MANY-MINDS RELATIVITY

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Main Objective

> Why is it that nobody understands me, and everybody likes me? (Einstein in *New York Times*, March 12, 1944)

> The King of Kings (Halie Selassie, Emperor of Ethiopia 1930-1974), preferred bad ministers. And the King of Kings preferred them because he liked to appear in a favorable light by contrast. How could he show himself favorably if he was surrounded by good ministers?.... Instead of one Sun, fifty would be shining, and everybody would pay homage to a privately chosen planet. No, my dear friend, you cannot expose the people to such disastrous freedom. There can only one sun. Such is the order of the nature, and anything else is a heresy. (Ryszard Kapuściński in *The Emperor*)

1.1 A Case Study of Mathematical Modeling

As a part of the Body&Soul Applied Mathematics educational program, we consider in this book the theory of *special relativity* proposed by Albert Einstein (1879-1955) in 1905. Our purpose is to exhibit fundamental aspects of mathematical modeling of the physical world we live in, through a careful study of special relativity. We choose to study special relativity because (i) relativity theory is supposed to form the foundation of modern physics, and (ii) relativity is not easy to understand. If we cannot understand the foundation, how can we understand what is built on it? We thus invite the reader to an experience of learning with the goal of understanding special relativity theory as a mathematical model of certain fundamental aspects of the World we live in. We start with open minds with a scientific attitude of only accepting what we can understand on good grounds, and not accepting anything by mere authority, and we will see where we end up. We promise that the reader will be surprised many times as we go along.

A *mathematical model* of some physical phenomenon builds on certain *basic assumptions* and derives by rules of logic and mathematical computation consequences of the basic assumptions, typically in the form of certain *output* from the model from certain *input* to the model. The basic assumption may be *Newton's 2nd Law* with input consisting of the position and velocity of an object at an initial time combined with the force acting on the object and its mass, and the output may be the position and velocity at a later time. From *Newton's law of gravitation*

$$F = \frac{Gm_1m_2}{r^2} \tag{1.1}$$

where F is the gravitational force between two bodies of mass m_1 and m_2 at distance r and G is the gravitational constant ($\approx$ 9.81 meter per second^2), you can e.g. predict by mathematical computation the coming position of the planets in our Solar system from their current positions and velocities. But there is little hook: You also have to put in as data the mass of each planet and the Sun (and the gravitational constant G). And how do you determine the masses of the planets, when you cannot put them on a scale? Nevertheless, Newton's theory of graviation became an immense success, which boosted mathematics and science based on mathematical modeling forming the basis of both the industrial society and the information society of today.

In this case study of mathematical modeling, we shall focus on the following questions:

- What motivated the development of special relativity?
- What are the basic assumptions of special relativity?
- What is the nature of these assumptions?
- What are the basic consequences of these assumptions?
- How can we test if the basic assumptions are valid?
- Is there an alternative to special relativity?

1.2 Inspiration

To get some inspiration from the sources browse through the following clips:

- A somewhat unfamiliar conception for the average mind.
- Einstein: How I see the World Part 1, 2, 3, 4, 5, 6.
- Einstein's Strike of Genius.
- Relativity for Dummies.
- The Train Paradox.
- The Twin Paradox.
- The Lorentz-Einstein Transformation
- Lorentz transformation 1, 2.
- Time Dilation Explained.

1.3 How It Started

Suppose two observers X and X' measure the speed of light, and both come to the same result of 300.000.000 meter per second. Would this be shocking? Would it not be more disturbing if they came to different conclusions? In any case, this was the upshot of Einstein's special relativity based on the assumption that all observers will agree on the speed of light.

This is like if in politics a rightist and leftist came to agree on something. Would that be shocking? Would you have to revise the whole political system if that happened? Probably not, but we shall see that in physics the agreement on the speed of light led to a crisis out of which the theory of relativity emerged.

1.4 Is Relativity a Physical Theory?

We shall find that what makes relativity theory so difficult to grasp is that it is not clear if it is a physical theory about the physical world we live in, or if it is a purely mathematical theory only concerned with mathematical form free from physics. We shall see that the answer is ambigous: Relativity is sometimes a purely mathematical theory and sometimes a physical theory and sometimes both.

The beauty of a *purely mathematical theory* is that it is true by definition and logic, as long as it is not contradictory. You cannot prove that $1+1=10$ by putting two mice in a cage and observing that after a while you have 10. Neither can you prove that $1+1=2$ by counting apples. We know that $1+1=2$, by definition, since 2 is just shorthand for $1+1$. More precisely, an (ideal) mathematical theory results from logical reasoning applied to a set of basic (non-contradictory) *axioms* or basic assumptions. *Euclidean geometry* is the basic example of such an axiomatic ideal mathematical theory, one of the axioms being that through two distinct *points* there is a unique *straight line*, with the concepts of point and straight line left undefined. To turn a mathematical theoy into a *physical theory*, you have to give the axioms a physical meaning. If you cannot do that, it is not a physical theory.

We understand that we have to go to the axioms or basic principles of relativity and analyze their form and content. If they are purely mathematical, only a purely mathematical theory can come out.

1.5 The Role of Coordinate Systems

We shall see that in relativity theory there is a lot of discussion about *coordinate systems* and observations made by different observers using different coordinate systems. So it is useful to understand the concept of coordinate system. Of course, everybody is familiar with coordinate systems for the Euclidean plane, right? You take two perpendicular axes, each a copy of the *real line* of *real numbers* $\mathbb{R}$. You can then label each point in the plane with two *coordinates* (x_1, x_2) as a *pair of real numbers.*

From a purely mathematical point of view you can say that the Euclidean plane $\mathbb{R}^2$ consists of all the pairs of real numbers (x_1, x_2), which represent *points* or *vectors*, and you can say that the line $\{(x_1, x_2) : x_2 = 0\}$ represents the x_1-axis consisting of all multiples of the (unit) vector $e_1 = (1, 0)$, and the line $\{(x_1, x_2) : x_1 = 0\}$ represents the x_2-axis consisting of all multiples of the unit vector $e_2 = (0, 1)$. By standard rules of computation you can then express each vector $(x_1, x_2) = x_1e_1 + x_2e_2$ as a *linear combination* of e_1 and e_2, which you refer to as *basis vectors.*

So far all this is purely mathematical: We consider $\mathbb{R}^2$ as the set of all pairs of real numbers without any connection to physical reality. We know that we can introduce different bases for $\mathbb{R}^2$, e.g. by translating the origin and changing the direction of the basis vectors. Thus there are many different bases for $\mathbb{R}^2$. Any two non-zero non-parallel vectors can be chosen as a basis.

Now, you can make *geometrical interpretation* of $\mathbb{R}^2$ as the *Euclidean plane* of *Euclidean geometry.* Or rather the opposite since in Euclidean geometry objects like points, lines and planes are not defined, but introduced through the axioms. What Descartes did in his revolutionary *analytical geometry*, was to give Euclidean geometry in the plane an interpretation using $\mathbb{R}^2$ as defined above. Descartes thus *digitized* geometry in the sense that geometrical relations were translated into relations between numbers or coordinates This digital revolution continues today with words, pictures, music all digitized.

But interpreting the Euclidean plane as $\mathbb{R}^2$ is still purely mathematical. To make it physical we have to give a physical interpretation of $\mathbb{R}^2$ as something like a black-board with each dot of chalk representing a point, and a vector an arrow of chalk dots. After having made this interpretation we can using analytical geometry to compute relations about collections of chalk dots on the board, such as lines, triangles and even curves. For example, we may say that a circle around the origin of radius 1 is the collection of chalk dots whose coordinates (x_1, x_2) satisfy the relation $x_1^2 + x_2^2 = 1$.

If we now interprete $\mathbb{R}^2$ as a (big flat) black-board, we understand that we can use different coordinate systems on the black-board, and that different observers can choose different coordinate systems with different basis vectors, and thus that one and the same chalk dot can be assigned different coordinates depending of the choice of basis. This is elementary *linear algebra*, where you in particular study *coordinate transformations* from one set of coordinates or basis to another. Often you choose perpendicular basis vectors and the coordinate transformations express the relation between coordinates after *translation* and *rotation* of coordinate systems.

