Zero: The Biography of a Dangerous Idea Study Guide

Zero: The Biography of a Dangerous Idea by Charles Seife

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Plot Summary

Zero: The Biography of a Dangerous Idea was written by Charles Seife, an American journalist and journalism professor at NYU. Seife's biography, of course, is of a number and hence it is not a standard biographical work. Instead, the book tries to explain math and physics to the interested lay person. The use of zero is largely a plot device to organize the information Seife wants to communicate. Thus all the stories of mathematical and scientific advances are built around the relationship of the breakthrough to the number zero and its compliment, which is infinity.

The first five chapters of the book tell the early history of zero. Zero was not always a number. At first, it served as a mere place-holder for other numbers invented by the Babylonians. Seife brings out the superiority of the Babylonian numerical system and how it led to zero, which is covered in the first chapter. In Chapter two, Seife explains how the Greeks, despite their great level of science and culture, missed zero which Seife explains through the philosophies of Pythagoras and Aristotle. Seife also reviews the nature of the calendar.

The third, fourth and fifth chapters explain how zero emigrated by Eastern religion and science into the west and the theological and scientific problems it was able to resolve. Chapter three explains the Indian use of a base-ten number system and Fibonacci's use of their numerology. Chapter four discusses the connection between zero and infinity, which continues throughout the book. Chapter five discusses the beginning of calculus in the work of Leibniz and Newton and how meditation on the role of zero led to calculus.

Seife argues that Hindu philosophy was friendlier to the idea of the void and that Aristotle's view, which had been adopted by the Catholic Church, was more hostile. When the authority of the Catholic Church broke down, the Renaissance was able to bring zero into the West and open up scientific progress. It also helped in the theologies of Descartes and Pascal, not to mention their mathematics.

Chapter seven explains how zero and infinity affected chemistry and physics, and introduces the idea of absolute zero and thermodynamics and the formation of quantum mechanics. The chapter also discusses black holes and general relativity. In Chapter eight, Seife uses the ideas of infinity and zero to address the contemporary challenges of string theory and the ultimate fate of the universe. The final chapter, fittingly entitled Chapter infinity, briefly finishes up the book, showing how advances in physics and math have proceeds by finding zero and eliminating it. As Seife points out, zero may always remain elusive and ineliminable. In fact, zero may stand at the end of time, waiting to be the victor in a universe that it can show will one day die a cold death.

Chapter 0, Null and Void, Chapter 1, Nothing Doing

Chapter 0, Null and Void, Chapter 1, Nothing Doing Summary and Analysis

The book opens with a story of a computer glitch that caused the USS Yorktown to come to a halt in 1997. A programming error had forced the computer to attempt to divide by zero which caused its systems to crash. For the author, Charles Seife, this is only a glimmer of the power of zero. No other number can do that much damage. And this is why cultures often protected themselves against zero and why philosophies were often destroyed by it. The book is the story of zero, from its ancient birth, to its threat to modern physics and of the history of social groups and institutions to deal with it. Zero is infinity's twin and invites similar fascination. Zero lies at the heart of many great battles and yet no one has ever mastered it. Instead, it has deeply shaped human history and human ideas.

Zero was born in the Fertile Crescent a few centuries before Christ. It produced images of nothingness and had strange mathematical properties. Initially, math did not require zero. It confined itself to simple tasks like counting sheep that did not require it. In fact, the earliest, prehistoric mathematics seems confined to distinguishing between few and many, less and more, one and many. Early counting systems seem to proceed by fives. But none of the languages used to express these number systems had a word for zero. The Egyptians created the decimal system and used math to make a calendar for the solar year. They also created geometry in part in order to successfully build objects that could block the flooding of the Nile each year. The Greeks adopted many Egyptian mathematical ideas and came up with some of their own. But still, zero arose from neither culture.

The Babylonians had an odd base 60 number system but it was used ably to calculate on the ancient clay tablet form of an abacus. The Babylonians had one symbol for 1, 60 and 3600 but they placed them in different positions. But it was hard to tell if one used two of the 'one' symbol whether one had the number 61, 3601, 3660 or some other greater number. Zero was the solution by created a 'placeholder' mark. It could be placed between the two base symbols to distinguish between numbers. The Mayans made a similar discovery of the usefulness of zero. And the Greeks and Romans refused to convert to the Babylonian system.

The reason they refused to convert is because zero was thought to be dangerous, because it was linked with the void and chaos. Only emptiness was present prior to the universe, most ancients believed. Many feared that at the end of time, the void would return and zero represented that fear. Further, the ancients found zero's mathematical properties impossible to deal with. Zero cannot stand alone; it is the only number that when added to itself remains unchanged. Zero will not make other numbers large. Zero lacks substance and so threatens multiplication and division. Anything times zero is always zero. And division by zero is not the opposite of multiplying by zero. It does not undo the destruction of multiplying by zero. For instance, 1/0 x 0 should be one if zero were like other numbers. However, that is not right. If you divide anything by zero, you could just as well employ any number as the answer. Dividing by zero destroys math.

Chapter 2, Nothing Comes of Nothing

Chapter 2, Nothing Comes of Nothing Summary and Analysis

The ancient Greek universe rested upon the idea that there was no void; the zeroless world created by Pythagoras, Aristotle and Ptolemy survived the collapse of Greece. So the West resisted zero for two thousand years. Doing so stunted the growth of math, blocked scientific development and screwed up the calendar. The Greek philosophy of number was first formed by Pythagoras who, while being a great mathematician, also led a sort of ancient 'New Age' cult that held that all that exists was number. Pythagoras also was well-known in the ancient world for inventing the musical scale. Music became controlled mathematical beauty, the sound of proportions. And the Pythagoreans were able to come up with the first model of the planets from this system of proportionality which was represented by the scale.

