Albert Einstein: *"The Miracle Year"*

ENGT-279 Digital Portfolio

Ivy Tech Community College

David M Rogers

May 6th, 2014

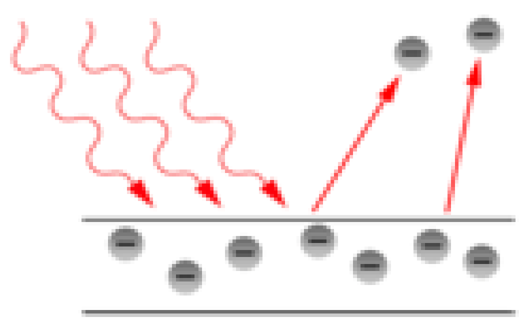
Abstract

Albert Einstein is widely considered one of the greatest minds of all time, but how much do people really know about him? His theories and accomplishments are well known on the surface level, but few people in the mainstream population can explain or even understand them on a practical or applicable level despite the fact many of today's technologies rely on them. This paper will shed some light on who Albert Einstein was as a person along with detailing the year 1905, which is sometimes referred to by historians as "The Miracle Year" because of his multiple accomplishments during it.

The story of Albert Einstein starts on March 14, 1879 when he was born in Ulm, Wurttemberg, Germany to secular Jewish parents. His father, Hermann Einstein, was a former salesman who later was able to run a fairly successful electrochemical factory. His mother, Pauline Koch, was a stay at home mom who ran the household and took care of Albert and his younger sister by two years Maria, who was called Maja. Another person who was very impactful on Albert's younger years was Max Talmud (later changed to Max Talmey). Max was a friend who often ate dinner with the Einstein family and became Albert's informal tutor, introducing him to higher mathematics and philosophy. Max also introduced Albert to a children's science series called *Popular Books on Physical Science* (translated from German) in which the question that would drive Albert Einstein to greatness was first brought to his attention. The question was asked, "What would it look like if a person could move next to a light beam at the same speed?" That question would be the foundation for many of his future daydreams, new ideas, and hypotheses and theories.

Albert Einstein's educational path was a tough one. His father left him at a boarding school to finish high school, but Albert dropped out at 16 because of fear of having to join the military. He eventually graduated from a high school in Switzerland with a diploma in 1896. He then attended the Polytechnic in Zurich, Switzerland, where he was an average at best student in most classes. Finally, in the spring of 1900, Einstein passed his final exam, placing 4th out of five candidates to receive his undergraduate degree. He then worked a few odd jobs such as being a tutor until he was hired to work in the patents office in Berne. While working there, he had lots of free time to pursue research and expound upon his own thoughts and questions. Then, in 1905, having worked there for a couple years, Einstein set in motion what is now called “The Miracle Year” in which he wrote four papers that would make him famous and change the way certain things were viewed.

The first of these papers was “Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt”, which in English translates to “On a Heuristic Viewpoint Concerning the Production and Transformation of Light”. In this paper, Einstein applies quantum theory to light to explain the photoelectric effect.. The photoelectric effect was a new theory that challenged the classical wave theory of light, which had been around for decades previously. The photoelectric effect basically states that when a light source or electromagnetic radiation collides with a metal surface, the surface can release electrons, which are then called photoelectrons.



Light collides with a metal surface, releasing electrons.
Distributed through Wikimedia Commons

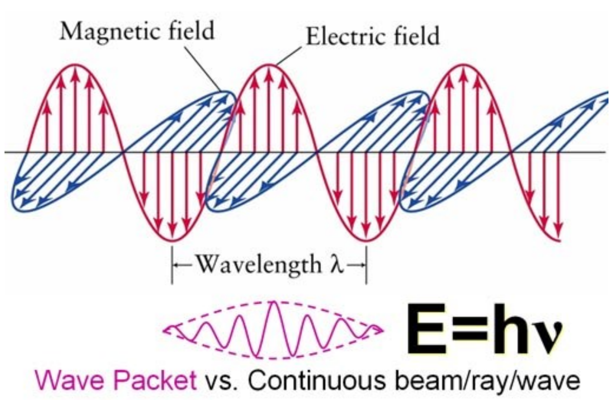
In the Classical Wave Theory, the energy of electromagnetic radiation is carried in the wave itself. This leads to 3 specific predictions:

1. The intensity of the radiation should have a proportional relationship with the resulting maximum kinetic energy.
2. The photoelectric effect should occur for any light, regardless of frequency or wavelength.
3. There should be a delay on the order of seconds between the radiation's contact with the metal and the initial release of photoelectrons.