We shall see that the ambiguity (and difficulty) of relativity comes from ambiguous nature of coordinate transformations, where it is never clear if the coordinate transformation is a formal mathematical relation or has a physical meaning. We shall see that this is truly confusing, and makes necessary to really dig into the meaning and nature of the basic assumptions of relativity.

Doing so will give us a valuable insight into of the nature of mathematical modeling and in particular we shall discover pitfalls which we have to avoid if we want to be rational scientists.

When studying the basic assumptions of a theory, it is useful not only seek to check their validity, but also to understand *why* a certain assumption was made. Assumptions are not made at random, but reflect some experience or (perceived) necessity to get around some (perceived) difficulty.

1.6 Is there an Aether?

We now return to the basic assumption of special relativity that different observers moving with constant velocity with respect to each other, using different *inertial coordinate systems* connected by uniform translation (without rotation), will agree on the *speed of light.* In short the basic assumption of the special theory of relativity is:

(r) *All observers measure the same speed of light.*

Let us compare with the following hypothetical basic assumption of acoustics:

(s) *All observers measure the same speed of sound.*

We know that the speed of sound is about 340 meter per second at sea level air pressure, and of course all observers at sea level should get this value. If somebody does not, we would blame it on the some measurement error.

What is now the difference between propagation of light and sound? Well, we know that sound propagates through air, by pressure variations, and thus there is a *medium*, that is air, through which sound waves propagate. We know the frequency of sound from a source moving through the air, changes by the Doppler effect. Further, an observer moving with respect to the air medium can measure a different speed of sound; in a supersonic jet plane it appears that the speed of sound is even negative, since the plane is moving faster than sound leaving it To measure the speed of sound properly, you would thus have to be at rest with respect to the air, or otherwise properly adjust your measurements according to your motion through the air.

Now, is there a corresponding material medium through which light, which we know is a form of of electromagnetic waves, propagates? In other words, is there an *aether* common to all observers?

This was the basic question posed to physics in the late 19th century after the discovery of electromagnetic waves described by *Maxwell's equations.* But nobody could figure what this kind of aether medium could be, but simply *vacuum*, or *empty space.* Michelson and Morley tried in famous experiments in 1887 detect a difference in the speed of light depending on the changing motion of the Earth around the Sun, but got too small results to support the idea of some form of aether medium through which the Earth was moving. This posed a troublesome question to physics: If there is no aether, how can electromagnetic waves propagate?

We shall see that this question can be approached in two different ways, one is Einstein's special relativity, and the other is the *many-minds relativity* presented in this book. In many-minds relativity you simply say: OK, there is no common aether, but each observer assumes that light propagets according to Maxwell's equations in a coordinate system, or a vaccuum, fixed to the observer. Different observers moving with respect to each other, thus use different coordinate systems or different vacui, but they all use the same Maxwell's equations. Then all observers will agree on the speed of light, and the non-existence of an aether is taken care of. We believe this is a simple and natural resolution of a dilemma. We believe the resolution should be simple, since it should not be a problem when observers agree on observations, only when they don't, just as in politics!

However, Einstein did not choose this way out, but another much more cumbersome route, as we will discover. The basic assumption of special relativity is thus (r) combined with the conviction that *there is no aether* or vacuum.

1.7 Einstein's Assumption vs the SI Standard

Let us now analyze the form of (r). What kind of statement is it? Is it a stipulation which observers have to obey, or does it express physical experience? In other words, is it purely mathematical or real physical? To seek an answer, let's see if we can express (r) more precisely: *Speed* is defined as *distance* or *length* per *time unit*, and so to measure speed we have to measure length in space and duration in time. The classical way to measure length is using a *meter stick*, calibrated to the *Archive meter* in Paris, and time is measured by a mechanical clock synchronized with some mechanical reference clock. This was the situation at the beginning of the 20th century, when special relativity was created. Observers thus were supposed to be equipped with identical meter sticks and clocks and allowed to move with respect to each other with constant velocity, yet measure the same speed of light. Out of this came special relativity with new strange effects of meter sticks shortening and clocks slowing down by uniform translatory motion. The basic question was if these strange effects were real physical as if (r) was a physical fact, or only fictional mathematical as if (r) was only a stipulation? We shall see below that no clear answer was ever given.

Let us now view (r) in the light of how distance and time are measured today, which is not by meter sticks and mechanical clocks: According to the generally adopted *1983 SI Standard*, time is measured in *seconds* according to atomic cesium clocks showing Coordinated Universal Time (UTC), coordinated in Paris by the International Bureau of Weights and Measures, and length is measured in *meters* with one meter being the distance traveled by light in 0.000000003335640952 seconds or 9192631770/299792458 cycles of a cesium clock. This is in particular the standard of the GPS system working so amazingly well. Equivalently, the length standard can be chosen as *lightsecond* or 299792458 meters. With the SI Standard the speed of light is 1 lightsecond/second, and thus all observers following the SI Standard, possibly moving with respect to each other, will agree on the same speed of light, namely 1 lightsecond/second. The constancy of the speed of light today is thus a matter of definition, or agreement, or stipulation, and not physical observation.

We thus understand that today the interpretation of (r) must be mathematical in the form of a definition reflecting a common standard of how to measure length and time. But if today (r) is mathematical and not physical, then consequences today will also be mathematical and not physical, and thus we are led to the suspicion that today special relativity is not a physical theory. But was special relativity a physical theory at the start and when did it cease to be, if it did? We will seek answers below.

We may compare with the definition or agreement that there are 100 centimeters on each meter, which has nothing to do with physics, of course. If someone comes up and tells you that he/she has measured that there are only 99 centimeters on 1 meter, you will probably laugh and say that this person is confused and has not properly understood the definitions.

We repeat, today the constancy of the speed of light for all observers is a matter of definition of length and time units, and thus has nothing to do with physics of light propagation. Of course, the pertinent question is to what extent different observers moving with respect to each other using the SI Standard, effectively will agree on length and time. We will consider this question in detail below.

Even if today (r) is mathematical and we therefore suspect that special relativity is no longer a physical theory, this was not so clear in the beginning of the 20th century. What gave special relativity such a formidable boost to form a new foundation of modern physics, was its pretension to reveal new fundamental physical aspects of space and time. In this light (r) would have a physical meaning, and the role of the physicist would be to figure out its physical meaning. This would be similar to first saying something, and then figuring out what the meaning may be, instead of first forming a meaning and then saying it.

1.8 Basic Questions

In this book we will follow the struggle of mathematicians and physicists to understand the meaning and consequences of the basic assumption (r) formulated by Einstein in 1905. We will in particular consider the following natural questions in addition to the ones listed above:

- To what extent can different observers using the SI Standard be expected to agree on distances betweeen physical objects and time duration between physical events?
- Is the GPS system based on special relativity?
- Is (r) mathematical or physical?

1.9 Confusion and Illusion

No scientific subject is surrounded with so much confusion as relativity. There are an endless number of popular science books presenting this state of confusion as a sign of scientific depth and truth. We cite from the recent National Bestseller *The Fabric of Cosmos* by the physicist Brian Greene from 2004:

- *The relativity of space and time is a startling conclusion. I have known it for more than 25 year, but even so, whenever I quietly sit and think it through, I am amazed.*
- *Einstein believed that reality embraces past, present, and future equally and that the flow of time we envision is illusory.*

- *Over the course of a few intense weeks in the spring of 1905, Einstein determined that space and time are not independent but are enmeshed in a manner that flies in the face of common experience.*
- *Most discussions of special relativity focus on what would happen if we traveled at speeds near that of light.*
- *Physcists spend a large part of their lives in a state of confusion.*
- *Features of space and time that for many of us are second nature have turned out to be figments of false Newtonian perspective.*
- *Many of today's leading physicist suspect that space and time, although pervasive, may not be truly fundamental.*
- *Physcists sometimes sum up this possibility by saying that spacetime may be an illusion.*

Books like this invariably get positive reviews indicating that at least the reviewer is not confused:

- *Greene's book is written in a colloquial language that anyone can understand. (New York Review of Books)*
- *The best exposition and explanation of early 21st century research into the fundamental nature of the universe as you are likely to find anywhere. (Science)*

But if the author/physicist is confused, how can the reviewer/reader not be? In other books, the incomprehensibility is made into a virtue [45]:

- *One might very well be left with the impression that the theory (of general relativity) itself is rather hollow.: What are the postulates of the theory? What are the demonstrations that else follows from these postulates? Where is the theory proven? On what grounds, if any, should one believe the theory? ....One's mental picture of the theory is this nebulous mass taken as a whole.....One makes no attempt to derive the rest of the theory from the postulates. (What, indeed, could it mean to "derive" something about the physical world?). One makes no attempt to "prove" the theory, or any part of it.*

Figure 1.1: Einstein and Lorentz in 1921.

