativity, and quantum theory produced a revolution in how scientists viewed matter and energy. Meanwhile, physicians identified the first virus. Laboratory-based science reshaped the practice of medicine. Research in scientific medicine first led to a cure for yellow fever. Then, it eliminated polio and smallpox. Humankind developed air transport, discovered antibiotics, and invented computing. They also split the atom and broke the genetic code. Communication technology was revolutionized with the telephone, the radio, and the Internet. Medicine, too, underwent a radical transformation. Contraceptives separated sex from procreation. The rapid spread of the automobile also modernized transportation technology. The 20th century also witnessed a revolution in economic productivity. But global production of goods and services rose 14 or fold. In , the index was Technological improvements shrunk the average work week by a day and a half. Technology also opened the workplace to increasing numbers of women, especially married and older women. Equally important was the rise of mass communication and mass entertainment. In , each person made an average of 38 telephone calls. By , the figure had grown to 2, phone calls. In , there were no billboards, no trademarks, no advertising slogans. There were no movies, no radio, no television, and few spectator sports. No magazine had a million readers. The s saw the advent of the mass circulation newspaper, the national magazine, the best-selling novel, many modern spectator and team sports, and the first million dollar nationwide advertising campaign. In , some 6, new books were published. By the end of the century, the number had increased more than fold. The 20th century also brought about a revolution in health and living standards. The latter part of the 19th century was an era of tuberculosis, typhoid, sanitariums, child labor, hour work days, tenements, and outhouses. In , more Americans died from tuberculosis than from cancer. Each day millions of horses deposited some 25 pounds of manure and urine on city streets. Life expectancy increased by 30 years. Child mortality fell fold. In , families spent an average of 43 percent of their income on food; now they spend 15 percent. In , the U. Government spending as a share of Gross Domestic Product the measure of wealth created in ranged from 1. At the end of the century, it ranged from 34 percent in the United States to 65 percent in Sweden. Less pleasantly, the 20th century also saw a visible increase in the human capacity for violence. He rounded up 75, people, mostly women and children, and confined them to prison camps where most quickly died. The turn of the century also introduced genocide--the deliberate attempt to exterminate an entire people. This slaughter produced forced labor camps, sex slaves, and the first academic studies of supposed Aryan superiority. After poisoning the water holes, the Herero were driven into the desert and were bayoneted, shot, or starved. Those not killed, Herero--were condemned to slavery on German farms and ranches. The human capacity for mass killing increased exponentially as a result of improved weaponry and the increased power of the state. The 20th century was scarred by gulags, concentration camps, secret police, terrorism, genocide, and war. Technology helped make the 20th century the bloodiest in history. World War I, which introduced the machine gun, the tank, and poison gas, killed 10 million almost all were soldiers. World War II, with its firebombs and nuclear weapons, produced 35 million war deaths. The Cold War added another 17 million deaths to the total. Technology made mass killing efficient; ideologies and ethnicity justified it. Underdeveloped countries driven to modernize quickly were often scenes of repression and sickening mass

killing, whether they were communist or non-communist. A Century of the Young Among the new words that entered the English language during the 20th century were "adolescence," "dating," and "teenager. In , children and teenagers under the age of 16 accounted for 44 percent of the population. Today, the young make up 29 percent. In , less than 2 percent of young people graduated from high school. Just , married women 6 percent were in the paid labor force. Today, the figure is 34 million 64 percent. In , women accounted for 1 percent of lawyers and 6 percent of doctors. At the end of the century, those percentages had risen to 29 percent and 26 percent, respectively. Today, women with comparable work and work histories as men earn 98 cents for every dollar that men do. A Century of Prosperity Despite an economic depression of unprecedented depth, the 20th century was a century of an extraordinary improvements in health and increases in prosperity. The average lifespan increased by 30 years, from 47 years to 77 years. Infant mortality decreased by 93 percent, and heart disease deaths were cut by half. The per person Gross Domestic Product was almost seven times higher in than in This did not include the growth in fringe benefits such as vacation, medical insurance, and retirement benefits. Household assets--everything from the value of our homes to our personal possessions--were seven times greater. Meanwhile, home ownership increased by 43 percent. In , only 1 percent of Americans invested in public companies or mutual funds. By the end of the century, the proportion of shareholders exceeded 50 percent. At the beginning of the century, 40 to 50 percent of all Americans had income levels that classified them as poor. At the end of the century, that was cut to between 10 and 15 percent. Today, thanks to social security and retirement plans, most Americans can expect to enjoy a period of more than a decade when they no longer have to work. During the 20th century, household incomes of African Americans increased fold. Although African Americans still earn less than whites, the gap has decreased. In , blacks earned about 40 percent of what whites earn. Today, they earn about 80 percent of what whites earn. The average length of the work week decreased by 30 percent, falling from 66 hours to 35 hours. With the introduction of more holidays and a shorter work week, the average number of hours worked in a year is half of what it was in the latter part of the 19th century. Meanwhile, the percent of workers on the farm fell by 93 percent. The percentage of households with electricity went from 10 percent to near universal. At the same time, the average American in had to work six times as many hours to pay his electric bill than did an American a century later. The number of telephone calls per capita increased 5, percent. The number of households with cars increased fold. The percentage of people completing college was four times higher. The Expansion of Freedom Perhaps the greatest of all 20th century revolutions was an expansion in human freedom and its extension to new groups of people. European imperialism and colonial empires came to an end. Lesser empires, including the Austro-Hungarian, the Ottoman, and the French, ruled large parts of the globe. In the span of less than 20 years, Europe had partitioned nine-tenths of Africa. France ruled Southeast Asia. The Netherlands established rule in Indonesia and part of New Guinea. These countries are home to 2. These nations enjoy free elections and the rights of speech, religion and assembly. The very meaning of freedom expanded in the 20th century. It referred simply to equality before the law, freedom of worship, free elections, and economic opportunity. Subsequently, early 20th century reformers argued that individual freedom could only be realized through the efforts of an activist, socially-conscious state. Freedom increasingly was seen to depend on government regulation, consumer protection, minimum wage, and old-age pensions.

