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Einstein's Miracle Year

Throughout scientific history there are but a handful of moments in which our understanding of the universe is challenged to its core. Einstein was 24 in January 1905, a year now shrouded in legend for being known as Einstein's miracle year [1]. In the following months, Einstein would publish four papers that replaced universally accepted absolutes in classical physics with theories that propelled the discipline into an entirely new era. As John Wheeler once remarked, "There was physics before Einstein in the same way that there was Biology before Darwin." Albert Einstein's revolutionary discoveries didn't merely augment existing theories; they fundamentally challenged humanity's perception of time, space, and the very fabric of reality itself.

Before 1905, the classical worldview was shaped by the minds of historical giants such as Euclid, Aristotle, Newton and the like. The laws of physics that governed space and time were considered absolute. Under these laws, one could assume that one meter will always one meter long, or that one hour will always be one hour long [5]. It was accepted that matter was composed of immutable and indivisible atoms, and that energy travelled through what physicists called 'ether' [4]. This way of seeing the universe laid the foundation for classical physics, and it persisted well into the late 19th century. By this time, discoveries such as that of thermodynamics, and consequently steam power and the lightbulb left scientists almost content with their understanding of the physical world [4]. As science historian Milena Wazeck put it "physics was perceived by many to be an almost completed discipline" [6]. However, an array of unanswered questions remained.

Several discoveries made around the turn of the 19th century casted doubt on the presumed absolute laws of nature. Most notably, the failed Michelson-Morley experiment of 1887. This experiment was designed to demonstrate a slight change in the speed of light when measured from the earth – which is always moving in relation to space (which never moves). ~~The tests yielded results that could not be explained by classical physics.~~ The speed of light remained constant, irrespective of the earth's motion which goes against the classical laws of space and time [3]. The discovery of the electron and radioactivity casted further doubt on the pillars of classical physics. In 1897, J.J. Thomson discovered the electron; a discovery which quickly led to a preliminary understanding of radioactive decay. Radioactive decay in its essence debunks the notion of indivisible matter. These discoveries revealed the inherent instability of an atom, tearing once again at the fundamental understandings of classical physics [6]. The elusive 'ether', a substance thought to be present in all of space, theorized to be that which energy travels through, was also about to be debunked [5]. These intellectual crises set the stage for a paradigm shift where the established laws of classical physics would yield to the revolutionary insights of one man: Albert Einstein.

Before all this, however, Einstein was in the midst of a failing a career in academics. He had found a job working as a patent clerk for the Swiss government. As he worked, he studied for his PhD, and published a few scientific papers, but his work up to this point was not noticed by most physicists of the time [6]. Yet Einstein kept working; and in 1905, the year he received his PhD, he published four papers that forever changed the way we understand the universe [1].

These papers discuss four different ideas that are now fundamental in modern physics: Brownian motion, the random motion of particles in fluids; wave-particle duality, which proposes that light behaves as a series of particles as well as a wave; the equivalence of mass and energy, and special relativity. His groundbreaking discoveries dismantled the classical worldview and replaced it with new paradigms that now are the cornerstones of modern physics [1, 6].

Einstein's first paper, published in March of this miracle year, proposed that light may in fact be made up of particles despite decades of evidence that supported light as a wave. This theory was used to expound certain unknowns in the world of classical physics. Notably, this theory offered an explanation to the photoelectric effect which is now understood to be the emissions of electrons from a material when it is exposed to light [4]. When this phenomenon was first observed by Heinrich Hertz in 1887, however, there was no understanding as to why this happened [3]. Einstein's findings in this paper were not widely accepted for years to come. Now, wave-particle duality is absolutely foundational to the study of quantum physics. But this discipline would not have its revolution for almost two decades after he published this paper [1]. His second paper, published in May, tackled the centuries old question of whether atoms exist. Previously, theories in physics were built on the idea of invisible atoms, yet there were prominent scientists who were skeptical of this idea, dismissing the atom as a convenient fiction [1]. Einstein ended this debate by proving that Brownian motion – the random motion of particles in fluid – could be precisely predicted by modeling the collisions of atoms. Experiments soon confirmed this model, and thus all atomic skeptics were forced to yield [1]. Einstein's first two papers published in 1905, his miracle year, were both revolutionary in physics, though neither received immediate recognition for the incredible new discoveries they had made.

All four of these papers from the miracle year introduced brand new ideas to the world of physics. However, Einstein's third paper, "On the Electrodynamics of Moving Bodies", was particularly disruptive to the classical worldview. Published in June, this paper theorized that nothing can move faster than light [2]. This discovery answered many of the remaining questions in classical physics, including why Michelson and Morley hadn't observed light slowing down as it traveled to earth through 'ether' [3]. Special relativity removes all frames of reference for space and time, which meant that there was no longer a universal space in which physics happens. His findings in this paper suggested that all measurements of space (e.g. one meter) and time (e.g. one hour) were relative to the position and speed of the observer, not absolutes [3]. With this new way of understanding space and time, we could now observe a new mathematically continuous dimension called spacetime. The spacetime dimension implied that an event at one time for one observer could happen at a completely different time for another observer. The only constant in this entire system is the speed of light – which classical physics predicted could change [6].

After his paper on special relativity, Einstein came out with the world-famous proof, $E=mc^2$, or energy is equal to mass multiplied by the speed of light squared. This proof implied that mass and energy were correlated, and that one could be converted into the other [6]. As Einstein put it, "mass and energy are both but different manifestations of the same thing." This idea, in tandem with the special theory of relativity, introduced an entirely new system of physics. Under the previous system, which was discovered by Issac Newton in the 1600's, mass and energy are two unchangeable absolutes. This is entirely different than what mass and energy mean in Einstein's system. Newton's systems for mass and energy only work here on earth, they do not apply on a universal level; Einstein's new systems for understanding the universe related the behavior of the cosmos to the behavior terrestrial matter and offered a new regime in which all matter operates under the same rules [6].

This epic saga of scientific discovery exemplifies a strongly Popperian conception of science. Einstein saw a plethora of issues with the accepted worldview in physics and set out to falsify these issues by offering alternative explanations and introducing entirely new concepts to science. Einstein began noticing discrepancies in the trends of scientific discovery and the previously accepted laws of physics at that time. In 1905, over a span of seven months, Einstein would bust those discrepancies completely open, by changing our entire perception of how the universe works. The legacy of Einstein's miracle year cannot be understated. If he were to have ended his career in physics after publishing any one of these papers from his miracle year, he would still be a giant in the physics world. But as we all well know; Einstein's career did not end in 1905. He went on to make myriad discoveries and innovations that pushed science to astronomical heights. These discoveries, such as theory of general relativity, gravitational lensing, the birth of particle physics and the atom bomb, and more all made Einstein a scientific titan, and pop culture icon, the likes of which the world hadn't seen since Darwin [2]. After World War II ended, and the Cold war began, scientific discovery became the indicator of global power thanks in large part to the physics that Einstein discovered – much to his beguile. Einstein regretted that his work was used for violence and was generally skeptical of unchecked technological progress [2]. Regardless, however, of the historical outcomes that were made possible because of Einstein's creations, Einstein propelled physics – and the entire world – out of an antiquated and lackluster understanding of the universe. The discoveries Einstein made in 1905 changed the world forever. Einstein's miracle year will stand the test of time as one of the most significant years in scientific and human history.

Works Cited:

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