The symmetry of physical laws: the CPT theorem for laymen

Let's look at a mirror. Do mirror images follow physical laws as original images do? Mirror images look exactly the same as original images except that left and right are interchanged. And under close examination, there is no evidence that mirror images do not follow Newton's laws.

There are four forces known to exist in our universe: gravity, the electromagnetic force, the strong force, and the weak force. Of these, according to physicists, the first three do not change as left and right are interchanged. Yet the weak force distinguishes between left and right. In other words, when gravity, the electromagnetic force, and the strong force act on an object, the mirror image seems to follow the same physical laws, while this is not the case when the weak force acts on an object. This property of the weak force was verified in an experiment proposed by two Chinese theoretical physicists who received the Nobel Prize in 1957. We will talk about this experiment in our later article "Parity in quantum mechanics." The interchange of left and right is called "parity inversion," and the "P" in "CPT" stands for "parity."

What then, you might ask, does "C" stand for? "C" stands for "charge conjugation," which means interchanging positive electrodes with negative electrodes which in turn results in the interchange of magnetic north poles with magnetic south poles. If a physical law is invariant under charge conjugation, this means that objects will follow the same physical law after the signs of charges are reversed (and the north poles and south poles of magnets are interchanged, consequently). Electromagnetism has been shown to be invariant under charge conjugation. However, not every physical law is C invariant.

Finally, "T" means time reversal. This means that the arrow of time is reversed. Let's say for example that you videotape the movement of an object, and you watch the video. If, as you rewind the video, the movement of the object seems to follow the same physical law as it did during playback, we say that the physical law is T invariant. Gravity is T invariant. If you throw a ball upward, the ball will go up and then come down. If you rewind this, the ball coming down will look like a ball going up, and vice versa. The image will still be that of a ball going up and then coming down. However, not all physical laws are T invariant.

Then what does "CP" mean? It means the combination of charge conjugation and parity inversion. In other words, it means interchanging positive and negative electrodes, north and south poles, and left and right all at the same time. One can then say whether a theory is CP invariant or CP violating.

Similarly, one can see the meaning of "CPT." It means the combination of charge conjugation, parity inversion, and time reversal all in one. In other words, it means interchanging positive and negative electrodes, north and south poles, and left and right, plus reversing the arrow of time. Surprisingly, it was proven in the 1950s that all viable physical laws must be CPT invariant! In other words, a physical law might be C violating, P violating, and T violating, but it should be CPT invariant: if charge conjugation, parity inversion, and time reversal are acted simultaneously, an object will always seem to follow the same physical laws.

Summary

- Charge conjugation means intechanging positive electrodes with negative electrodes and magnetic north poles with magnetic south poles.
- Parity inversion is the interchange of left and right. Out of the four forces known to exist in our universe, only weak force is not invariant under parity inversion.
- Time reversal means the arrow of time is reversed.
- It was proven that all viable physical laws must be CPT invariant.