Greeks applied proportions rigorously, classing them into ten types, such as the harmonic mean. The Pentagram became the Pythagorean cult's most sacred symbol because it contained the golden ratio, another favored proportion.

Zero did not fit within the Pythagorean view. For the Pythagorean, shapes were tied to numbers and zero could never be a shape. Taking a ratio with zero would also defy nature. The ratio of zero to anything is zero. The Pythagoreans suppressed the idea as they had suppressed the idea of the irrational before, such as the diagonal between two opposing points in a square. Ultimately, however, the Greeks could not ignore the irrational due to their constant presence in architecture.

The Greeks had learned about zero due to their interest in astronomy, which they learned from the Babylonians. Learning from the Babylonians brought the Babylonian number system. The Greeks learned to divide hours into sixty minutes and minutes into sixty seconds which brought in zero as a placeholder, creating the use of the lowercase omicron, o, which looks like zero. But the Greeks tried to avoid using zero. Philosophy led to the rejection of zero.

Both the infinite and the void scared the Greeks. The infinite threatened the possibility of motion whereas the void threatened to shatter the universe. As time progressed, Pythagorean number theory became the center of Western philosophy. But the infinite was always a problem, constantly lying behind the questions, "But what is bigger than that?" and "But what is beyond that?"

Zeno of Elea was a particular threat; born in 490 BC, Zeno developed a paradox. Suppose that you would like to travel one mile. Zeno pointed out that you must first walk half a mile. Then, you must walk a half of a half of a mile, or a quarter of a mile, by the same logic. And by the same logic, you must walk an eighth of a mile. But if you do so, you will never walk a mile, but only approach it ever more slowly. Infinity, embodied in the recognition of this process, seemed to make motion impossible. Zero helped to solve the problem because it allowed one to see that as the ratios become smaller they approach zero or, to put it another way, they came to nothing at all and so could be ignored. Zeno's paradox had a mathematical 'limit'. The Greeks could not use this trick.

Zeno saw no need to solve his paradox. He happily thought that motion was impossible because he followed his Eleatic school's founder, Parmenides, in believing that the nature of the universe was changeless and immobile.

Aristotle, perhaps the greatest of all Western philosophers, created a metaphysical worldview in which zero could not exist. Instead, there are no 'actual infinities' but only 'potential infinities'. The infinite cannot exist in reality. His world was also a world of concentric crystalline spheres in which all the planets and stars orbited the earth. There was an outermost sphere and there was no such thing as what was beyond it.

Aristotle's view also entailed the existence of God, for someone needed to get the first sphere moving. A finite number of spheres required a prime mover. And so when Christianity took over the West, it picked up the Aristotelian view of the universe and the proof of God's existence. And so Aristotle's system continued for thousands of years after his death. In fact, through Alexander the Great, Aristotle's philosophy would dominate the West until Elizabethan times.

The void or zero destroyed Aristotle's argument for the existence of God and his refutation of Zero. However, infinity and zero are not so easily rejected. What happened before creation? Aristotle responded that the universe was eternal and so there was no first event. But this led to infinity because there could be no zero or void prior to creation. So Aristotle chose the eternal universe over one with a vacuum. The Aristotelian view of physics thus prevented the progress of science until scientists disposed with Aristotle's physics.

But in ancient Greek times, one philosopher grasped the infinite, Archimedes, born in 287 BC. He was the one who yelled "Eureka!" when he figured out how to measure the density of objects by how they behaved when submerged in water. He found the infinite when he studied the parabolic shape of mirrors, which focused any degree of the sun's rays into a single point. When Archimedes tried to find the area of a parabola, he drew an increasingly large series of triangles and measured their areas, which led him to face infinity. Archimedes would fill up the parabola with a triangle and then draw triangles in the remaining spaces, as long as he could. Archimedes stumbled on the idea of a limit.

Archimedes also wanted to grasp the number of grains of sand on the sea and so had to invent representations for 'the myriad' and myriads of myriads. But Archimedes was killed by Roman invaders in Syracuse before he could move forward and the Romans dominated the West for seven hundred years, during which time there were no significant mathematical developments.

The confusion surrounding zero extended into the Middle Ages when Christian monks were the only learned people. They needed math for prayer and money and to pray, monks needed a calendar. They had to calculate the correct day for Easter which was quite difficult given that Christians used a solar calendar and Jesus and the Jews used a lunar one. Easter became a drifting holiday. Pope John I asked Dionysius Exiguus to extend the Easter calendar into the future and Dionysius realized he could extend it backward in time to calculate the year of Christ's birth, but Dionysius needed zero to divide B.C. from his term for the years afterward: A.D., anno Domini or 'The Year of Our Lord'.

Two centuries later, the Venerable Bede built on the previous calendars. He wanted to write a history of England and started his history in 60 B.C. Since B.C. dates could be represented as negative numbers up until Jesus' birth, Bede numbered up to -1, but then he saw that -1 immediately skipped to 1. Another number was needed as a placeholder.

Zero never entered the minds of the monks of the Middle Ages as the Romans had squelched the idea. The monks, in the author's opinion, cannot be blamed for their ignorance.

Christianity had a mixed relationship with zero. Medieval Christians liked Aristotle so they abhorred zero, needing to abolish it to prove God's existence. But the Judeo-Christian story of Creation starts with a void, and Christianity is first and foremost a Semitic faith. Not all civilizations had such trouble with zero.