DOWNLOAD PDF THE STATE OF PHYSICS AT THE END OF THE 20TH CENTURY

Chapter 9 : 20th century - Wikipedia

The 20th century was a century that began on January 1, and ended on December 31, It was the tenth and final century of the 2nd www.nxgvision.com is distinct from the century known as the s which began on January 1, and ended on December 31,

A printable version of this chapter in html or pdf both without appendix. These achievements were made prior to Einstein holding an academic position. He was then still a patent examiner in the Bern patent office. The years that followed brought Einstein a succession of ever more prestigious academic appointments; and, in the mid s, he delivered his masterpiece, the general theory of relativity. In all this, there was a real sense that Einstein was ahead of his peers, leading the way. The special theory of relativity was absorbed into the mainstream of physics fairly quickly. The general theory of relativity was not quite so readily accommodated. This was in part due to its burdensome mathematical demands of the theory, at least relative to the standards of mathematical expertise then found among physicists. But the tide was flowing with Einstein. It was regarded by many as an odd aberration from an otherwise brilliant mind. Even in the early s, it was doubted by Niels Bohr, who had a decade before developed the first quantum model of the atom. By the end of the s, however, another Einstein began to emerge. As the quantum theory enjoyed success after success, Einstein found himself unconvinced. He took on the role of critic, complaining that the new quantum theory, for all its virtues, could not be the final theory. He remained a revered figure. But he became increasingly isolated and marginalized, as he labored on his alternative theories with the help of a few assistants. The old Einstein is a recalcitrant Einstein, unwilling to swim with the new quantum tide that flooded over physics. We should not judge that harshly. No thinker can ever think purely new thoughts. We all sit at the junction of the old and the new. Einstein was one of the first of new physicists of the twentieth century. His discoveries and methods exercised a profound, defining influence on the development of twentieth century physics. However, there is also a strong sense in which he was one of the last of the nineteenth century physicists. Perhaps he was the greatest of them. We shall look at three categories: Nineteenth century electrodynamics now succeeded in probing the properties of things moving close to the speed of light: Mixed in were now familiar kinematical effects: These were encoded in mathematical transformation equations discovered by H. He saw that they could be separated out as a novel theory of space and time, independent of the electrodynamics. The result was the special theory of relativity. Its central equations were the same transformation equations that Lorentz had employed in his development of electrodynamics. Einstein is commonly understood as repudiating nineteenth century electrodynamics in his rejection of its ether. That assessment is altogether too narrow. In extracting the kinematics as an independent theory, Einstein was harvesting one of the greatest fruits of the nineteenth century theory. The ether was merely surplus foliage that needed to be trimmed away during the harvest. The special theory of relativity is the natural completion of nineteenth century electrodynamic theory. Thermal and statistical physics Another significant achievement of nineteenth century physics was the final recognition that thermal processes were to be understood statistically, as the average behavior of systems made of very many components. The simplest case was ordinary matter. It is made of atoms and molecules and heat resides in the energy distributed randomly over them. The same analysis could be given of heat radiation. The many components are the many frequencies that comprise radiation. In all cases, equilibrium thermal systems arise when energy is distributed in its most probable configuration over these components. Probabilities arise merely out of our ignorance of the precise microstate of the system. Reality of atoms When Einstein began work on thermal physics, this statistical approach was still struggling for mainstream acceptance. Boltzmann had shown that a molecular theory would fit with the known thermal properties of matter. However he had failed to convince a significant portion of his community that they ought to adopt his molecular approach. Thermodynamicists, such as Nernst, had found their thermodynamic theories adequate to all observed thermal processes. Why should they trouble themselves with molecules too small to be seen? If that attitude puzzles

