Einstein's innovative discovery which is indispensable for our modern lives

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In the early 1900s, Albert Einstein proposed an innovative theory, called a theory of relativity. This new basic theory was a substitution for the traditional physics so-called Newtonian mechanics. In the theory of relativity, many new and intriguing ideas were found about space-time and gravity.

Firstly, it was discovered that people moving at different speeds feel the time flow in a physically different way. In other words, we aren't sharing the same time flow. This new idea of time brought us new physical phenomena, Lorentz contraction and time dilation. The former is an effect about the change of apparent length. When an object moves towards you, the length of the object seems shorter. This is not an optical illusion but a physical phenomenon. The latter is an effect about the feeling of time flow. Let's think about a particle whose lifetime is 1 second. If this particle is static for you, you find that the particle decays in 1 second. However, if this particle is moving toward you, you find that the particle decays in more than 1 second. This is not a mistake of your brain, either. (To perceive these two strange phenomena, the speed of the object or the particle has to be about the speed of light (~3×10^8m/s). So, it is almost impossible to notice these effects in daily life.)

Another important discovery of relativity is about gravity. For about 200 years before relativity, gravity was thought of as a power between two objects with mass. In the theory of relativity, however, gravity is explained as a space-time distortion. For simplicity, let's think about a heavy ball put on a rubber membrane. The area where the ball is located is dented. In fact, this dent of the membrane corresponds to a space-time distortion. Then, if we put a light ball near the heavy ball, the light ball moves toward the heavy ball because of the dent. This means that a space-time distortion made by the heavy ball pulls the light ball as if there is gravity. This new interpretation of gravity proposes a new effect on light. In Newtonian mechanics, gravity cannot affect light because light has no mass. However, in the theory of relativity, because the light path can be bent by space-time distortion, light can also be affected by gravity. Also, gravity affects time. In fact, the stronger gravity becomes, the slower time flows.

Thus, the theory of relativity is a discovery that radically changed the way of thinking about space-time and gravity. Then, how did Einstein reach this discovery? To construct the theory of relativity, three fundamental ideas are needed.

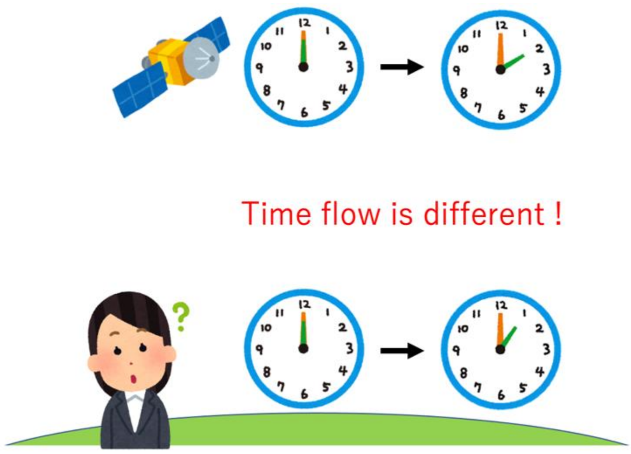
One principle is the constancy of the speed of light. Roughly speaking, this means that the speed of light has nothing to do with how fast an observer moves. This is not obvious. For example, for people who ride on a train, the train appears to be static. On the other hand, for people who see the passing train at a station, the speed of the train is nonzero. So, the speed of objects usually depends on the velocity of the observer. Actually, a little before Einstein, the constancy of the speed of light was guaranteed experimentally. And then, Einstein introduced this idea for the new theory.

When you ride on a train and suddenly train brakes, you stagger in the direction of motion. Such force which acts during acceleration or deceleration is called inertial force. Before Einstein, this inertial force and gravity were treated as different forces in Newtonian mechanics. However, through a thought experiment, Einstein realized that we cannot physically distinguish between these forces. And he introduced this original idea as a principle of relativity. This is called the equivalence principle.

The last principle is the general principle of relativity. This principle requires that the physical law can be written in the same form in all coordinate systems. In Newtonian physics, it was common knowledge that the physical law is significantly changed under a coordinate transformation. However, Einstein doubted this convention and supposed a new principle.

Beginning with these three principles, Einstein finally constructed the theory of relativity. By the way, at first glance, these fundamental ideas and the discovery of relativity may seem to have no meaning in real life. However, in fact, relativity affects our daily lives.

There is an important use of relativity that makes our lives more comfortable. That is Global Positioning System (GPS). If we need to know where we are, the distance between GPS satellites and us is needed. To know this, satellites and our electronic devices (for example, car navigation systems and smartphones) exchange radio waves. And then, by using the time taken to exchange and the speed of light, we can calculate the distance and finally know where we are. So, for an accurate calculation, the correct time is needed. Then, because the satellite moves so fast, we need to consider time dilation. Also, because satellites feel weaker gravity than us on the surface of the earth, there is a time difference made by gravity. Thus, to correct these effects to specify our location accurately, GPS uses the theory of relativity.



From three fundamental principles, Einstein constructed a new theory that dramatically changed human recognition and life. Therefore, studying basic concepts (like space-time and gravity) has a potential to change our recognition radically and this accurate understanding may result in a useful invention. Furthermore, you have a potential to become a great and influential scientist like Einstein by cherishing a fundamental concept and studying hard.

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Method

As hints for writing, I used DeepL (https://www.deepl.com/translator) and Weblio (https://ejje.weblio.jp) to look up words I could not come up with. Also, I used Grammarly to check my grammatical errors.

References

[1] Dr. Robert A. Nelson's slide "GPS Time as Critical Infrastructure Application Robust Time Dissemination & Chip Scale Atomic Clocks" 9-10 November 2011. (https://www.gps.gov/governance/advisory/meetings/2011-11/nelson.pdf)