Einstein acceptance in Cambridge was not immediate. G. F. Searle was the only physicist in England who tried to read Einstein, before the breakthrough in 1919. He writes in a letter to Einstein in 1909:

- *I am sorry that I have so long delayed to write to thank you for sending me…a copy of your paper on the principle of relativity. I have not been able to gain any really clear idea to the principles involved or as to their meaning and those to whom I have spoken in England about the subject seem to have the same feeling.*

Chapter 2

Many-Minds Relativity

> How is it that there are so many minds that are incapable of understanding mathematics? (Poincaré [94])
>
> It is not the depth of mathematics that makes Einstein's relativity challenging. It is the degree to which the ideas are foreign and apparently inconsistent with our everyday experience. (Brian Greene in [47])
>
> But no Anglo-Saxon can understand relativity. (Wilhelm Wien)

2.1 An Apology

As an outcome of the learning experience of this book, we shall be led to formulate an alternative to the special theory of relativity which we refer to as *many-minds relativity* [62, 63]. We ask the reader, in particular a possibly critical physicist, take this with a good grain of salt and to view many-minds relativity simply as an exercise in our study aimed at illustrating basic aspects of relativity. We thus do not at all claim that many-minds relativity is a new revolutionary theory, for some reason missed by physicists, which will change the world. We only want to put forward, in all modesty for the purpose of discussion, a concrete alternative to special relativity and Lorentz invariance of coping with the experiment of Michelson-Morley. Thus, if many-minds relativity sounds pretentious, we ask the reader to change the volume control and simply view it as a little "thought experiment" for illustration.

Maybe some physicists will consider this book to present a caricature picture of special relativity, and this may be correct: We have emphasized certain aspects, in quotations and the presentation which may give a biased view, but a good caricature may capture something essential. We thus encourage the reader to look into other presentations of special relativity, and there are many, to get a better balance.

Many-minds relativity is not a new idea: Already in 1907 the Cambridge physicist Ebenezer Cunningham stated in *The Structure of the Ether* (Nature 76:222.):

- *The aether is in fact, not a medium with an objective reality, but a mental image which is only unique under certain limitations...Two frames of reference imply two aethers.*

However, Einstein's bold dismissal of the aether as non-existing altogether, was more impressive than Cunningham's more low-key multivalued many-minds aether. We present below evidence that Cunningham's approach makes a lot of sense, while Einstein's does not. Without some form of (non-material) aether, electromagnetic waves and light cannot propagate and thus cannot be subject to observation. But we see light at the end of the tunnel...

2.2 Towards a Unified Field Theory

Our motivation to seek an alternative comes from the fact that Einstein's relativity does not naturally combine with *quantum mechanics* into a *unified field theory* including both gravitation and electro magnetics. Special relativity is based on *invariance* with respect to the *Lorentz transformation* or *Lorentz invariance*, while the basis of quantum mechanics, *Schrödinger's equation*, is not Lorentz invariant. There is a version of quantum mechanics which is Lorentz invariant in the form of *Dirac's* equation, but no version combining with general relativity. The incompatibility of relativity theory for gravitation and quantum mechanics has remained as the basic open problem of physics since the birth of quantum mechanics in 1925:

- *But now we are stuck...For decades we had no mathematically satisfactory quantum theory of gravitation.* (Steven Weinberg, Nobel Prize for Physics 1979, [108])

- *The theory of relativity and the quantum theory seem little adapted to fusion into one unified theory.* (Einstein [37])

- *Quantum mechanics is known to be inconsistent with general relativity.* (David Lindley [76])

- *By the 1940s Einstein and a few others who still pursued a unified field theory were mostly laughed at.* (Lee Smolin [100])

- *The first great unsolved problem in theoretical physics is to combine general relativity and quantum theory.* (Lee Smolin [100])

- *We do not yet have a complete consistent theory that unifies general relativity and quantum mechanics, but we do know a number of features it should have.* (Stephen Hawking [51])

- *The modern physicist is quantum theorist on Monday, Wednesday and Friday, and a student of gravitational relativity on Tuesday, Thursday and Saturday. On Sunday the physicist is neither but is praying to his God that someone, preferably himself, will find the reconciliation between these two views.* (Norbert Wiener [109])

In many-minds relativity Lorentz invariance has no role, which may open to a natural combination with quantum mechanics. In such a combination it is natural to extend the many-minds aspect to also quantum mechanics, and thus open to a unified field theory as a combination of many-minds relativity and *many-minds quantum mechanics*. In this book we focus on many-minds relativity, but we also present some elements of many-minds quantum mechanics, which is developed in more detail in [57], while we leave many-minds unified field theory for possible future work.

We do not use the concept of Lorentz invariance, not only because it is not possible to combine with Schrödinger's quantum mechanics, but even more fundamentally, because the Lorentz transformation is a mathematical construct, for which the physical interpretation has kept oscillating between mere illusion and contradictory reality ever since it was first introduced by Voigt in 1887 [107], in the writing by many including the the Dutch physicist Hendrik Lorentz (1853-1928, Nobel Prize in Physics 1902), the French mathematician Henri Poincaré (1854-1912), who named the transformation after Lorentz, and Einstein himself.

To dismiss Lorentz invariance must be shocking, and probably even laughable, to physicists trained to consider (non-trivial) Lorentz invariance as the incarnation of modern physics, as compared to classical physics based on

Figure 2.1: Einstein 1900:*I neglected mathematics...because my intuition was not strong enough to differentiate the fundamentally important from the dispensable erudition...[39]*

(trivial) *Galilean invariance.* In any case, we show that many-minds relativity offers a solution, using only (trivial) Galilean invariance, of the same basic problem that led Einstein to his special relativity based on the supposed Lorenz invariance of all “laws of nature”.

As a key reference to special relativity we use the text book [8] by Max Born (1882-1970), who received the Nobel Prize in Physics in 1954 for his work on quantum mechanics. This book is a revised version of notes from a series of lectures by Born at Frankfurt an Main in 1920: *To a large audience when a wave of popular interest in the theory of relativity and in Einstein's personality had spread around the world following the first confirmation by a British solar-eclipse expedition of Einstein's prediction that a beam of light should be bent by the gravitational action of the sun. Though sensationalism was probably the main cause of this interest, there was also a considerable and genuine desire to understand* (from Preface of [8]).

We have found Born's presentation very useful in our “genuine desire to understand” special relativity, and we refer to it many times below. Born and Einstein kept a long friendship through a correspondence documented in [7]. They quarrelled about quantum mechanics with Einstein heavily protesting to Born's statistical interpretation, but never about Einstein's relativity, which Born accepted without any protest.

We now proceed to present an introduction to basic aspects of the concept of *many-minds* as opposed to *one-mind.* But first, let us get into mood by recalling the big picture painted by the famous historian Paul Johnson in his monumental treatise *Modern Times* from 1983 presenting Einstein as the greatest scientist of all times:

2.3 Modern Times by Paul Johnson

The modern world began on May 29 1919 when photographs of a solar eclipse taken on the island of Principe off West Africa and at Sobral in Brazil, confirmed the truth of a new theory of the universe. It had been apparent for half a century that the Newtonian cosmology was in need of serious modifications. It had stood for more than 200 years. It was the framework within which the European Enlightenment, the Industrial Revolution, and the vast expansion of human knowledge, freedom and prosperity which characterized the 19th century, had taken place. But increasingly powerful telescopes were revealing anomalies.