Chapter 3, Nothing Ventured

Chapter 3, Nothing Ventured Summary and Analysis

Indians and Arabs welcomed zero. Indian mathematicians first learned of zero from the Babylonians by way of Greek conquest. India was insulated from the rise of Christian and Aristotle's philosophy. India never feared the void and it had a key place within Hinduism. Hinduism was initially a polytheistic religion. Over time, the gods of Hinduism began to merge and Hinduism became a monotheistic faith. Like other Eastern faiths, Hinduism was steeped in duality. The god Shiva was both creator and destroyer and also represented nothingness. Shiva was the ultimate void or the incarnation of lifelessness. The Hindu universe is full of many other worlds but the cosmos still has a sort of emptiness. The world came from nothingness and achieving nothingness is the goal of man. This meant the elimination of self. Liberation from the cycle of reincarnation requires one to stop paying attention to the illusion of reality. So India accepted zero.

Indian mathematicians transformed zero into a number, which gave it great power. Around the fifth century, Indians moved to a Babylonian style number system but it was base-10. The Indians had also borrowed Greek geometry yet never worried about the diagonal of the square. They did learn to use the abacus to add and subtract large numbers.

For the Indians, numbers started to become distinct from geometry and numerals without geometric significance gave birth to algebra. Mathematicians did not have to worry about making geometric sense of numbers any longer. The Indians could thus make sense of negative numbers; in fact, negative numbers first appeared in India and China. Since 2 minus 3 was a number, so could 2 minus 2 be a number. It finally made sense. However, the Indians thought zero was bizarre.

The East flourished in the seventh century. Islamic civilization was on the rise and Islam would take zero from India. Islam quickly conquered much of the known world and took much of Indian mathematics into their own culture. They built a House of Wisdom at Baghdad and one of their first mathematicians was Mohammed ibn-Musa al-Khowarizmi, who wrote many important books and coining the term algebra. The Arabs turned the Indian name for zero, sunya, to sifr. The West turned sifr into zephirus, from which zero is derived.

To accept zero, Arabs, who were steeped in Aristotle at the time, had to reject Aristotle and they seized upon the early atomists, who required the void. Zero was part of what led to the banning of Aristotle among Muslims. Early medieval Jews took up residence in Muslim Spain and they found that Aristotle's aversion to zero contradicted Jewish theology. Thus Maimonides, the twelfth-century rabbi, sought to reconcile Greek philosophy with the Semitic Bible. So Maimonides rejected Aristotle's view that the universe was eternal and argued that it was created from nothing. Nothingness and zero entered Jewish theology, leading in part to the offshoot Jewish mysticism known as kabbalism.

Christians were battling Muslims from the ninth to the thirteenth centuries and the Crusaders brought Muslim ideas back home. The monks discovered the astrolabe, though the Arabic numerals etched upon them did not catch on. In the 13th century, the Bishop of Paris had Aristotle's philosophy condemned because it was thought to contradict God's omnipotence. God could make a vacuum, which allowed the void back in.

Christianity would come to accept zero through the Italian mathematician Fibonacci. Fibonaaci discovered the Fibonacci sequence, which generates the Pythagorean golden ratio. He learned math from the Muslims and knew zero. His book, Liber Abaci, introduced zero to Europe. And Italian merchants came to love Arabic numbers, though local governments hated them. Eventually governments relented to commercial pressure and Arabic notation spread. Aristotle's philosophy began to crumble. If the universe was infinite, however, how could Earth be at the center? Zero provided an answer.

Chapter 4, The Infinite God of Nothing

Chapter 4, The Infinite God of Nothing Summary and Analysis

Zero and infinity were popular during the Renaissance. The papacy did not initially see the danger. However, the church eventually retreated into Aristotelian doctrine. Yet zero had already taken hold. The proofs of God's existence fell apart. God could now be found in the void.

Zero would become necessary for Renaissance art through the work of Italian architect Filippo Brunelleschi, who created a realistic painting through the use of a vanishing point. Before the vanishing point, paintings were notoriously flat. The vanishing point was made possible by zero because the painting could approach 'nothing.' Filippo's painting of a famous Florentine building called the Baptistery, had a vanishing point. Zero allowed the representation of three-dimensions.

Aristotle had also maintained that the Earth was unique, at the center of the universe and the only world that could have life. But zero allowed Earth to cease being at the center of the universe and so there could be many other worlds. Copernicus was then able to show that the Earth revolved around the sun; the author describes how Copernicus and Nicholas of Cusa 'cracked open the nutshell universe of Aristotle and Ptolemy'.

However, due to the Protestant Reformation, which began in 1517, the Catholic Church became rigid in its defense of its Aristotelian theology which caused the Church to be hostile to Copernicus. Intellectuals had started to reject Papal authority; in the 1530s, King Henry VIII did as well. So the Catholic Church struck back with orthodox Aristotelian philosophies. Zero became a heretic. The void had to be rejected. Giordano Bruno, a former Dominican, published a book on the infinite universe in the 1580s and was burned at the stake in part for this reason. Zero was not so quick to be destroyed. It got stronger due to astronomy and physics, as it allowed incredibly precise predictions of the movements of the heavens.

Zero and the infinite were at the heart of the war of ideas that started in the sixteenth and seventeenth centuries. The void undermined Aristotle and many Jesuits themselves became attracted to zero, such as philosopher Rene Descartes, who was trained as a Jesuit. Descartes placed zero at the center of the number line. Descartes was also a famous mathematician, creating the Cartesian coordinate system. The author explains how zero came to be placed at the center of the intersection of the y and x axes in a Cartesian plane. For Descartes, zero was also a key part of God's domain. Nothing can be created from nothing, so for Descartes, ideas in people's minds were innate. The concept of an infinite perfect being was also innate to the mind, which allowed the inference that God existed through what is called an 'ontological argument'. Descartes insisted to his death that zero did not exist. He knew there was a tension between his mathematical views and his loyalty to Aristotle.

