The Arrow of Time

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Notes Abstract: Topics of microscopic reversability, macroscopic invariance, information Modern theories are

Consider ball going up and down Velocities appear reversed in time reversal yet acceleration is the same Inconsistency of Newtonian mechanics and electrodynamics —-¿ Special Relativity! :O Non-holonomic constraints?? e.g. bikes???

1 Introduction

What is ThERmoDYnAmiCS?

2 Newtonian Mechanics and Time Reversability

2.1 Subsection

The Newtonian picture of the world, although known to not be an entirely correct view of the world, is a good place to start when considering the symmetries of time due to its simplicity. All processes in this picture are seen to be time-reversal symmetric: a ball, for example, thrown upwards such that its trajectory is a parabolic arc could be filmed and the video, run in reverse, would appear to be as likely to have occurred as the original footage. This is a common starting point for discussing time-reversal symmetries. We start by saying that a process is time-reversal symmetric if the process run in reverse (under the transformation T: t —¿ -t) is a legitimate process according to the laws of the governing theory. In this way, all processes in the Newtonian picture of the world seem to be time-reversal symmetric. A video billiard ball on a frictionless table which knocks into another, setting both balls on new trajectories could be reversed and the situation would look as believable as if it had occurred running forwards in time. This is due to the microscopic reversibility of Newtonian mechanics. Unfortunately, by discussing the motion of billiard balls and other macroscopic processes, we have taken a foray into the one of the simplest violators of time reversibility: friction. Imagine a book slides along a surface. The book will be seen to have some initial velocity which is reduced parabolically until the object is stationary. If this process were filmed and viewed backwards, it would appear non-sensical that an object might go from being stationary to having its velocity increase parabolically. This clearly violates Newton's First Law and therefore shows no time-reversal symmetry.

Before we get ahead of ourselves, we must take a more exact description of the necessary conditions for a process to be time-reversal symmetric. If we suppose that there is some fundamental theory of the world, T, any process can then be described as a sequence of instantaneous events, Si,. . . ,Sf. Then the requirement for the process to happen backwards is simply that the sequence Sf,. . . ,Si must also occur in T.

But how can we know the sequence of instantaneous conditions? Suppose we had a system which was sufficiently small such that we could gather and store all the information we needed to fully define the system (remembering that absolute positions and velocities are possible as we are still in a Newtonian picture and quantum effects are not present). The causal nature of Newtonian mechanics would allow us to determine the later instantaneous conditions in the sequence Si,. . . ,Sf thus we would be able to determine the full sequence from the initial condition.

However, a complete, instantaneous description of the world is not sufficient in the Newtonian picture as the positions and velocities of all particles in the universe (along with non-dynamical properties such as mass and charge) are necessary. The positions and velocities of all the particles in the world at any one instant are not independent of their positions and velocities at other instants therefore this description of the world is not that of an instantaneous state. Consider now a sequence of dynamical states Di,. . . ,Df which fully describe the Newtonian picture of the world. If this sequence describes a particle moving to the left, then its reverse should logically describe the particle moving to the right if the theory is time-reversal symmetric. However, the sequence Df,. . . ,Di (the reverse of the original) would describe the particle moving to the left with its velocity vector pointing to the right which is non-sensical. This suggests that something more complex is required to reverse time than simply the events run in reverse. In this example we must invert the dynamical conditions such that the velocity vector points in the opposite direction. This idea is specific but can be generalised. A sequence of dynamical conditions Di,. . . ,Df must be translated to a sequence of instantaneous states such that they can be reversed. If the Newtonian picture simply requires that the velocity direction is reversed then the commonsensical sequence of instantaneous states Si,. . . ,Sf that we originally used, in reverse, amount to the same as the set of transformed dynamical conditions in reverse such that the more simple sequence can be used (although slightly incorrectly) to describe the Newtonian picture of the world.

2.2 What does it mean to be reversible?

For a theory to be time-symmetric, we expect to observe the same results if time is running forwards or backwards.

If the theory predicts the f

2.3 Equivalence of Statements

2.4 Planck's Proposition and Perpetual Motion of the Second Kind

3 Entropy and the Arrow of Time

It is well known that time has a specific direction; the past is unchangeable and we are left with only memories, whilst the future is not yet determined and we can have no understanding of the future until it arises. This intuitive arrow of time allows us to distinguish whether a video of a burning fire is played in reverse and is our natural interpretation of entropy and the laws of thermodynamics.

Mention time assymmetry of only the 2nd law

3.1 Principle of Microscopic Reversability

3.2 Loschmidt's Paradox

In 1876, Johannn Josef Loschmidt argued that it should not be possible

4 Information Theory

5 Uses of the Second Law in the Explanation of Natural Phenomena

5.1 Brownian Motion

5.2 Osmosis

6 Appendix

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