The originality of Einstein, amounting to a form of genius, and the curious elegance of his lines of argument, which colleagues compared to kind of art, aroused worldwide interest. In 1907 he published a demonstration that all mass has energy, encapsulated in the equation $E = mc^2$, which a later age saw as the starting point in the race for the atomic bomb. Einstein's theory aroused enormous interest throughout the world in 1919. No exercise in scientific verification, before or since, has ever attracted so many headlines or become a topic of universal conversation. From that moment onward, Einstein was a global hero, in demand at every great university in the world, mobbed wherever he went, his wistful features familiar to hundreds of millions, the archetype of the abstracted philosopher. The impact of his theory was immediate, and cumulative immensurable.

We shall below scrutinize the following (partly contradictory) aspects of Paul Johnson's description of Einstein and his work: "a form of genius", "curious", "kind of art", "enormous interest", "global hero", "mobbed", "abstracted philosopher", "immensurable impact".

2.4 One-Mind vs Many-Minds

We know that the *geo-centric* view of the World with the Earth in the center was replaced by Copernicus, Kepler and Galileo by a *helio-centric* view with the Sun in the center, while astronomers of today see no center at all in an expanding Universe of hundreds of millions of galaxies moving away from each other with velocities increasing with distance, which can be described as a *many-centers* view.

Thus, physicists have given up geo-centricity for a many-centers view, but have kept a principle of *objectivity* in the form of objective observations by objective observers of an objective reality. Each observer uses one or several coordinate systems, and so the observations in different coordinate systems by one observer or by several observers, may come out differently, but should conform to a unique existing objective reality. Specifically, a basic principle is that of a *one-mind* view of an *ideal physicist* capable of making conforming observations in different coordinate systems of a unique objective reality.

This is of course a desirable feature of a scientific theory, and may be maintained in many cases, but special relativity came out as an attempt to combine this principle with observations indicating that

(r1) *the speed of light is independent of the motion of the source,*

Figure 2.2: Einstein as a child: *Great spirits have always found violent opposition from mediocrities. The latter cannot understand it when a man does not thoughtlessly submit to hereditary prejudices but honestly and courageously uses his intelligence [39].*

(r2) *detection of a common aether is impossible.*

An *common aether* would be a unique “luminiferous material medium” common to all observers, through which light would propagate with constant velocity independent of the motion of the source, thus satisfying (r1). The aether would thus be an analog for propagation of light, to air as the material medium for the propagation of sound.

If there was a material aether, of some sort, it should be possible to detect its presence by comparing observations of the speed of light of different observers moving with different velocities with respect to each other and thereby with different velocities through the common aether and subject to different “aether winds”.

Michelson and Morley made experiments in 1887 to determine variations in the aether wind of the Earth on its path around the Sun, but the variations were less than one quarter of the results compatible with the existence of a (stationary) aether, as if the Earth all the time was (more or less) at rest with the aether or alternatively “dragging the aether along” (more or less). The experiments were repeated by Miller in the 1920s with similar results. Thus (r2) has a strong experimental support, while this is less clear for (r1), since slight variations in the speed of light were obtained. Nevertheless, the Michelson-Morley-Miller experiments are commonly considered to support not only (r2) but also (r1).

In many-minds relativity we only use (r2), which thus has experimental support, while we turn (r1) into a definition not requiring any experimental support, simply by using *lightsecond* as length scale. We thus avoid the difficulty of the weak experimental support of (r1), which has been subject to strong criticism by many, including Nobel Laureate Maurice Allais (as will see below). We may formulate (r2) in short as: *there is no (material) aether*, which is the form used by Einstein.

But if there is no material aether through which light can propagate, then (r1) would seem inexplicable, and thus (r1) and (r2) would seem contradictory. This was the starting point of Einstein which led to special relativity as a reconciliation of the apparent contradiction of (r1) and (r2), assuming a one-mind view.

Many-minds relativity offers a different reconciliation of (r1) and (r2), where each observer considers light to propagate with unit speed through a *vacuum* or *non-material aether*, which is at rest relative to the observer. Since different observers may move with with respect to each other, this

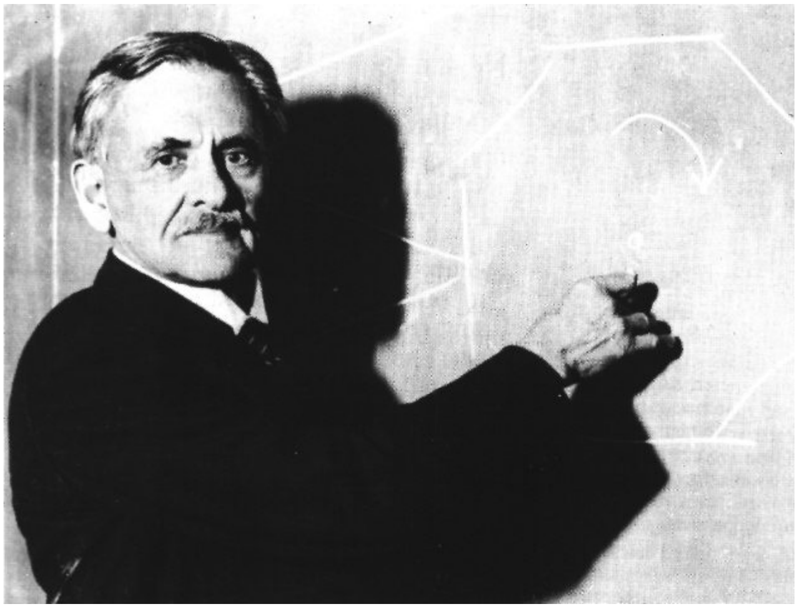


Figure 2.3: Michelson:*I cannot really detect any aether wind in my experiments.*

represents a many-minds view with no vacuum common to all observers.

We shall below see that such a many-minds view naturally may be adopted for *Maxwell's equations*, which is the fundamental mathematical model for electro-magnetic wave propagation (such as light), in different vacuui for different observers. We thus use the many-minds view to allow each observer to express Maxwell's equations in a coordinate system representing an immaterial vacuum in which the observer is at rest, and the main question concerns the coordination of the observations of different observers using different coordinate systems or vacui moving with respect to each other.

Einsteins resolution boils down to the Lorentz transformation, which Einstein borrowed from Lorentz and Poincaré, and then claimed to connect space-time observations by one observer or one-mind in different *inertial coordinate systems* moving with constant velocity with respect to each other, with effects of *length contraction* and *time dilation.* The official standpoint today in the physics community, is that these effects are real and not just illusions from coordinate transformation. However, this represents a cover up of a different reality:

- Born: *Length contraction and time dilation are ways of regarding things and do not correspond to physical reality.*
- Lorentz: *A transformation of the time was necessary. So I introduced the conception of a local time which is different for all systems of reference which are in motion relative to each other. But I never thought that this had anything to do with real time. This real time for me was still represented by the old classical notion of an absolute time, which is independent of any reference to special frames of coordinates. There existed for me only this true time. I considered my time transformation only as a heuristic working hypothesis* [80].
- Sartori: *Poincaré never spells out how he interpretes the primed coordinates in the Lorentz transformation....and like Lorentz believes in local time....* [96].
- Einstein in 1911: *The question whether the Lorentz contraction does or does not exist is confusing. It does not really exist in so far as it does not exist for an observer who moves (with the rod);* **it really exists***, however, in the sense that it can* **as a matter of principle be demonstrated** *by a resting observer* [26, 89].

We understand that both Born, Lorentz and Poincaré consider the Lorentz transformation to be a mathematical construct without any real physical correspondence, and thus consider the space contraction and time dilation of special relativity resulting from the Lorentz transformation, to be matters of mathematical definition and not falsifiable physical reality. We see that Einstein in 1911 expresses an ambigous position: The Lorentz contraction is both real and not real, and it is real "as a matter of (mathematical) principle". We will come back below to the question if it really is possible to "demonstrate" the existence of some reality "as a matter of principle", as a central question in philosophy and epistemology.

