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Einstein's contributions

Einstein is one of history's most well-known physicists. His theories prompted a revolution in twentieth century science that modern technology such as computers and GPS could not exist without. Despite this, many people are unfamiliar with his theories. This essay will look at Einstein's contributions and assess their impact on the world.

The Photoelectric Effect

In the nineteenth century Heinrich Hertz discovered that when a light was shone upon a metal, the metal would emit electrons, causing it to become positively charged (Wikipedia, 2015). However, conditions necessary for photoelectric emission contradicted Maxwell's widely accepted wave model of light (Wikipedia, 2015). Electrons are emitted when they gain enough energy from light to overcome the bonds holding them in the metal. Maxwell's theory predicts that whatever the light's energy, if a metal plate is exposed to it for long enough, electrons will eventually absorb enough energy to be liberated from it (Wikipedia, 2015). However, this is not what is observed. If the light's energy is too low, no electrons will be emitted, and electrons are always emitted immediately if energy is high enough, there is no delay for energy to be absorbed. As such, the photoelectric effect directly contradicts the accepted theory of light, which perfectly explained phenomena such as refraction and diffraction.

Einstein explained this in his paper 'Ueber einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt'. He suggested that the light energy was not transferred to electrons as a wave, but in discrete packets of energy, which he called quanta (Wikipedia, 2015). This meant that each electron received its energy from a one-one interaction with a quantum, and so could only be released if each individual quantum had enough energy to liberate an electron. This theory predicted that light could act as both a particle and a wave, which created the foundations of quantum mechanics. Quantum mechanics was one of the most important developments in twentieth century physics, and paved the way for modern technology such as computers. Einstein won the Nobel prize in 1921 for his work on the photoelectric effect (Nobelprize.org, 2015).

Brownian motion

In 1827, whilst observing the movement of a pollen grain in water under a microscope, the botanist Robert Brown noticed that it moved erratically, with no apparent cause for this motion (Wikipedia, 2015). By repeating this with inorganic particles he showed that this was not caused by any biological process (Wikipedia, 2015). Throughout the nineteenth century this was one of physics greatest dilemmas: nobody could explain why this happened. In his paper 'Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen' Einstein suggested that this was because of the random movements of water molecules (Wikipedia, 2015). If more molecules collided with one side of the particle than the other, it would begin to move. Einstein used very complex statistical methods originally used in economics to explain this process (Wikipedia, 2015). This does not immediately seem especially exciting, just a small curiosity: however, it was written before the existence of molecules and atoms was proved.

In 1908 the physicist Jean Baptiste Perrin proved that Einstein was correct using experimental methods. This lead to the particle theory of matter being widely accepted, which changed the development of physics and chemistry forever (Wikipedia, 2015).

Mass-energy equivalence

Einstein's 1905 paper 'Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?' leads to what is arguably the most famous equation in popular culture, '$E=mc^2$' (Wikipedia, 2015). This theory suggests that a particle's mass and energy are completely interchangeable. These ideas lead to the development of nuclear technology. Nuclear fission reactions work because the bonds holding a nucleus cause it to have a slightly higher mass than the individual particles. Since 'c^2', the speed of light squared, is such a big number, a small amount of mass converts to an extremely large amount of energy. This means that when a nucleus is split the small amount of extra mass gives out a massive amount of energy. This led to the development of nuclear power and weaponry.

As a result of his work on mass-energy equivalence Einstein is often thought of as being directly responsible for the creation of nuclear weapons. This attitude is well shown on the cover of 'TIME magazine', from the 1st of July 1946, which shows Einstein standing in front of a 'mushroom cloud' from a nuclear explosion, with the text '$E=mc^2$' in it. However, this attitude does not accurately describe Einstein's work, and also seems to ignore anything positive to have come out of Nuclear energy in order to vilify Einstein. Of course, mass-energy equivalence did lead to nuclear power, however only very indirectly. The main work towards sustainable nuclear power and nuclear weapons was advanced by groups such as the Manhattan project and the work of other physicists such as Ernest Rutherford and Marie Curie (Wikipedia, 2015). Without their work, Einstein's theoretical framework would have meant nothing. Another way that critics choose to link Einstein with nuclear weapons is through a letter which he wrote to US President Franklin Roosevelt upon discovering that the NSDAP government in Germany were importing radioactive Uranium from Ukraine. However, Einstein only wanted to warn the Government about what might happen, and make sure they were able to combat the NSDAP. Einstein believed 'that the USA would treat the discovery with respect and would resist actually using the bomb' (ppu.org.uk, 2015); he did not want the US to use it on Japan. And despite this, the overall effect of nuclear fission has not been negative. Approximately eleven percent of the world's energy comes from nuclear power plants, and it is one of the cleanest, most sustainable and practical methods of energy production we have (nei.org, 2015). And, barring Chernobyl, it has a very high safety record compared to other forms of energy production (world-nuclear.org, 2015). Those who vilify Einstein for his work on mass-energy equivalence do not truly understand him, his science, or the nuclear industry.

Special Relativity

The ideas behind relativity were initially proposed by Galileo Galilei in his 1632 work 'Dialogue Concerning the Two Chief World Systems' (Wikipedia, 2015). He proposed that motion is relative to an observer's frame of reference, so an observer would be unable to tell what the motion of their frame of reference was. For example, we cannot tell that the Earth is travelling at massive velocities around the sun, because our frame of reference is the Earth, so we cannot tell that it is moving. Sir Isaac Newton incorporated this idea into his law of mechanics, making it a key part of traditional physics (Wikipedia, 2015). Einstein's theory of Special Relativity, initially proposed in 1905 in his paper 'Zur Elektrodynamik bewegter Körper', reinvented Newton's ideas to create a more accurate version of relativity theory.