These predictions were all proven wrong through experiment by 1902. So Einstein, building on the work by Max Planck, proposed that radiation energy is not continuously distributed over the wave front, but is instead localized in small packets (1). The photon's energy would be associated with its frequency (ν), through a proportionality constant known as Planck's constant (h), or alternately, using the wavelength (λ) and the speed of light (c):

$E = h\nu = hc / \lambda$

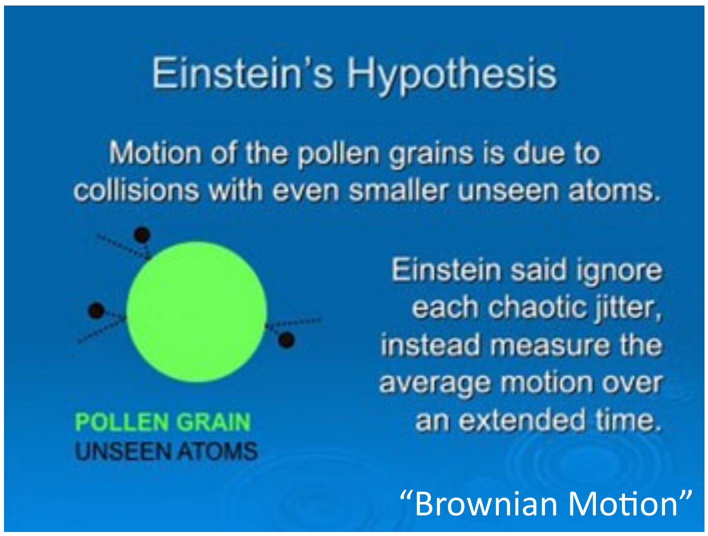
or the momentum equation: $p = h / \lambda$



(1) Einstein's small wave packets

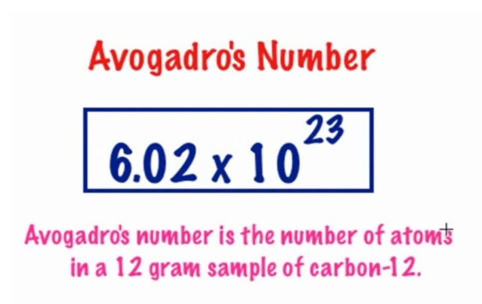
Einstein was able to prove that, though light behaved as a wave, it was also a particle as well.

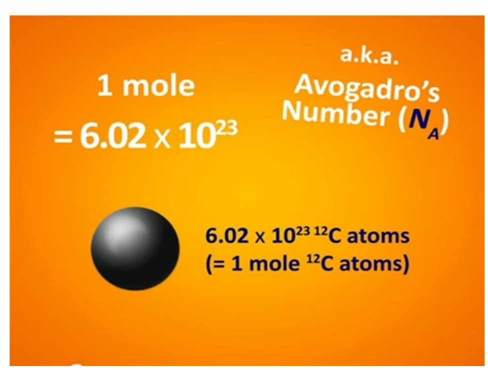
The second paper that Einstein wrote in 1905 was titled, "*Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen*", which in English translates as, "*On the Movement of Small Particles Suspended in Stationary Liquids Required by the Molecular-Kinetic Theory of Heat"*. In this paper, Einstein offers the first experimental proof that atoms exist as well as using Brownian motion to calculate the size and Avogadro's number.



Einstein looked at pollen grains and soot in liquids and explained "Brownian Motion" was due to particles colliding with atoms . He explained how to measure the motion as well.

Einstein also used some experimental data on sugar dilutions in water and some expressions on viscosity to come up with a calculation for Avogadro's Number, which is simply the number of molecules per gram mole of a substance. This number is the same for the same volume of a gas that is at the same temperature and pressure.