But the complexity of this question was not properly understood by Einstein in 1905, when he as a young clerk at the patent office in Bern boldly put forward special relativity as a physical interpretation of the Lorentz transformation: The Lorentz contraction was a reality to Einstein in 1905 (but less so in 1911).

We shall below very clearly understand, together with the mathematical genius Poincaré, that the realm of the Lorentz transformation is not of this world, and thus that special relativity does not concern any reality. But Einstein, as an ambitious autodidact without much of mathematical training, could not clearly separate mathematics from physics, and in his ambition he was led to an over-interpretation of a simple mathematical transformation, into (supposedly) nothing less than a whole new foundation of physics of relativity replacing classical Newtonian mechanics.

In his dark moments, and they were quite many, even Einstein doubted the physical reality of special relativity, as indicated in the above citation. But both Born and Einstein officially kept a low profile on the illusionary characters of relativity, and did not argue about it in their correspondence.

The starting point of this book is the realization following Born, Lorentz and Poincaré, that the Lorentz transformation is not a transformation between two coordinate systems of equal physical stature, in contrast to Einstein's belief of 1905. Thus special relativity is a non-physical theory and a different reconciliation of (r1) and (r2) must be sought: Many-minds relativity then naturally suggests itself.

An essential aspect of many-minds relativity is the distinction between *essential* and *inessential information* related to a given physical system. The essential information typically is that needed for the physical system to evolve in time following the relevant laws of physics, even without any observations by external (human) observers, while inessential information may be information beyond essential information. In many-minds relativity, different observers agree on essential information, but may disagree on inessential information (more or less) and thus different observers may have partially different views representing a *many-minds view*. We illustrate the main point in the following example.

2.5 A Many-Minds Monetary Market

We consider a currency market with different currencies $A, B, C, ...$, such as US Dollars, British Pounds, Swedish Crowns, Russian Rubel and Japanse Yen. The market establishes for each pair of currencies through the operation of the corresponding pair of central banks, an *exchange rate*, for example two Dollars for one Pound (omitting exchange costs). This is obviously a many-minds or many-banks/currencies market.

Now, for the market to function, it is essential that any two central banks, say bank A and B, agree on the exchange rate between their mutual currencies

A and B. However, it is inessential what exchange rate a third bank C would set between currency A and B, since all exchange of currencies A and B would be handled by the banks A and B, and C would not be involved in such a transaction, only in exchange with currency C. This is the way a currency market functions. To require that all banks should agree on all exchange rates, which is requiring more than necessary for the market to function, would most likely result in endless negotiations without convergence and the market would not come to existence. We understand in this example the importance of the notion of essential information, typically representing a *minimum of information* for the system to function.

2.6 A Many-Minds Gravitational Market

The basic model of many-minds relativity concerns a collection of bodies $A, B, C, ...$ interacting by gravitational forces according to Newton's laws. In this case the essential information concerns the length and direction of the vector connecting any pair of bodies. Thus body A and B would have to agree on their mutual distance and direction, but not necessarily on the inessential information of distance and direction to a third body C, since Newton's laws concerns mutual interaction between pairs, just as exchange of currencies does. We shall see that in many-minds relativity, indeed there is no agreement on inessential information, which however does not affect the physics requiring only agreement on essential information.

2.7 Many-Minds Relativity

In many-minds relativity, different observers fixed to different coordinate systems moving with respect to each other, may have different inessential perceptions of space by using different systems of coordinates in space, but they will agree on the essential information, which typically includes mutual distance/direction and time. With classical terminology all observers will thus share a common *absolute time*, but there will be no *absolute space with an absolute length scale* shared by everybody. Thus many-minds relativity represents a departure from classical Newtonian mechanics based on an absolute length scale shared by all observers.

In many-minds relativity, each observer assumes that light propagates through a vacuum at rest in the observers coordinate system. Different observers moving with respect to each other thus will use different vacuui, which effectively means that there will be no vacuum or absolute space common to all observers. Each observer may thus for his/her own convenience assume the presence of an aether fixed to the observers coordinate system, but this medium has no physical correspondence and is just a fictional aether represented by the space coordinate system used to express Maxwell's equations. Without any aether, there would be no space coordinates and Maxwell's equations would have no meaning. We can thus identify "aether" with space coordinate system and we immediately understand that there are as many aethers as there are space coordinate systems.

A many-minds view is more flexible and thereby possibly more useful, than a one-mind view, as shown in the currency market example. Thus. there is no reason to ask that observations by humans in a coordinate system fixed to the Earth, or our Solar system or our galaxy, should be in full conformity with observations by humans in a coordinate system fixed to a planet or planetary system in a far away galaxy (or a fast particle in a particle accelerator), the latter anyway being impossible to perform.

In particular, a many-minds view allows a physical system based on exchange of certain essential information, to exist even without any human observers, reflecting that the Earth (probably) orbits the Sun the same way regardless if humans make observations or not.

Thus, in a many-minds approach, the observer takes a passive role, or is simply non-existent leaving the physics to the physics. This is very different from Heisenberg's interpretation of quantum mechanics, which beyond observation by humans has no existence of its own.

2.8 Einstein Cartoons

No other scientist has so many cartoons as Einstein, today offered on many commercial web-sites evidently in strong demand. Of course Einstein invites to jokes: What he says is completely incomprehensible and beyond any reason, he looks like a caricature of an absent-minded professor without connection to realities, while everybody knows that he has changed our entire world view making us all believe in "curved space-time", whatever that means.

We just give one example below, and let the reader judge if it is funny, or just tragic. It seems natural to ask if the many Einstein jokes reveal an (unconscious) insight that Einstein's science in fact is a joke, a truth which is so hard to take (for humanity) that it cannot be expressed bluntly as a matter of fact, but only in humorous form with the truth hidden in the joke? Maybe Sigmund Freud's treatise *Jokes and Their Relation to the Unconscious* from 1905 can give an answer?

2.9 Einstein Anecdotes

There are also very many Einstein anecdotes. We recall typical ones:

- *In 1931 Charlie Chaplin invited Einstein, who was visiting Hollywood, to a private screening of his new film City Lights. As the two men drove into town together, passersby waved and cheered. Chaplin turned to his guest and explained: "The people are applauding you because none of them understands you, and applauding me because everybody understands me."*

- *One of Einstein's colleagues asked him for his telephone number. Einstein reached for a directory and looked it up. "You don't remember your own number?" the man asked, startled. "No," Einstein answered. "Why should I memorize something I can so easily get from a book".*

- *Scientific American once ran a competition offering several thousand dollars for the best explanation of Einstein's general theory of relativity in three thousand words. "I am the only one in my entire circle of friends who is not entering," Einstein ruefully remarked. "I don't believe I could do it".*

2.10 Can You Question Einstein as Scientist?

The reader will find that this book is critical to Einstein as a scientist. However, questioning Einstein is cumbersome for several reasons: First, he is the Icon of Modern Physics and as such untouchable, and secondly, because of his Jewish background, criticism can be (and has been) misinterpreted as a form of anti-semitism. Both the communist and nazi world heavily criticized Einstein, which boosted his fame and popularity in the capitalistic West.

Figure 2.4: Einstein at the black-board

Thus Einstein's relativity theory has (had) strong political undercurrents, making it (rather) difficult to isolate science from politics in Einstein's work. Nevertheless, in this book we make this distinction clear. The fact that both Lenin and Hitler criticized Einstein, should not make it impossible to make a critical investigation into the nature of Einstein's science and mathematics, right?