Galileo's secretary, Evangelista Torricelli, created the first vacuum by using a pump used by Italian workmen to pull water out of wells. At nearly the same time, Blaise Pascal, the great theologian and mathematician who invented Pascal's Wager, created the first mechanical calculating machine. Pascal also engaged in a number of experiments with mobile vacuums and mercury, allowing him to discover the idea of atmospheric pressure. Vacuums do not suck, but the atmosphere pushes. This experiment undermined Aristotle's view that nature hated a vacuum.

Pascal also used nothing to create probability theory and he used probability theory to make an argument for God's existence. He argued that we should believe in God as a bet, for if we did so and were right, we would receive infinite happiness and if we were wrong, we would receive nothing. However, if we did not believe in God, we would either receive infinite pain or nothing. It is therefore rational to believe in God. This was the beginning of expected utility theory, which multiplies expected benefits or costs by the probability of achieving them to produce a rational method of choosing among gambles.

Chapter 5, Infinite Zeros and Infidel Mathematicians

Chapter 5, Infinite Zeros and Infidel Mathematicians Summary and Analysis

In the modern period, Newton and Leibniz created calculus which involved dividing by zero and adding infinities. Calculus defied the previous logic of mathematics. Calculus allowed adding an infinite number of terms to get a finite result. The author explains the ideas of summing under limits. The problem with calculus is that adding infinite things can sometimes yield weird results, such as that an infinite sum of zeros can equal anything at all. But the physical world fit calculus well and Johannes Kepler used it to determine that the planets had elliptical orbits. Calculus also raises the problem of the tangent, a line that 'just kisses' a curve. For any curve, there is a tangent and tangents have important properties for physics, such as throwing a baseball. Calculating tangent lines was an important achievement of early modern mathematicians. Zero can wreck the calculation of the slope of a tangent line as it appears to involve dividing by zeros. The areas of curved shapes posed the same problem.

Calculus involves the method of differentiation, which allows one to figure out the tangent to any smooth curve at any point. The author discusses Newton's method of differentiation, which involved an illegal mathematical method that had the great advantages of working. It solved both the tangent and area problems. The operation of finding the area under a curve is now called integration, the reverse of differentiation. Calculus combines integration and differentiation. Calculus also allowed Newton to combine the known natural laws of physics into one grand set of laws which could be expressed as differential equations. Differential equations take equations as inputs and render equations as outputs. Differential equations can explain object motion. However, Newton's method involved dividing zero by itself.

Leibniz is said to have independently developed the calculus, though in a slightly different way. It is not clear how the two influenced each other. Leibniz wanted to use infinitesimals which were infinitely small but Newton found the concept ridiculous. This was termed 'dx' and the ratio of infinitestimals 'dy/dx'. Modern mathematicians and physicists use Leibniz's notation, as it could do a bit more. But Leibniz was still dividing by zero. A Frenchman named l'Hopital would take the first stage at the division-by-zero problem by creating l'Hopital's rule. L'Hopital's rule, showed that the value of 0/0 was indeterminate. Zero was now an enigma that mathematicians thought should be studied. Bishop Berkeley, seven years after Newton's death, began to pounce on the problem and ultimately solved it.

Until the French Revolution, calculus had had mystical foundations due to the religious beliefs of its founders. But by the eighteenth century's end, mathematicians throughout Europe were using calculus successfully. It was Jean Le Ron D'Alembert who came up with the idea of a 'limit' which solved the zero problem in calculus. Instead of thinking of a line as a summation of an infinite number of parts, D'Alembert suggested thinking of it as a limit of a finite number of smaller races. Limits allow one to talk about infinities and zeros without using them as terms. D'Alembert had satisfied the mathematician's need for logical rigor. No longer did mathematicians have to divide by zeros and mysticism vanished from math. Logic ruled again.

Chapter 6, Infinity's Twin

Chapter 6, Infinity's Twin Summary and Analysis

Zero and infinity shared a lot. Multiply either by itself and you get itself. Dividing anything by one yields the other.

Zero was not the only ignored number. One number, 'i', was ignored as well. 'i' appears whenever one takes the square root of a negative number. Descartes refused to permit these 'false roots'. Over time, algebraists came to accept negative answers to equations but later they had to accept 'imaginary numbers' as well. With the introduction of imaginary numbers, every polynomial equation could be solved and the fundamental theorem of algebra was discovered.

Before imaginary numbers could be fully accepted, several developments had to occur. The first development was projective geometry, which allowed armies to use projectile weapons effectively. Kepler used projective geometry to better understand the elliptical orbits of the planets. By employing the concept of infinity, he showed that ellipses and parabolas were the same. Carl Gauss, an early 19th century German mathematician, was an early researcher of imaginary numbers and realized that real and imaginary numbers could be graphed together. In doing so, Gauss showed that multiplication and exponentiation could be converted into a geometrical diagram.

Friedrich Riemann combined Gauss's ideas of imaginary numbers of projective geometry. Riemann was able to show how to generate the geometry for non-Euclidean spaces, or curved space. The geometry of spheres, it turns out, show that mathematically the north and south poles of spheres turn into one another. One side Riemann represented as infinity and the other as zero. So they became one another. The author explains this in much more detail.

Infinity increasingly became an ordinary number but many were disturbed by the continual reappearance of zeros within infinity. Some Riemann functions blew up at certain points on a sphere: singularities, points where infinity and zero seems to become one. German mathematician Georg Cantor made some important discoveries about infinity in the mid-19th century. For one, he discovered two types of infinities: countable and uncountable infinities. A countable infinity is one with discrete terms that can be counted in an orderly way, despite the fact that the process never ends. But uncountable infinities cannot be.