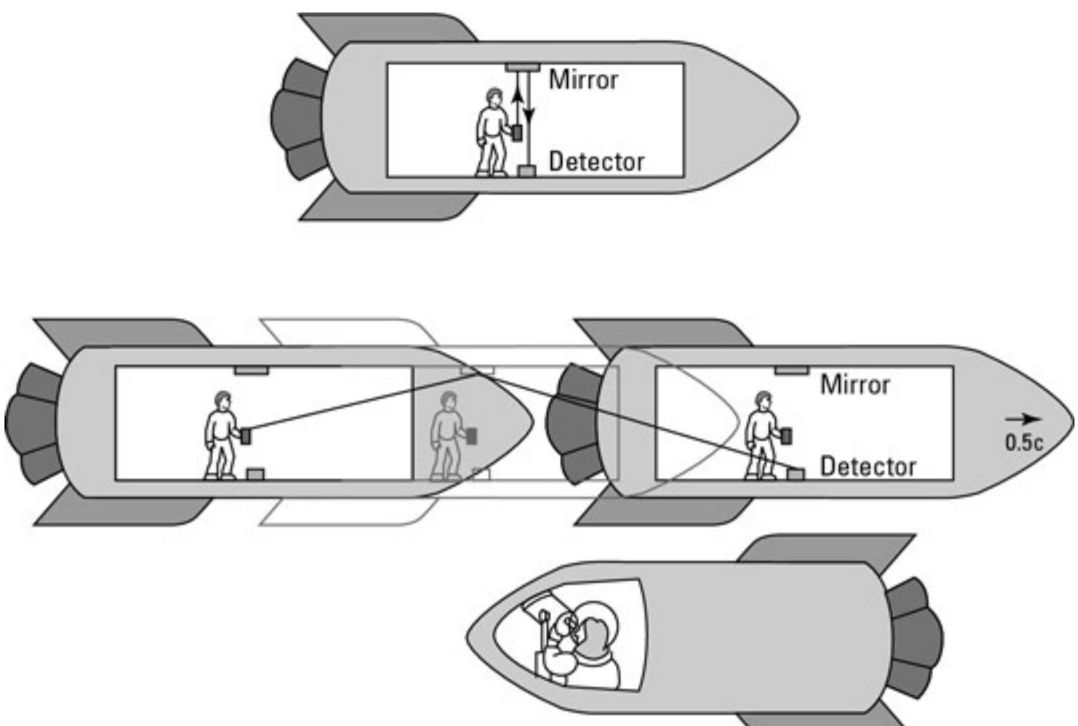




Einstein was able to calculate it as 6 x 10^{23} , which is less than 23 thousandths off.

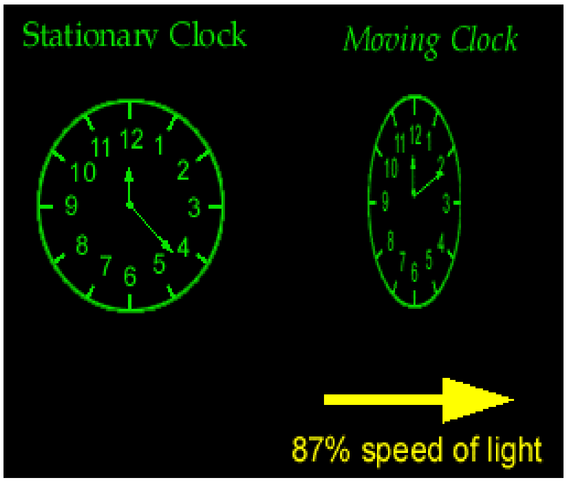
Einstein's third paper was titled, "*Zur Elektrodynamik bewegter Körper*", which translates in English to, "*On the Electrodynamics of Moving Bodies*". In this paper Einstein lays out the mathematics to his Theory of Special Relativity, which is central to modern physics. Special Relativity is limited to objects moving in a straight line at constant speed. It states that light is a constant speed regardless of an observers motion in relation to it and nothing with matter can reach that speed. It also surmises that there is a fundamental link between space and time and that time is the fourth dimension along with length, width, and height. So for example, the concept of time-dilation comes into play when two objects are in uniform motion at different speeds. For each individual observer, time seems to be normal, but when one observer looks at the other who may be going a lot faster, time seems to be moving slower for them relative to his/her own time reference.

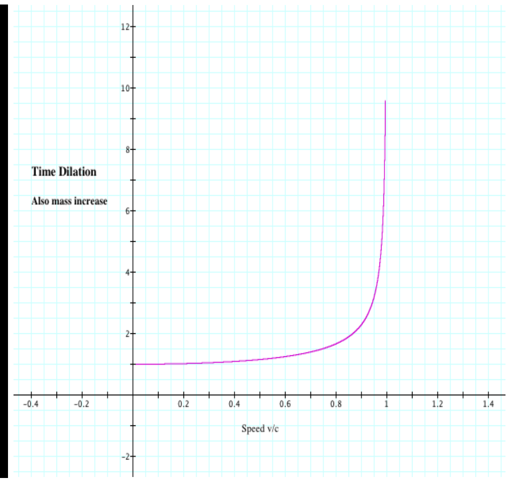
You can picture this for yourself by understanding the thought experiment depicted in this figure. Imagine that you're on a spaceship and holding a laser so it shoots a beam of light directly up, striking a mirror you've placed on the ceiling. The light beam then comes back down and strikes a detector.