Chapter 3

Perspectives on Relativity

> It is my conviction that pure mathematical construction enables us to discover the concepts and laws connecting them, which give us the key to the understanding of the phenomena of Nature. (Einstein [36])
>
> At the moment physics is again terribly confused. In any case, it is too difficult for me, and I wish I had been a movie comedian or something of the sort and had never heard of physics. (Wolfgang Pauli)
>
> The chief aim of the theory was originally and is now to secure for all physical laws that invariance with respect to transformations of inertial systems, which appeals so much to the **esthetic sense of the physicist**...The most reasonable attitude of the physicist would appear to be that the theory of relativity has proved to be too valuable to be given up unless it encounters **much more drastic disagreement with experiments than it has met to date**. (Lindsay-Margenau [77])

3.1 Relativity of Position and Velocity

Even in the classical mechanics of Galileo and Newton, it is clear that the *position* of an object, and also its *motion* as change of position per unit of time, always has to be viewed *with respect to* some other object, or *relative* to something. For example, the position and motion of a point-like object can be recorded with respect to a system of polar coordinates as the distance and direction from the origin to the object. Each observer thus has to choose a certain coordinate system, and there is no absolute space defined by an absolute coordinate system. The coordinate system may be fixed to a train moving on Earth, the Earth, the Sun, the Milky Way galaxy, a set of distant galaxies. Position and motion can be described with respect to any of these systems, and an observer may freely choose whatever system serves the purposes the best.

We understand that a coordinate system is something constructed by humans for the use of humans, and that Nature in all its forms works without using any coordinate systems at all. The birds migrating from North to South and back again following the seasons, somehow manage to find their precise destinations without (as far as we know) any coordinate systems, as well as the planets on their lonely paths around the Sun. This insight is important as concerns what information, for a given problem, is essential and not essential.

3.2 Galilean Invariance

Newton's 2nd law, the basis of classical mechanics, is *Galilean invariant* in the sense that it takes the same form in different *inertial systems*, which are coordinate systems in space moving with constant velocity with respect to each other. This means that there is no inertial system which is more "absolute" than any other, as concerns Newton's 2nd law.

To understand the essence of Galilean invariance, it is best to go directly to Galileo's original *Dialog Concerning the Two Chief World Systems* presented in 1632, and listen attentively together with the (stupid) traditionalist Simplicitus to the (clever) modernist Salvatius:

- *Shut yourself up with some friend in the main cabin below decks on some large ship and have there some flies, butterflies, and other small flying animals. Have a large bowl of water with some fish in it; hang up a bottle which empties drop by drop into a wide vessel beneath it. With the ship standing still, observe carefully how the little animals fly with equal speed to all sides of the cabin. The fish swim indifferently in all directions; the drops fall into the vessel beneath it; and, in throwing something to your friend, you need throw it no more strongly in one direction than another, the distance being equal; jumping with your feet together, you pass equal spaces in every direction. When you have observed all these things carefully (though there is no doubt that when the ship is standing still everything must happen in this way), have the ship proceed with any speed you like, so long the as the motion is*

Figure 3.1: Galileo in front of the Inquisition in 1933: *I, Galileo Galilei, son of the late Vincenzio Galilei of Florens. aged 70 years, tried personally by this court, and kneeling before You, the most Eminent and Reverend Lord Cardinals, Inquisitors-General throughout the Christian Republic against heretical depravity, having before my eyes the Most Holy Gospel, and laying on them my own hands; I swear that I have always believed, I believe now, and with God's help I will in future believe all which the Holy Catholic and Apostolic Church doth hold, preach and teach.*

> *uniform and not fluctuating this way or that. You will discover not the least change in all the effects named, nor could you tell from any of them whether the ship was moving or standing still. In jumping, you will pass the same space on the floor as before, nor will you make larger jumps toward the stern than toward the prow,...despite the fact that during the time you are in the air the floor under you will be going in a direction opposite to your jump....Finally the butterflies and flies will continue their flights indifferently toward every side, nor will it ever happen that they are concentrated toward the stern, as if tired out from keeping up with the course of the ship, from which they will be separated during long intervals by keeping themselves in the air...The cause of all these correspondences of effects is the fact that the ship' motion is common to all the things contained in it.*

We understand that the reason that it is not possible to detect the motion of the ship by mechanical experiments inside the ship, is that the equations describing the experiments do not depend on (are invariant to) the constant motion of the ship.

We know that the Dialog contained explosive stuff: In 1633 Galileo was arrested and threatened by a death penalty by the Inquisition if he did not retreat from (the clever) Salvatius stand-point, which Galileo did (because he was not stupid).

Maxwell's equations are however not Galilean invariant, which made physicists of the late 19th century search for an aether without success, which led to Lorentz invariance and Einstein's special relativity. But Newtonian mechanics and quantum mechanics are not Lorentz invariant, so the price is high of using Lorentz instead of Galilean invariance, since a unified field theory is sacrificed.

3.3 GPS and Special Relativity

For motion on Earth, the classical system of latitude, longitude and height over sea level, is still used today for outputs of the *Global Positioning System GPS* [46]. At the press of a button on your GPS-receiver (now often in your mobile telephone), you get the GPS-coordinates of your present position as well as your velocity and standard GPS-time.

A GPS receiver receives radio wave signals from at least 4 out of 24 satellites orbiting the Earth with 12 hour periodicity. Each satellite signal has encoded the time of transmission from the satellite, which allows the GPS-receiver to compute the time lag (time for a light signal to pass from satellite to receiver) and thus the distance to the satellite (in lightseconds), and from 4 signals determine its position including synchronization of its own clock to standard GPS-time needed to determine the time lag. The satellites have all identical cesium clocks synchronized to a GPS-time at launch. The information whether the GPS-system confirms special relativity is contradictory or of many-minds quality: Some claim that without special relativity GPS would not work, and others claim that GPS does not use any special relativity at all. The source [46] does not mention relativity at all.

3.4 Relativity in Academics

As an illustration of the concept of relativity, we may think of the academic system, where both position and velocity of advancement is of prime concern. We know that academic positions and merits are relative, with the most desired quality to be ahead relative to the others on a certain scale. Other examples concern the ranking of academic excellency of academic institutions or standard of living of nations, which of course are both relative.

3.5 The King and Queen of Science

Physics is commonly viewed to be the King of Science, and mathematics its Queen, while all the other disciplines fill lower levels. Why is physics and mathematics considered superior to e.g. psychology in the hierarchy of sciences? It is likely that this reflects a common belief that in physics and mathematics, there is only one truth accepted by all scientists acknowledged as physicists or mathematicians. While in psychology, there may be as many truths as there are therapies, therapists and clients. It appears that a science with a unique truth is viewed to be superior to one with many truths, or in other words, a one-mind view seems to be superior to a many-minds view.

Of course, one can see, if one wants, an analog in the One-God Christian religion as compared to more “primitive” Many-Gods religions in the hierarchy of religions.

Many-minds relativity moves away from a one-mind view, and thus makes physics look more like all the other sciences struggling with partly different views. It may thereby open to a dethronement of physics, which of course physicists may not appreciate very much, in their search for a unique Grand Unified Theory of Everything as the ultimate One-Mind Theory of the Ideal Physicist.

3.6 1983 SI Standard of Time and Length

Many-minds relativity is based on the *1983 SI standard of Conference Generale des Poids et Measure*: The time unit is *seconds s* with one second equal to 9192631770 cycles of a cesium clock (more precisely the duration of that number of periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom at rest at temperature 0 Kelvin). The length unit is *meters m* with one meter being the distance traveled by light in 0.000000003335640952 seconds or 9192631770/299792458 cycles of a cesium clock. This is the standard of the GPS system. Equivalently, the length standard can be chosen as *lightsecond* or 299792458 meters. We will use this length scale below.

The 1983 SI length standard is different from the standard used by Einstein in the form of rigid rods scaled against the platinum archive meter in Paris, which was the earlier standard. With the 1983 SI standard the speed of light is by definition equal to one for all observers independent of the motion of the observer, with each observer defining his own length standard from his own conception of the speed of light using his cesium clock.

The new standard puts relativity in completely new light: With the 1983 SI standard the constancy of speed of light no longer the basic postulate (r1) requiring experimental verification, but is simply a definition or agreement. However, the fact that the SI standard works so well in practice, gives experimental justification of turning (r1) into a definition.

