
The Arrow of Time: Can Time be Reversed?



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ABSTRACT: In the year 1928, Arthur Eddington, a British physicist, first introduced the word “time’s arrow” to physics. He believed that the arrow of time is vividly recognized by consciousness and insisted that the reversal of this arrow would render the physical world nonsensical. It is widely known that the laws of physics remain unchanged under the combination C, P, and T and that the laws of physics do not change with the flow of time but that is not the case under the operation T alone. This paper focuses on mainly three arrows of time, the thermodynamic arrow of time, the psychological arrow of time and the cosmological arrow of time and discusses the reversal of the arrow of time and its implications.

INTRODUCTION

It is a well known paradox that the laws of physics do not change under the flow of time id est the laws of physics are unchanged under the combination of operations C, P, T where C stands for changing particles to antiparticles, P stands for the mirror image and T stands for reversing the direction of motion of all the particles, in effect, running the motion backward. The laws of physics governing the behaviour of matter remain unchanged under the operations C, P and T. It means that life would be the same if we were the mirror image of ourselves and made up of antimatter. Antiparticles are particles that have the same mass as ordinary particles but opposite charge. For e.g. positron is a positively charged electron or the antiparticle of an electron and antineutron is like an ordinary neutron and has a net charge zero but its magnetic polarity is the opposite to that of a spinning neutron. Therefore, if we were to come in direct contact with the other version of ourselves, which is under the operations C, P and T, the most likely outcome would be the annihilation of both of us in a flash of light.

Now the question that arises is, since the laws of physics remain unchanged under the combinations C, P and T, that must be the case under the operation T alone as well. But that is not the case. Even if one observes the direction of time in ordinary life, one realises that there is quite a big difference between the forward and the backward direction of time. For instance, when a cup falls on the floor and breaks into pieces anyone can tell that the time was moving forward. Now imagine, the same cup gathering its pieces back together and returning back to its original form on the table. It is quite hard to imagine since this kind of observation can not be generally made in normal life. This is the simplest example of the backward flow of time. This shows that under the operation T alone, the laws of physics may change contrary to what happened under the condition C, P and T.

THE ARROWS OF TIME

In the year 1928, in his book ‘The Nature of the Physical World’, Arthur Eddington first introduced the word “time’s arrow” to physicists. He believed that the arrow of time is vividly recognized by consciousness and insisted that the reversal of this arrow would render the physical world nonsensical. According to Eddington, the arrow of time indicates the direction of the increase in entropy i.e. the forward progression of time would lead to an increase in entropy and is thus a property of entropy alone. The increase in the randomness or entropy is just an example of the arrow of time. In this paper, mainly three different arrows of time would be covered.

1. The Thermodynamic Arrow of Time:

The thermodynamic arrow of time is the one-way direction or the asymmetry of time. The second law of thermodynamics is based on the fact that the state of disorder of a system or the entropy constantly increases with time. It means that as the time increases, the state of the system would gradually become more disordered if the initial condition of the system was of high order. Therefore, this asymmetry can be used to distinguish between the future and the past although the entropy can not be an accurate measure of time due to several reasons. The entropy of an open system can decrease with time. The second law of thermodynamics is largely true but violations to this law can often be observed at a microscopic level. Since no such violation has ever occurred at a

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larger magnitude, it is not evident whether this law breaks down under any circumstance. If we are to consider that the universe started in a disordered state and would finish at a state of high order, the entropy would gradually decrease with time. However if an observer were to experience this gradual decrease in the entropy of the universe, the psychological arrow of time would also be backwards.

2. The Psychological Arrow of Time:

The psychological arrow of time arises due to the perception made by one's memory which continuously moves from the known past to the unknown future. In simpler terms, the fact that we can remember the past but not the future proves the forward flow of the psychological arrow of time. Memory and perception can not be completely observed or explained in detail and thus the example of the psychological arrow can be explained in context to the memory of a computer which works quite similarly to the human brain but is a lot easier to understand when memory or perception is taken into account. Similar to the human brain, the memory of a computer can remember the past but not the future and as the time goes by, the computer uses the data provided to it to reach a conclusion and thus moves from the state of disorder to a state of high order. To process all this information in the computer, energy is required. This energy, provided to the computer, dissipates as heat energy and increases the entropy or the amount of disorder of the universe. It can thus be observed that while the disorder of the computer memory decreases, the universe moves to the state of higher disorder. This leads to the conclusion that our sense of time i.e. the psychological arrow of time is directly determined by the thermodynamic arrow of time which makes the second law of thermodynamics almost inconsequential. It can thus be noted that entropy increases with time because we measure time in the direction in which entropy increases.

3. Cosmological Arrow of Time:

The cosmological arrow of time progresses in the direction of the expansion of the universe. According to the theory of general relativity, the universe began with a singularity of infinite density where the curvature of space-time was infinite. It is a condition when all the known laws of physics break down and thus they can not be used to predict the conditions which were present when the universe began. It can thus be presumed that the universe started in a state of high order. This would have resulted in the distinct thermodynamic arrow of time. On the contrary, there is an equally high possibility of the universe having started in the state of disorder. In this case, since the universe started in the state of complete disorder, the entropy can not increase with the passage of time and can possibly decrease instead. This would result in the thermodynamic arrow of time pointing in the opposite direction to the cosmological arrow of time. This possibility can not be observed and thus we can conclude that the first case must hold true. The universe started in a state of high order and the entropy increases with time. Furthermore, the psychological arrow of time points in the same direction as the thermodynamic arrow of time and it can thus be concluded that our sense of time would point forward to the direction in which the universe is expanding rather than contracting.

CAN THE ARROW OF TIME BE REVERSED??

The answer to this question is, quite frankly, no. When we talk about the reversal of time, what comes to mind is the contraction of the universe and what would happen if the universe starts to contract. One might presume that the entropy would start decreasing and the universe would ultimately reach the state of high order before reaching singularity but that is not the case. If it were to happen, the universe would enter a time reversal state before recollapsing which is quite hard to imagine. In simpler words it would mean that the life of a person would start with death and end at birth and that one would remember the future rather than the past. This would result in the symmetry of the expanding and the contracting phase of the universe but can not be adopted on its own. Stephen Hawking's no boundary condition implied that the entropy of the universe would continue to increase during the contraction as well and thus both, the psychological arrow of time and the thermodynamic arrow of time can not be reversed. If we take the example of the broken teacup again, the broken fragments can not gather back together and thus form the whole cup again. Due to the same problematic reason, time travel is highly unlikely because for the reversal of time, one would have to bring the entire universe back to the condition of less entropy and since one can not decrease the entropy at a macroscopic level, one can not reverse the arrow of time.

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