However, the spaceship is traveling at a constant speed of half the speed of light (0.5c, as physicists would write it). According to Einstein, this makes no difference to you — you can't even tell that you're moving. However, if astronaut Amber were spying on you, as in the bottom of the figure, it would be a different story. Amber would see your beam of light travel upward along a diagonal path, strike the mirror, and then travel downward along a diagonal path before striking the detector. In other words, you and Amber would see different paths for the light and, more importantly, those paths aren't even the same length. This means that the time the beam takes to go from the laser to the mirror to the detector must also be different for you and Amber so that you both agree on the speed of light.

This effect from the last example is called time-dilation, which means that time passes slower on a fast moving object when compared by an observer on Earth. This kind of effect only becomes noticeable when you start approaching speeds closer to the speed of light.

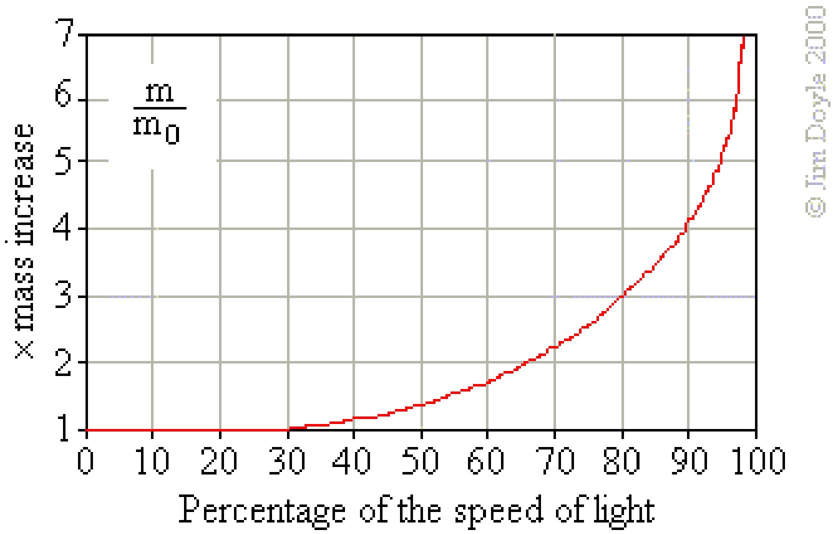




As you can see by the diagrams, time on the moving clock seems to be going slower relative to the stationary clock and the observed time dilation really starts increasing as you get closer and closer to the speed of light. We also know that matter can never actually get to the speed of light, although scientists have been able to accelerate particles above 99.99% the speed of light.

Einstein's fourth major paper of 1905 was titled, "Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?" In English, it was titled, "Does the Inertia of a Body Depend Upon Its Energy Content?" In this paper, Einstein shows how relativity leads to the equation $E=mc^2$ and how matter and energy are related. This means that you can take matter and turn it into energy and also take energy and turn it into matter. The most famous example of turning matter into energy is the atomic bomb. There are a few things that have to be explained before we get to the equation $E=mc^2$.

The first concept is the fact that as the speed of an object increases, the mass of that object also increases as well. This isn't noticeable until you start getting to significant percentages of the speed of light, typically at least 35% of it. The following graph shows that as an object gets closer to the speed of light, the mass increases on an exponential curve, but never actually getting to the speed of light.



One important note about this is the fact that the mass increase isn't felt by the object traveling this fast. It is only observed as a mass increase by a separate observer in a different frame of reference. To this other observer, it seems that the faster the object moves, the more energy is needed to move it thus signifying that its mass is increasing.

The second concept we need to look at is kinetic energy. If the faster an object moves increases its mass, then we know that it also takes more energy to move that object. Normally we would use the Newtonian equation for kinetic energy, but at speeds approaching the speed of light it becomes inaccurate. To keep the process of getting to the famous equation simple, here's a summary of what happens followed by a graph on next page. First, we take the mass increase formula(1) and add into it the Newtonian kinetic energy formula. This gives us formula (2). Then, we have to rearrange the formula and replace the Newtonian kinetic energy part with relativistic kinetic energy so that the formula will work at high speeds (3). Next we rearrange again and simplify the equation by setting the speed of the particle to zero, thus removing it from the equation (4).