With the 1983 standard we can be absolutely absolutely sure that all observers will say that the speed of light c is one lightsecond per second, that is, all observers will say that $c = 1$ using lightsecond as length scale. If an observer claims that he has measured the speed of light to be different from 1, we can be absolutely absolutely sure that he has made some error in observation or standard.

The idea of using lightsecond as length standard is not new: Poincaré suggested this already in [94]:

- *This hypothesis of Lorentz and Fitz-Gerald (space contraction) will ap-*

> *pear most extraordinary at first sight. All that can be said in its favor at the moment is that it is merely the immediate interpretation of Michelson's experimental result, if we* **define** *distances by the time taken by light to traverse them.*

With the 1983 standard each observer has his own length standard of lightsecond and the central question is of course, to what extent different observers moving with respect to each other, will agree. This is the central question addressed in this book.

3.7 Principles of Many-Minds Relativity

In many-minds relativity all observers use the 1983 SI standard and thus are equipped with identical cesium clocks and measure length in lightseconds. We assume that the clocks are synchronized to a common standard time, and we present below a technique for synchronization. The basic assumptions of many-minds relativity are the following:

(m1) *all observes share a common standard time*,

(m2) *each observer assumes that light propagates with unit speed in a vacuum at rest with respect to the observers system of space coordinates*,

(m3) *each observer uses lightsecond as a length scale.*

As an option we shall also consider the following capability (realized in the GPS system):

(m4) *light signals encode their time of emission.*

By (m4) an observer receiving a light signal from an object, can determine the time-lag of the signal, and thus the distance (in lightseconds) to the object at the time of emission. In particular, each observer can determine the distance to other observers (assuming they emit light). We assume (by symmetry) that any two observers agree on their mutual distance, which is the same as requiring that (by symmetry) the time-lag of a light signal between the observers is the same in both directions.

We understand that (m3) is a definition, that (m2) reflects Maxwell's equations for propagation of light with unit speed in a vacuum at rest with each observers system of coordinates in space, and that (m4) is a technical capability of a form used in GPS.

We thus assume that any two observers agree on a common absolute time and their mutual distance, which represents essential information, while (as we will see below) they may disagree on distances to third parts, which may represent inessential information.

We understand that a system of gravitating bodies represents many-minds relativity, because the information required in Newton's 2nd law is standard time and mutual distance (and direction), while distances to third parts are inessential. We give details below.

We recall that the 1983 standard and the GPS system seem to work very well, which may be viewed to give experimental support of the functionality of (m1)-(m4), including in particular a common time for all observers.

3.8 Politics, Science and Agreement on Essentials

We know that political problems with seemingly incompatible demands, can only be handled by suitable agreements focussing on the essentials. It may be that also certain problems in science can only be handled by a similar approach, like reconciliation of (r1) and (r2) in many-minds relativity.

Leibniz pointed to the virtue, in any discussion, of first seeking points of agreement, rather than first seeking points of disagreement, in order to create a common ground for progress. Agreement on essentials may facilitate acceptance of disagreement on inessentials, in the many-minds world we live in.

3.9 Einstein's Principle of Relativity

As a basis of special relativity Einstein states in 1905 [23] the following *Principle of Relativity*:

(r3) *The laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of co-ordinates in uniform translatory motion.*

With proper interpretation this principle can replace both (r), (r1) and (r2). In particular, the constancy of the speed of light (r) in all inertial systems is included, if we consider propagation of light to follow a physical law, and this is only possible if there is no aether (r2). Einstein assumes that the coordinates in "two systems in uniform translatory motion" (two inertial systems) are connected by the Lorentz transformation, and then (r3) then expresses Lorentz invariance.

Einstein does not change position on this principle and states in 1940 [38]:

- *The content of the special theory of relativity can accordingly be summarized in one sentence: all natural laws must be so conditioned that they are invariant with respect to Lorentz transformations.*

In fact, he extends it to his principle of general relativity expressed in two forms as follows:

- *The laws of physics must be of such nature that they apply to systems of reference in any kind of motion.*
- *The general laws of nature are to be expressed by equations which hold good for all co-ordinates, that is, are co-variant with respect to any substitutions whatever (generally covariant).*

3.10 Is Newton's 2nd Law Galilean Invariant?

Newton's 2nd law

$$ma = F,$$

where m is mass, a is acceleration and F a force, takes the same form in all inertial systems (moving with constant velocity with respect to each other), simply because the acceleration a is the same in all inertial systems. With the common terminology this is expressed as: "Newton's 2nd law is Galilean invariant". We took this position above. The essence is that you cannot determine the speed of a train in uniform motion from only experiments inside the train, thus without looking out or using information coming from the exterior of the train. This seems pretty obvious and natural.

But if we remember that using Newton's 2nd Law to predict something, we need *initial conditions*, which may or may not be *not* Galilean invariant. To see this, recall that finding the position $x(t)$ of a body of mass m moving along an x-axis subject to a force $F(x(t), t)$, as a function of time t over a time interval $[0, T]$, would require according to Newton's 2nd law the solution of the *initial value problem*:

$$m\ddot{x}(t) = F(x(t), t) \quad \text{for } 0 < t \leq T, \quad x(0) = x^0,\ \dot{x}(0) = \dot{x}^0,$$

where $\dot{x} = \frac{dx}{dt}$, $\ddot{x} = \frac{d^2x}{dt^2}$, and x^0 and $\dot{x}^0$ are given initial conditions for the position $x(t)$ and velocity $\dot{x}(t)$. Now, a Galilean coordinate transformation in space has the form $x' = x + vt + \bar{x}$, where $\bar{x}$ is a constant translation and v a constant translation velocity. Clearly, $\ddot{x}' = \ddot{x}$, so Newtons 2nd law takes the same form $m\ddot{x}' = F(x'(t), t)$ in the transformed space coordinates x', assuming F is *translation invariant* so that $F(x, t) = F(x', t)$. *But* the initial conditions do change:

$$x'(0) = x^0 + \bar{x}, \quad \dot{x}'(0) = \dot{x}^0 + v,$$

(as well as F if F is not translation invariant). The result is that by comparing the initial conditions in the two systems you may determine the translation $\bar{x}$ and translation velocity v, while this is impossible from the 2nd law alone (if F is translation invariant).

This means that *relative* motion is possible to detect, if two observers can share information and compare initial conditions, while this is impossible from the 2nd law alone (if F is translation invariant).

We conclude that Newtons 2nd law including initial conditions (and non-translation invariant force), takes different mathematical forms in different inertial systems. This is what you expect: The mathematical form of a physical law changes with the coordinate system used to express it, while the physical meaning remains the same.

3.11 Triviality or Absurdity?

Einstein's formulation of his principle (r3) gives an example of Einstein's often unclear and cryptic style of scientific writing. The question is of course how to interpret "the laws by which physical systems undergo changes" or "physical laws" in short, and "are not affected by". Should the interpretation be (a) literal as in the case of Newton's 2nd law, that is, should the