Cantor used the idea of the uncountable infinite to understand God, though one of Cantor's teachers, Leopold Kronecker, hated Cantor's work, thinking it made God's universe ugly and so attacked his work, ultimately forcing him into a mental institution. Cantor nonetheless founded the entire field of set theory.

Cantor also showed that the rational numbers were uncountably infinite and so were infinitely small even on an infinite number line, but the irrational numbers were countably infinite. Thus, if you threw a dart at the number line, it would always hit an irrational number and never a rational number.

Chapter 7, Absolute Zeros

Chapter 7, Absolute Zeros Summary and Analysis

Mathematicians had to make their peace with infinity and zero, but did physicists? Eventually they too would have to do so. The first problematic zero is absolute zero or the lowest possible temperature, where gases have their smallest possible volume, the temperature discovered by Lord Kelvin. Absolute zero has no energy and is unattainable because any attempt to get a space to absolute zero exerts some at least an incredibly small degree of energy.

The idea of absolute zero, however, created the field of thermodynamics, which studies how heat and energy behave. Thermodynamics has taught us that there are many things we cannot do, like build a perpetual motion machine. It can also, however, teach us about the nature of light by explaining how light waves work. Thermodynamics led physicists to conclude that light was not a particle, but an electromagnetic wave. Light holds energy in its wavelength.

Eventually something called the Rayleigh-Jeans law was developed which did well at predicting how much low-energy light radiated from a hot object, but the law broke down at high energies, close to infinity. At that point it became clear that the law actually implied that at zero-wavelengths, all objects give off infinite amounts of high-energy light. This was called the 'ultraviolet catastrophe' which gave birth to quantum mechanics.

Quantum mechanics eliminated zero in classical thermodynamics by removing infinite energy but this required admitting that the entire universe, even the vacuum, contains an infinite amount of zero-point energy which leads to 'the phantom force of nothing'.

To solve the ultraviolet catastrophe, Max Planck came up with a new equation that solved the catastrophe but implied that energy was released in discrete packets that have come to be called quanta and that thus energy cannot be released at any degree at all. At an early age, Albert Einstein showed that energy in fact manifested only as quanta. Einstein also wrote a paper that explained the photoelectric effect, which made quantum mechanics mainstream. When it was accepted, the mysterious power of zero was as well.

The author then explains the photoelectric effect and Einstein's solution, which led him to theorize that light was composed of small packets called photons, which meant that light was not a wave, but something that was part particule and part wave. In quantum theory, every particle and everything in the universe has wave-like and particle-like properties at the same time. Mathematicians who do quantum theory now claim that all objects have wave functions.

Zero-point energy came up in the work of Werner Heisenberg who discovered the Heisenberg Uncertainty Principle, which holds that there is an inverse relation between the fineness with which a particular's location can be determined and the fineness with which its velocity can be determined. Uncertainty therefore pervades the universe and so physicists theorized that we can never know how much energy exists in a vacuum at any one time and so the volume of energy in the vacuum must always be fluctuating. And it is thought to be full of virtual particles, particulars that pop into being and disappear. In the middle of the 20th century, physicists Casimir and Polder realized that zero-point energy cannot always be ignored. They showed that something called the Casimir force, which ascribes force and power to the vacuum.

Zero in physics at the astronomical level led to the paradox of the black hole, which is an infinite kind of nothing. The author explains how Einstein discovered that the speed of light is constant and how one's location in space and time cannot be described objectively, but varies according to one's perspective, thus the theory of special relativity. Time, length, and mass, it turns out, changed with speed. The flow of time varies. When Einstein tried to build gravity into special relativity and create the theory of general relativity, his equations implied that an object could be so massive that not even light could escape.

Einstein's theory allowed space and time to be treated as a single thing called space-time. Space-time could be curved. Ultimately, Einstein described gravity as a force that curves space-time. Space-time however could become so curved that nothing could escape. The black hole takes up no space at all but it still has mass. It is infinitely compressed and the very concept is troublesome. Einstein thought black holes could not exist but we now know that they do.

The author then discusses black holes in more detail. Along the way, he explains how a singularity, a point of infinitely dense and infinitely small matter, is located at the center of a black hole. In theory, a naked singularity might contain the power to create a wormhole that could send one back in time. When zero is used in general relativity, it shows that time travel is possible.

NASA hopes that zero could hold the key to travelling faster than light. In space there is nothing to 'push against' to start moving quickly. Rockets carry a supply of stuff to move against but rockets will probably always be too inefficient to get us to the stars. By creating a wormhole, a connection between disparate points in space time due to an extreme curvature in space-time, could allow one to travel faster than light. NASA has also wondered whether zero-point energy might be sufficient to power spacecraft, but we have no idea how to harness it.

Chapter 8, Zero Hour at Ground Zero

Chapter 8, Zero Hour at Ground Zero Summary and Analysis

Modern physics is divided between general relativity which holds at the macro-level and quantum mechanics that holds at the micro level. But black holes are both very massive and very tiny and so black holes are where the two sets of laws clash. And to understand the big bang, physicists have to unite quantum theory and relativity. They need a Theory of Everything which in fact is a theory of nothing.

Electrons are zero-dimensional; the electrons scientists observe are imposters. The true electron is located within a group of particles composed of zero-point fluctuations that pop in and out of being. It is hard to measure electron masses and charges as a result. But physicists cannot get closer. Instead, zero helps to smooth and spread out the sharp charge of an electron into a fog. And it isn't clear how to eliminate zero in the electron or in the black hole, but the physicists tried by adding dimensions.

Adding dimensions created string theory by treating each particle as a vibrating string, so electrons and black holes are one-dimensional strings. According to string theory, everything in the universe is made of strings and the theory purports to solve all the infinity problems within quantum mechanics.