(1). $$m = \frac{m_0}{\sqrt{1 - v^2 / c^2}}$$

(2). $$E \approx mc^2 + \tfrac{1}{2} mv^2$$

(3). $$\text{Relativistic kinetic energy} = E - mc^2$$

(4). $$E = \text{Relativistic kinetic energy} + mc^2$$

$$= 0 + mc^2$$

$$= mc^2$$

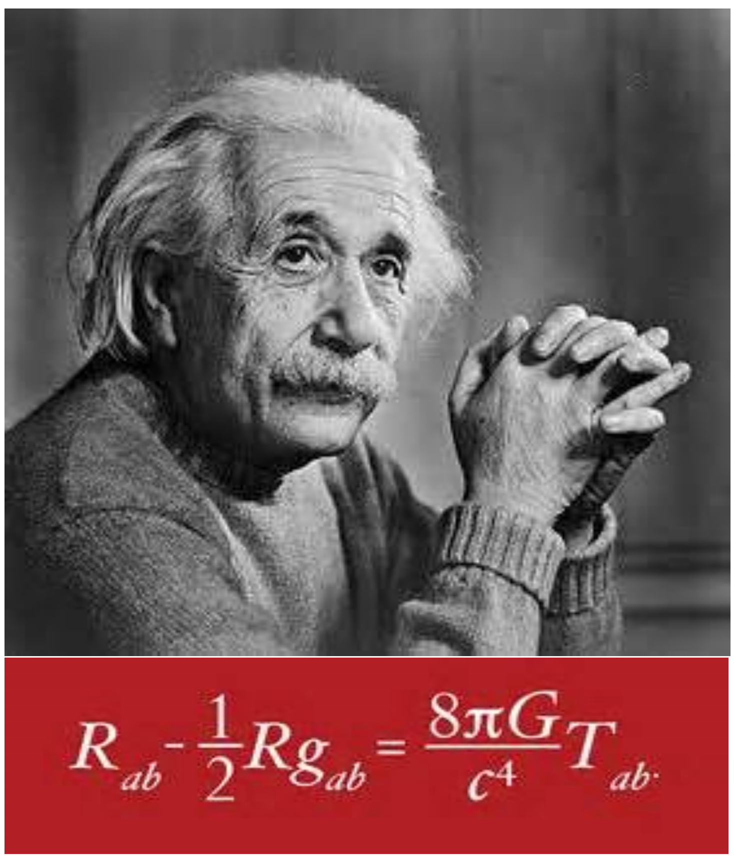
so :

$$\underline{E = mc^2}$$

This equation shows the relationship between mass and energy, but this specific equation is used for Energy. Einstein realized that you could get a lot of energy out of only a little mass. He considered mass to be just really tightly packed energy. Here's the full equation, which takes into account total energy (E), mass of the body (m), and the speed of the body (v) :

$$E = \frac{mc^2}{\sqrt{1 - v^2 / c^2}}$$

In conclusion, Albert Einstein accomplished a lot in the year 1905, which is now called the "Miracle Year" by most historians. He wrote four different papers that would change the whole landscape of physics and set the basis for modern day physics. He also would go on to win the Nobel Prize for his work on the photoelectric effect where he showed that light not only behaved as a wave, but that it also was a particle. He took his work on Special Relativity and turned it into a theory of General Relativity, which generalized his theory of special relativity and unified it with Newton's Law of Universal gravitation providing a description of gravity as a geometric property of space and time called space-time. His theories would lead to the creation of the atomic bomb and also the prediction of black holes. Einstein eventually died in the year 1955 and will historically be remembered as one of the greatest minds of his generation, if not all time.



Einstein's formula for his theory of General Relativity.

Bibliography

Neffe, Jurgen. *Einstein.* Translated by Shelly Frisch. New York: Farrar, Strauss and Giroux, 2007.

http://physics.about.com/od/quantumphysics/a/photoelectric.html

http://www.Britannica.com/EBchecked/topic/181349/Albert-Einstein/256583/From-graduation-to-the-miracle-year-of-scientific-theories.html. Kaku, Michio. Updated 1/13/2014.

http://www.dummies.com/how-to/content/einsteins-special-relativity.html.

http://www.emc2-explained.info/emc2/Derive.html

http://www.netplaces.com/einstein/blank/avogadros-number.html