you, note that it is merely the analog of the electrodynamicist who is quite happy with the theory of electric and magnetic fields and resists ether theories that account further for these fields in terms of hidden ether machinery--little wheels spinning and meshing at microscopic scales in the ether. The thermodynamicists now had to adopt these methods; and they did. That goal is a nineteenth century one: This was work that Einstein largely abandoned. However, during this early work, he developed methods for inferring from the observable thermal properties of substances to their microscopic structure. The easiest and simplest of these was the observation of the ideal gas law in the thermal appearances. Robust argumentation showed that it must derive from a microstructure of very many, spatially localized components. Systems of this simplest type were the ones Einstein investigated in his annus mirabilis of The tiny particles of Brownian motion form such a system. So do the sugar molecules in dilute solution investigated in his doctoral dissertation. In , in a letter to a friend, Einstein was already calling this one result, among all those of , "very revolutionary. For it contradicted the picture of light as a wave whose energy is spread out over space. There is another way to see it, as I reported in the chapter "Atoms and the Quanta. Heat radiation is a thermal system. Einstein found in that system the same observable signature of discreteness as he found in ideal gases and dilute sugar solutions. So Einstein merely needed to hold true to the methods he had already developed to infer that heat radiation, under the conditions he specified, consists of many independent, spatially localized units of energy. What results is the light quantum. The result follows from applying his statistical methods to heat radiation. Making sense of that result, however, proved harder and, over a hundred years later, the project remains incomplete. Geometry If the twentieth century was the century of novel physics, the nineteenth century was the century of novel mathematics. Geometry had always been central to science, but it was languishing. That changed in the nineteenth century. There was an explosion of new ideas and methods. One of the foremost achievements of the century was a new conception of geometry. It included the idea of non-Euclidean geometries and their accommodation to yet more sophisticated geometries, notably projective geometry. From a mathematical perspective, however, it simply applied nineteenth century mathematical techniques to a new and highly interesting application. It provided the framework he needed for his new theory. Unification A major theme of nineteenth century physics was the theme of unification. The conception was that all the forces of nature were somehow related and that the burden of physics was to reveal those relations. Nineteenth century physics is punctuated by successful unifications. Electromagnetic theory managed to bring electricity and magnetism together in the one theory. Light then proved to be merely a wave propagating in this electromagnetic field. The single notion of energy unified many powers, such as heat, work and everything into which they may transform. He had merged gravitation with the geometry of space and time in his general theory of relativity, completed in In the decades that followed, he resolved to continue the unification. He now sought a single geometrized theory that embraced both gravity and electromagnetism, his unified field theory. Ether The grounding of nineteenth century electromagnetic theory was the ether. Electric and magnetic fields were not distinct processes, but were merely manifestations of different states of an all-pervading medium, the ether. However, in his general theory of relativity and his unified field theories, Einstein retained an analogous background medium. It was not the ether of the nineteenth century. Rather it was a kind of geometrized version of it: Indeed, as a concession to Lorentz, for a short time around , Einstein talked of the metrical field, the carrier of geometrical properties, as an "ether. Causation The nineteenth century conception of causation was determinism: This was a bare notion purged of the many finer aspects routinely assumed by a causal metaphysics. Years later, Einstein himself described this nineteenth century conception: If the state of the objects is completely given at a certain time, then their state at any other time is completely determined by the laws of nature. Part of the original shock of quantum theory was the sense that its stochastic laws deprived the world of its causal character in this nineteenth century sense. On its face, it is an honest expression of the nineteenth century alarm at the loss of causation. Einstein was quite nineteenth century in his expectation that the probabilities of quantum theory would somehow emerge from the supposed incompleteness of quantum description; that was precisely how the probabilities of statistical physics of the nineteenth century arose.

Somewhere in his efforts to extend the theory to electromagnetism, Einstein hoped, the odd quantum phenomena would emerge. These hopes hold the quantum up to a nineteenth century ideal of a field theory in which notions of separability and locality are most fully implemented.