Getting rid of zero helps general relativity as well. If a black hole is a string, objects won't fall through a space-time rip. Instead, a loop will touch the black hole. Some physicists think the merging of a particle and a black hole creates a tachyon or a particle with imaginary mass that could move backward in time. Strings could generate a theory of quantum gravity.

However, string theory requires ten dimensions to work. For some, four dimensions are too easy. The six dimensions other than height, width, length and time are rolled up into little balls that cannot be seen, like the third dimension on a very thin sheet of paper. It is not clear what the other six dimensions mean. They are just mathematical constructs. Today scientists prefer a monster theory called M-theory, which requires eleven dimensions. Strings are now calls branes and no instrument that exists or that we can even imagine test for their existence. Particle accelerators are not powerful enough. So today, banishing zero is merely a philosophical ideal rather than a scientific goal.

The universe in fact was born out of the void, or zero. It suggests the universe is finite. Western Civilization began divided between the eternal universe of Aristotle and the finite universe of the Jews. General relativity foretells the end of the universe. The universe may collapse under its own gravity or expand forever, growing colder forever. In other words: death by fire or death by ice. Einstein hated the idea and invented a cosmological constant that counteracted gravity; Einstein came to regard this as his greatest error.

Today astronomers estimate that the universe is fifteen billion light-years across and thus fifteen billion years old. The Hubble space telescope used Cepheid stars to do the measuring. And Hubble also saw that most galaxies were flying away from one another by using red-shifting and blue-shifting effects, the cosmological equivalent of the Doppler Effect. But Hubble also discovered that the farther away galaxies were from one another, the faster they moved away. Physicists had already proved that the big bang theory was true at least with respect to its alternative or the steady-state theory by observing cosmic background radiation. The author tells the story of how the radiation was discovered. The universe was not static.

Where did the big bang come from? For the author, zero contains the secret. Zero-point energy might have been greater in the early universe. And so the vacuum or void returns. Zero might spawn universes through a froth of quantum foam. Zero unhinges the laws of physics. Zero cannot be ignored; it was there at creation and it will be there at the end.

Chapter ∞, Zero's Final Victory

Chapter ∞, Zero's Final Victory Summary and Analysis

Physicists try to eliminate zero, but it might have the last laugh. Physicists are trying to figure out whether the universe will die in fire or ice. They have found that the expansion of the universe is not slowing down and might be speeding up. Physicists are also reviving Einstein's idea of a cosmological constant. This force might be the force of the vacuum. Supernovas are often used to test theories but the results are preliminary. Other studies look for 'gravitational lenses'. It looks like the universe will die a cold death. Zero wins.

Zero lies at the heart of physics' big puzzles, as the reader can see throughout the book. Each time zero was eliminated from a theory progress was made. Zeros continue to pop up in future theories. Physicists hope to achieve a final set of physical laws. It would generate knowledge of the mind of God. However, quantum gravity is so far away from experimental verification, given that the best experimental grounds are black holes, that it may not even be possible to test the theory. All we know is that the universe came from zero and will return to it.

Following this chapter, there are a number of appendices where Seife explains some of the mathematical concepts in the main text of the book in formal detail.

Characters

Zero

While zero is near universally regarded not as a person but as an abstract object, it is hard to see how zero could be the most important person in Zero: Biography of a Dangerous Idea. However, the author, Charles Seife, goes out of his way to treat zero as a character, to give zero a personality and to place zero within a complex plotline, so it is appropriate to treat zero as an important character.

Zero is a kind of eternal being for Seife, something that existed at the beginning of time and something that will exist at the end. Zero holds the secrets of physics and math, always beckoning mathematicians and physicists. Zero is a dangerous theological idea because it carries the threat of tearing the ruling theological ideas of a society to pieces. Zero is mysterious, so much so that it carries an air of unfathomability.

In some ways, zero is the joker of human history. Zero plays tricks on history's greatest thinkers, plays practical jokes on thinkers who exclude it, and scares many by popping up when one least suspects it.

Zero is always one step ahead of humanity. She was ahead of the Greeks and the Egyptians, she held the key to algebra, to calculus, to thermodynamics, relativity and quantum mechanics. She even knows the answer to the ultimate fate of the universe. Zero 'always has the answer.'

Modern Physicists

In some ways, zero is not the protagonist of Zero: The Biography of a Dangerous Idea but instead is the antagonist. Zero creates problems and holds answers for important groups of people: philosophers, mathematicians, theologians and physicists. But it is perhaps these groups that are best described as protagonists. They often pursue zero, often ignore it, and are nearly always frightened by it.

The most prominent of these groups are modern physicists, who Seife describes in detail in the final chapters of the book. 'Modern' physicists refer to those physicists who have lived from the beginning of the Enlightenment. These physicists include Kepler, Galileo, Gauss, Maxwell, Leibniz, Newton, Einstein, Heisenberg, Planck, and many others. Their characteristic features are a fascination with the natural world and an unusually great tolerance for new ideas. However, they are also characterized as being held back by particular dogmas. Descartes refused to believe in zero due to his devotion to Aristotle, to give one example. Einstein could not handle what zero taught him about the end of the universe, so he created a cosmological constant that he believed was his greatest blunder.

The physicists pursues zero with trepidation. They know that zero is a threat but they often seek to eliminate it. When they do, new features of reality are revealed. By eliminating zero, L'Hopital was able to make better sense of calculus. By allowing zero to be represented, algebra could be created.

The Babylonians

This is an ancient people whose base 60 number system led them to use zero as a placeholder.

The Greeks

These are ancient people who were widely considered to have the greatest civilization of antiquity but whose worldview could not allow for zero.

Aristotle

This is the ancient Greek philosopher and scientist whose worldview made zero impossible. His views are influential down into modernity, where they continually blocked the use of zero and consequently, the advent of modern mathematics and science.

