# Heisenberg’s uncertainty principle explained

In the year of 1927, the time when modern physics has become prosperous, plenty of influential physics breakthroughs and discoveries struck the globe, especially quantum physics. One of the most significant quantum physicists is a German, named Werner Heisenberg, who stated the Uncertainty Principle in “ On the Physical Content of Quantum Theoretical Kinematics and Mechanics”, which has indispensable impact on the physics sphere. By going through the definition, the formulas, using a daily life example, explaining its applicability and a strange phenomenon, the intricate and abstract Heisenberg’s Uncertainty Principle will hopefully become comprehendible.

In Heisenberg’s Uncertainty Principle, it states that the position and the momentum of a particle cannot be measured with absolute precision because the more accurately we know one of these values, the less accurately we know the other and when multiplying together the errors in the measurements of these values, which are represented by the Greek letter â-³, the result has to be a number greater than or equal to half of the Planck’s Constant *h* divided by 2π. Though it sounds an extremely involved definition of the Uncertainty Principle, which is formidable enough by the name, especially for those who do not know much about science, yet as it is elaborated more deeply subsequently, the Principle will become comprehensible.

According to the definition above, it is clear to observe that there are formulas for the Uncertainty Principle, which are â-³ *x* â-³ *p* ≥ *h* /2 or â-³Eâ-³ *t* ≥ *h* /2. In the former formula, *x* is the position of a particle and *p* is its momentum. As it is explained in the upper paragraph, â-³ represents the errors in the measurements, which means â-³ *x* is the uncertainty of position and â-³ *p* is the uncertainty of momentum; *h* is Planck’s constant, which is a fixed number. In the latter formula, E is the energy measurement of a particle and *t* is the time interval during which the measurement is made. Thus, â-³E is the uncertainty of an energy measurement and â-³ *t* is the uncertainty in the time interval during which the measurement is made.

Although the explanations of the formulas seem to make the Uncertainty Principle more intricate, yet by demonstrating it with a daily life example, it would become clearer. Theoretically, by throwing an elastic ball to an object and measuring how long it takes to reach back one’s hands can determine how far away the object is. For instance, if one throws the elastic ball to a nearby stool, it would bounce back quickly, indicating that the stool is pretty near the ball-thrower. Similarly, if one throws the elastic ball to a stool that is on the other side of the street, it would bounce back after a while, which means the stool is far away. For a period, physicists thought by this way they could measure where a particle is. The truth is it will never work because indeed the elastic ball would bounce back, yet it is quite possible that the elastic ball is heavy enough to knock away the stool and still has enough momentum to bounce back. In this case, one can only determine where the stool *was* , but not where it is *now* . Referring back to something more physics-related, there was a time that physicists wanted to make measurements by shooting a particle toward another particle, which is exactly an analogy of the daily life example – they could not measure where the particle was after it had been hit by the other.

There was a mystery that had confused many physicists for decades: In an atom, negatively-charged electrons orbit a positively-charged nucleus.

Thinking with traditional logic, it is expected that the two opposite charges attract mutually, leading everything to collapse into a ball of particles. The most singular thing was, they never collapse into a ball of particles. This mystery is perfectly unveiled by Heisenberg's Uncertainty Principle – if an electron gets too close to the nucleus, its position in space would be precisely know, so the error in measuring its position would be quite accurate, meaning that the error in measuring its momentum and velocity would be enormous; as a result, the electron could be moving fast enough to fly out of the atom altogether. It is obvious how significant the Principle is to modern quantum physics.

Furthermore, Heisenberg's Uncertainty Principle has great compatibility – not only can it explain atom movements, but also can it be applied to nuclear radiation. Alpha decay, which is a type of nuclear radiation, can be explained using Heisenberg's idea. Alpha particles are two protons and two neutrons emitted by some heavy nuclei, which are usually bound inside the heavy nucleus and would need lots of energy to break the bonds keeping them in place. Whereas, because inside a nucleus, an alpha particle has a very well-defined velocity, which is $p$ , its position, $x$ , is not so well-defined, indicating that there is a small but non-zero chance that the particle could at some point find itself outside the nucleus, under the circumstance that it technically does not have enough energy to escape. When this happens, which is a process metaphorically known as " quantum tunneling" since the escaping particle has to somehow dig its way through an energy barrier that it cannot leap over, the alpha particle escapes and it becomes radioactive. Under the same reasoning, not only does the uncertainty principle apply to micro world, but also does it also apply to the sun, of which a similar quantum tunnelling process happens in reverse at the center, where protons fuse together and release the energy that allows the sun to shine. Technically, the temperatures are not high enough for the protons to have enough energy to overcome their mutual electric repulsion at the core of the sun, but as the uncertainty principle is correct, they can tunnel their way through the energy barrier.

It is definitely worthy to mention that Heisenberg’s Uncertainty Principle has a very strange result about vacuums. Albeit vacuums are often defined as the absence of everything, yet it is not so in quantum theory because there is an inherent uncertainty in the amount of energy involved in quantum processes and in the time it takes for those processes to happen. By looking at the energy-time version of Heisenberg’s equation, which is â-³Eâ-³ *t* ≥ *h* /2, it is shown that the more constrained one variable is, the less constrained the other is, which means it is possible that for extremely short periods of time, a quantum system’s energy can be immensely uncertain, so much that particles can appear out of the vacuum. These particles appear in pairs – an electron and its antimatter pair – for a short while and then annihilate mutually, which is well within the laws of quantum physics, as long as the particles only exist fleetingly and disappear when their time is up.

With this bunch of elaborations, including Heisenberg’s Uncertainty Principle’s definition, formulas, a comprehensible example, explanations of applicability and a strange phenomenon, hopefully this legendary Principle has become less complex.

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