Einstein's theory relies on two key principles: that the laws of physics are the same for all observers, regardless of relative motion, and that the speed of light is constant for all observers. However, the most important prediction of Special Relativity is that time does not pass in the same way for different observers. It suggests that time is part of 4-dimensional space-time, and is affected by relative motion (dummies.com, 2015). This directly contradicts Newton's assertion that all frames of reference share a universal time.

The following analogy will try to explain Special Relativity's prediction of relative time. Imagine an Astronaut travelling at close to the speed of light with two mirrors aligned opposite each other, perpendicular to the direction of travel. If the Astronaut bounced a ray of light between the two mirrors, to an Observer in another frame of reference the light would appear to have taken a 'zig-zag' path, as the mirrors would have moved further in the direction of travel, and the light would have to travel diagonally to reach them. As such, the light would have travelled further from the observer's perspective. But if time passed at the same rate for the Observer and the Astronaut this would not make sense, as the speed of light is constant for all Observers, regardless of motion. As such, Special Relativity predicts that time passes more slowly for the Astronaut than for the Observer, as this is the only way that the light travelling a shorter distance could be explained. Essentially, more time passes from the observer's perspective than from the astronaut's perspective (dummies.com, 2015). This effect is known as time dilation.

One might assume that time dilation would not affect people on Earth too much, but this is wrong. GPS only works when the effects of time dilation are taken into account. For GPS to work, the clock on a satellite has to sync exactly with the time on Earth (astronomy.ohio-state.edu, 2014). As satellites are in freefall, their relative motion is much greater than that of an observer on Earth, and as such time travels more slowly for them. If the effects of relativity were not taken into account, the error in the location given by GPS would increase by ten kilometres every day (astronomy.ohio-state.edu, 2014).

General Relativity

The last of Einstein's major contributions to science was his extension of Special Relativity, known as General Relativity. Here, Einstein reconciled gravity and acceleration with special relativity (Wikipedia, 2015). Einstein suggested that space-time, his description of a four-dimensional continuum consisting of three space dimension and one time dimension, could be warped by massive objects. These massive objects cause a curvature in space-time that other objects can fall into, creating the force of gravity.

The theory was proved to be more precise than Newton's law of gravity by Sir Frank Dyson and Arthur Eddington in 1919. They observed that a particular star was in a different position in the night sky compared to during the day (the second measurement was taken during a solar eclipse). The star was observed to be in a different position both times. The deflection of the star was caused by the Sun's gravity distorting the light. Newton's theory also predicted that gravity could bend light, but Einstein's General Relativity predicted a greater distortion that better matched Eddington's data (Singh, 2005).

Conclusion

Einstein is commonly thought of as one of the greatest scientists ever to have lived, and this is clearly shown to be true by his contributions. In his later years Einstein's work had much less of an impact. His unsuccessful attempts at reconciling electromagnetism with General Relativity and debunking the theory of quantum mechanics have largely been forgotten. However, Einstein's earlier contributions had the greatest effect; paving the way for major developments such as Nuclear power and the microchip. As such Einstein's contributions should always be recognised as some of history's greatest.

Word count(excluding quotations) – 1695

Word Count – 1778

Bibliography

Astronomy.ohio-state.edu. (2014) *Real-World Relativity: The GPS Navigation System* [Online] Available from: http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit5/gps.html [Accessed 2nd June 2015]

Dummies.com. (2015) *Einstein's special Relativity* [Online] Available from: http://www.dummies.com/how-to/content/einsteins-special-relativity.html [Accessed 2nd June 2015]

Nei.org. (2015) *Nuclear Energy Around the world* [Online] Available from: http://www.nei.org/Knowledge-Center/Nuclear-Statistics/World-Statistics [Accessed 2nd June 2015]

Nobelprize.org. (2015) *The Nobel Prize in Physics 1921* [Online] Available from: http://www.nobelprize.org/nobel_prizes/physics/laureates/1921/ [Accessed 2nd June 2015]

Ppu.org.uk. (2015) *Einstein and The Atomic bomb* [Online] Available from: http://www.ppu.org.uk/learn/infodocs/people/pp-einstein3.html [Accessed 2nd June 2015]

Singh, S (2004) Big Bang. London: Harper Perennial

Wikipedia. (2015) *Annus Mirabilis Papers*[Online] Available from: https://en.wikipedia.org/wiki/Annus_Mirabilis_papers [Accessed: 2nd June 2015]

Wikipedia. (2015) *Brownian Motion* [Online] Available from: https://en.wikipedia.org/wiki/Brownian_motion [Accessed: 2nd June 2015]

Wikipedia. (2015) *General Relativity* [Online] Available from: https://en.wikipedia.org/wiki/General_relativity [Accessed: 2nd June 2015]

Wikipedia. (2015) *Jean Baptiste Perrin* [Online] Available from: https://en.wikipedia.org/wiki/Jean_Baptiste_Perrin [Accessed: 2nd June 2015]

Wikipedia. (2015) Mass-energy equivalence [Online] Available from: https://en.wikipedia.org/wiki/Mass%E2%80%93energy_equivalence [Accessed: 2nd June 2015]

Wikipedia. (2015) *Nuclear Fission*[Online] Available from: https://en.wikipedia.org/?title=Nuclear_fission [Accessed: 2nd June 2015]

Wikipedia. (2015) *Photoelectric effect* [Online] Available from: https://en.wikipedia.org/wiki/Photoelectric_effect [Accessed: 2nd June 2015]

World-nuclear.org. (2015) *Safety of nuclear Power Reactors* [Online] Available from: http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Safety-of-Nuclear-Power-Reactors/ [Accessed 2nd June 2015]