Pythagoras

This is the ancient Greek geometer who associated numbers and geometry and since zero could not be represented as a shape, could not admit zero into his influential mathematics system.

The Catholic Church

This is the powerful branch of Christianity whose Aristotelian metaphysics made it hostile to zero despite Christianity's Semitic heritage, which made it friendlier to zero.

Isaac Newton and Gottfried Leibniz

These are the two great seventeenth century founders of calculus for who zero created a number of unique challenges for their mathematical systems.

Werner Heisenberg

This is the founder of the Heisenberg Uncertainty Principle which acknowledged the limitations zero placed on what could be known about reality.

Objects/Places

Infinity

This is Zero's constant companion and fellow troublemaker in the book.

Geometry

This is the science of shapes, size and space. Ancient ways of understanding geometry made zero hard to represent.

Algebra

This is the branch of mathematics concerned with relations and operations that zero made possible.

Classical Physics

This is the science invented by Isaac Newton for which zero made difficulties.

Calculus

This is the branch of math focused on limits and infinities that was invented by Leibniz and Newton. It was both made possible by zero and challenged by it.

Quantum Mechanics

This is the modern theory of the physics of the very small which was made possible by zero.

Thermodynamics

This is the science of heat made possible by zero.

General Relativity

This is the theory of very large physical structures invented by Einstein in which the zeroes involved with black holes are a particular challenge.

Black Holes

Black holes are incredibly small concentrations of mass and energy with incredibly large physical effects. By combining the very small and very large, the existence of black holes challenges both quantum mechanics and general relativity, which the author interprets as another challenged posed by zero.

String Theory and Quantum Gravity

These are modern theories of physics that may hold the key to a final theory of nature but that the author thinks zero may already be a step ahead of.

Themes

Scientific Progress and Zero

Charles Seife tells the story of scientific progress through the lens of the number zero. Zero has prompted most of the major advances in mathematics and physics. At the very least, dealing with zero was required in order to make progress. Seife makes a number of extravagant claims about scientific progress and its relation to zero. For instance, he attributes to Aristotelian metaphysics an inability to recognize the number zero and then blames that inability not only for the Roman civilization's failure to advance mathematics but for the failure of scientific progress during the entire medieval period.

Seife claims that each major advance in physics and mathematics all involved facing some challenge presented by zero. For instance, without zero, algebra could not be created and algebra was needed for any number of important advances. It was an inability to deal with the implications of zero that prevented mathematicians from discovering the calculus and it was only Newton's willingness to face zero that allowed him to make sense of it.

While Seife sometimes argues that facing zero is required to make progress, at other times he claims that it is eliminating zero is required to make progress. As a result, scientific progress always requires dealing with zero, but it is not always recognizing zero within a system but abolishing as well.

Zero and Theology

While Zero: The Biography of a Dangerous Idea is primarily a story of the progress of science and mathematics, it is also a story about theology, particularly a theology of creation and apocalypse. Zero is associated with the idea of a void, the idea of beginning and the idea of death and destruction. As such, zero is bound to evoke theological questions. Seife argues that it was fear of finding particular answers to these questions that prevented the Greeks, Romans and Medieval Roman Catholics from accepting zero.

Accepting zero is associated with the theologies of particular societies. For instance, Aristotle's eternal, beginningless universe banished the fear of the void but also blocked out the appearance of zero. Semitic theology contained the idea of a void and was therefore friendlier to zero. But Hinduism was particularly friendly to the concept of zero.

Seife argues that many of the failures of great minds to make progress was due to the fact that their theology got in the way of accepting zero. For instance, Seife claims that Descartes could never admit the idea of zero for theological reasons. He thinks that Leibniz and Newton could not see as far as they might have because of the theological and religious underpinnings of their approach to mathematics.

But perhaps the most theological aspects of the book are the implications that zero has for the end of the universe. Physicists think the universe will end either in a big crunch or a cold death and so zero has implications for the end of time itself.

The Victory of Zero

For whatever reason, Seife puts zero in competition with humanity's greatest minds. Zero is seen as an opponent to be beaten, to be chased away from obscuring the truth from human inquiry. If embraced, zero can help one understand the world better. But zero still threatens. Again, the story of scientific progress always has zero dangling in front it, taunting it and pushing it forward.

Regardless of whatever challenges, zero has posed to humanity in the past, a serious question arises as to what zero can bring or threaten in the future. The future of zero may lie in the center of a black hole, which may be the closest to zero that one can get within a universe of extant things. Zero may even hold that promise for solving the greatest current challenge to physics, which is the tension between general relativity and quantum mechanics. A theory of 'quantum gravity' could give humanity an ultimate set of laws of nature, ones that perfectly describe reality. Since the theory that physicists have developed seems impossible to test, zero may have the last laugh.

The biggest threat posed by zero is tied to the fate of the universe. Today the laws of physics uncovered by facing zero suggest that the universe will die a cold death. It looks like the universe will continue to expand forever, leaving all the galaxies and stars in the universe to die. Thus zero stands at the end of time telling humanity that it can never be defeated.

Style

Perspective

Currently employed as an associate professor of journalism at New York University's Carter Journalism Institute, Charles Seife is the author of Zero: The Biography of a Dangerous idea and three other books. He regularly writes on mathematics and physics for popular audiences. Seife has been a writer for the magazine Science and the New Scientist. He holds mathematics degrees from Princeton and Yale.

Seife is arguably the most important person in Zero: The Biography of a Dangerous Idea because it is his stylized history of zero that draws the narrative together. Seife goes out of his way to personify zero in order to use it as an organizational concept for discussing the history of the fields of physics and math. Seife's place in the book, therefore, reflects his interest in mixing his backgrounds in mathematics and journalism. While no mathematician would tell the story of the evolution of physics and mathematics from the perspective of a personified number, Seife's journalistic abilities motivate him to do so. By assigning zero a kind of personality, Seife seems to think that he can make the story come to life and arguably, it does.

Seife has a number of biases that the reader should be aware of. First, his perspective on Aristotle holds that Aristotelian physics and even metaphysics was a barrier to scientific progress because it was inevitably hostile to the idea of nothingness. There are many who think that Aristotelian physics and metaphysics were barriers to scientific progress, but next to none who think this due to Aristotle's attitude towards nothingness. Second, and relatedly, Seife's conception of the relationship between zero and theology is highly stylized in part as a result of his conception of the role of Aristotle within Catholic theology.

Tone

Since Seife combines the perspective of a mathematician and physicist with the perspective of a journalist, the tone of Zero has a dual structure. On the one hand it reads like a popular science text and on the other it reads like a 'who-dun-it' thriller.

The tone of the book is scientific since it is a book about physics and mathematics. To be sure, then, nearly all the issues discussed have a partly scientific tone or one that can be dry, detailed, and objective. However, the intensity of this tone varies throughout the book depending on whether Seife is focused on the main narrative of the book or is busy explaining some complex mathematical concept to the reader. For instance, the chapter on calculus explains the idea of a derivative at length, as does one of the appendices concerning the same idea.

This tone contrasts sharply with Seife's tone writing as a journalist. Seife clearly sought out a narrative device to tell his story, and his narrative device is to present zero as a kind of elusive leprechaun. It is magical, mysterious, and just when the physicist and mathematician thinks he has been caught, disappears and pops up again in the next generation. The book therefore has an excited feel which can even become ethereal when Seife talks about the relationship between zero and human ideas of creation and God. This element of the tone varies inversely with the scientific tone of the book.

Structure

Zero: The Biography of a Dangerous Idea has ten chapters. However, the first chapter is chapter zero. Since Seife pairs zero and infinity, the final chapter is titled chapter ∞, reflecting themes in the book. There are therefore these two introductory and epilogue chapters with eight 'regular' and regularly numbered chapters in between. The chapters proceed in chronological order through the history of mathematics and science from the time of the ancient Babylonians and ancient Greeks to the present day. Each chapter contains several sub-chapters, each of which covers either a discrete scientific controversy, discovery or conflict or analyzes a particular mathematical, theological or scientific idea.

The pre-scientific history of zero occupies chapters one through five. Zero began as a placeholder symbol within the Babylonian number system. It was initially resisted by the Greeks for theological and philosophical reasons, which the author attributes to the influence of Pythagoras and Aristotle. Seife also explores how Zero affected the formation of calendars. These matters occupy the second two chapters (one and two).

The next three chapters explain how zero migrated to the West and how it led to a number of early scientific advances. Chapter four explains how zero and infinity are intimately related and chapter five shows how this intimate relationship led to the discovery of the calculus. Chapter six shows how Hindu philosophy was more open to zero than the medieval Western view, which was still heavily influenced by Aristotle. Zero entered the West with the advent of the Renaissance and this, in the author's view, led to great scientific progress and new theological ideas.

Chapter seven begins modern scientific history in earnest, explaining how zero led to the development of many ideas within chemistry and physics. Chapter eight applies zero and infinity to explain a number of current challenges in physics and chapter infinity closes the book with a discussion of how zero may challenge scientists and mathematicians in the future.

Quotes

"Underneath every revolution lay a zero" (Chapter 0, pg. 2.)

"Yet through all its history, despite the rejection and the exile, zero has always defeated those who opposed it. Humanity could never force zero to fit its philosophies. Instead, zero shaped humanity's view of the universe—and of God" (Chapter 0, pg. 3.)

"Within zero there is the power to shatter the framework of logic" (Chapter 1, pg. 5.)

"In the history of culture the discovery of zero will always stand out as one of the greatest single achievements of the human race" (Chapter 1, pg. 12.)

"Zero clashed with one of the central tenets of Western philosophy...there is no void" (Chapter 2, pg. 25.)

"Infinity, zero, and the concept of limits are all tied together in a bundle" (Chapter 2, pg. 44.)

"Though the West was afraid of the void, the East welcomed it. In Europe, zero was an outcast, but in India and later in the Arab lands, it flourished" (Chapter 3, pg. 63.)

"Indeed, to the devout, God could be found, hidden within the void and the infinite" (Chapter 4, pg. 84.)

"Zero was a heretic" (Chapter 4, pg. 91.)

"These troubles would have ended as an interesting footnote but for one thing: these infinities and zeros are the key to understanding nature" (Chapter 5, pg. 113.)

"Zero and infinity are two sides of the same coin" (Chapter 6, pg. 131.)

"The infinity of the rationals is nothing more than a zero" (Chapter 6, pg. 156.)

"This, in turn, leads to the most bizarre zero in the universe: the phantom force of nothing" (Chapter 7, pg. 165.)

"Zero dwells at the juxtaposition of quantum mechanics and relativity; zero lives where the two theories meet, and zero causes the two theories to clash" (Chapter 8, pg. 192.)

"The Theory of Everything is, in truth, a theory of nothing" (Chapter 8, pg. 192.)

"The universe will die a cold death, not a hot one. The answer is ice, not fire, thanks to the power of zero" (Chapter ∞, pg. 213.)

"The universe begins and ends with zero" (Chapter ∞, pg. 215.)

Topics for Discussion

Why was zero such a hard sell to the West?

How did zero originate?

How did zero enter the West? How did it open up scientific progress?

Discuss three connections that the book draws between zero and infinity.

How did zero bring about calculus?

How did zero bring about quantum mechanics and general relativity?

Why does Seife think that zero may finally have the last laugh?