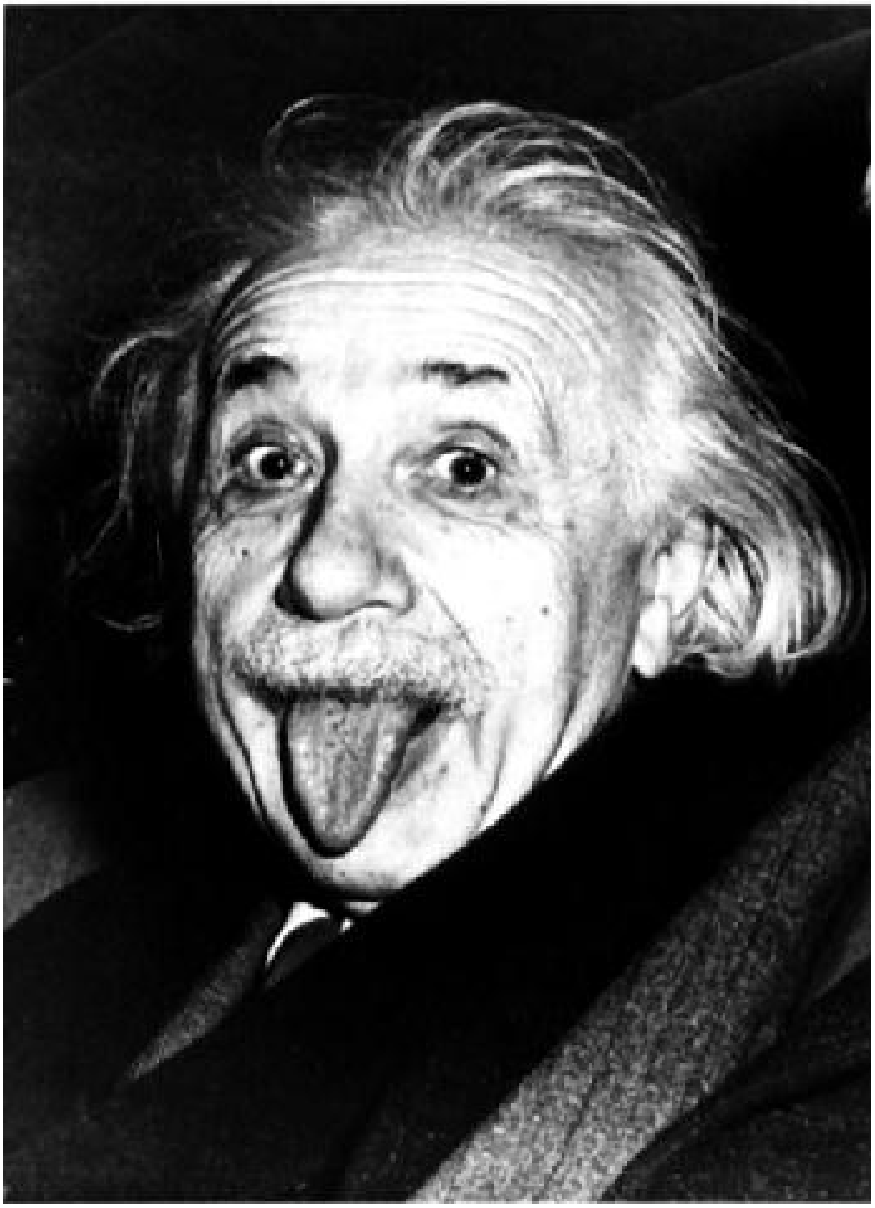


Figure 3.2: Einstein: *The more success the quantum theory has, the sillier it looks.....It strikes me as unfair, and even bad taste, to select a few individuals for boundless admiration, attributing superhuman powers of mind and character to them. This has been my fate, and the contrast between the popular assessment of my powers and achievements and the reality is grotesque.*

mathematical expression of the physical law be identical in different inertial coordinate systems? Or should it (b) be required that the physical meaning of the law should be the same, while the mathematical expression could change?

Now (b) seems like a mere truism: The very meaning of a physical law must be independent of the coordinate system used to express the law. If the law is conservation of mass, it may take different mathematical expressions in different coordinate systems, but the very meaning of the physical law, that mass cannot appear or disappear, but only be shifted around in space and time, cannot change. But of course conservation of mass and conservation of momentum are different physical laws having different mathematical expressions.

We are thus led to choose (a) as the interpretation, at least in special relativity: A physical law should have a mathematical expression independent of the choice of inertial coordinate system. But this is absurd in the sense that most physical laws surely depend on the (inertial) coordinate system, just as the coordinates of a given point depends on the coordinate system being used. There are in fact very few physical laws whose mathematical expression do not change under a change of inertial coordinate system. The mathematical expression of most physical laws do depend on the coordinate system. We give a basic example in the next section. Newton's 2nd law is really a rare exception, and with initial conditions included, it is "affected by" the choice of inertial system.

In the *tensor calculus* of general relativity, the mathematical form changes with the choice of coordinates, but the dependence is restricted to the properties of *curved space-time* such as *curvature*, and is then referred to as *covariance*. Special relativity corresponds to *flat (Minkowski) space-time*, with effectively no dependence reflecting Lorentz invariance.

We have seen that like (r), the meaning of (r3) is not clear, and thus open to speculative interpretation. The standard interpretation of (r3) in special relativity is that laws of physics are supposed to be Lorentz invariant.

3.12 Einstein's Logical Mistake I

Einstein really got hooked on the Principle of Relativity (r3), and used an extension of it as a basis of general relativity, allowing also accelerating coordinate systems. Einstein's main contribution to science is commonly viewed to be his bold and uncompromising use of the Principle of Relativity to derive new (astonishing) results of physics. To understand the scientific nature of relativity, it is instructive to analyze how Einstein motivated his principle (r3) in the case of special relativity stated in short form:

(r3) *laws of physics take the same form in all inertial systems.*

Now, Einstein motivates this principle from the observation (r2) that there is no unique aether or "absolute vacuum", which can also be expressed as follows:

(r4) *any inertial system is as good as any other to express a law of physics.*

If there was a unique aether, common to all observers, there would be a preferred inertial system at rest with the aether without aether wind, but no system shows any aether wind and thus any inertial system is as good as any other. Einstein now uses the following logic:

- *Since any inertial system is as good as any other to express a law of nature, it follows that laws of nature take the same form in all inertial frames.*

Thus Einstein insists that (r3) is a logical consequence of (r4). This is Einstein's contribution to science in a nut-shell.

To find out if (r3) really follows from (r4), let us compare with the following two statements:

(a3) *all men take the same form,*

(a4) *all men are equal, i.e., any man is as good as any other,*

where we replaced "a law of nature expressed in a (certain) inertial frame" by "a (certain) man". We know that (a4) reflects the American constitution and is the basis of a democratic system. Now, is it true that (a4) implies that all men take the same form? Of course not! We know that a democratic society consists of individuals of many different forms, of which no-one is better than the other. In the ideal democratic society all are equally good but all take different forms. This is a society compatible with (a4) and (r4).

On the other hand, in Orwell's society of 1984, all men would be equal (although some would be more equal than others), and also take the same form. This would be a society compatible with (a3) and (r3).

We now come to the punch line: (r3) is not a logical consequence of (r4), contrary to Einstein's belief: Just because any inertial system is as good as any other to express a law of nature, it does not follow that a law of nature takes the same form in all inertial systems.

We have understood in several ways that (r3) is absurd, while (r4) is very reasonable, and we have also understood that (r3) does not follow from (r4), so everything is in order logically. But if you claim, like Einstein, that (r3) follows from (r4), then you are in trouble, because then you claim that something reasonable implies something unreasonable. We will give more evidence of the absurdity of (r3) below.

3.13 Einstein's Logical Mistake II

We now analyze also the principle (r2) from a logical point of view, a principle which Einstein boldly reformulates into

(R) *there is no aether.*

Einstein claims (R) to be true because experiments give strong evidence that the following statement is false:

(nR) *there is a common aether,*

where "common) aether" is a unique aether medium shared by all observers. But even if (nR) is false, the following statement may be true:

(R+) *there are non-common aethers.*

The negation of "a common aether" is "no aether" *or* "non-common aethers". Einstein forgets (R+), which is a basic principle of many-minds relativity, and takes instead (R) as basic principle.

To make the argument completely clear from a logical point of view, consider the following statement concerning the languages of the different populations of human beings on the Earth:

(nL) *there is a common language.*

We know that (nL) is false. We conclude that one of the following statements must be true:

(L) *there is no language,*

(L+) *there are non-common languages.*

We also know that (L) is false, and thus (L+) must be true: It is true that there are non-common languages and no common language.

With Einstein's logic we would say that (L) must be true because (nL) is false, but this would be incorrect: It is (L+) which is true, not (L). Likewise, starting from the premise that (R) is true instead of (R+), may be disastrous.

We have now exhibited two logical flaws in Einstein's arguments. This is serious because Einstein's main contribution to science is considered to be logical conclusions from basic principles, not experimental observations.

3.14 Questioning Covariance of Laws of Nature

We cite from the critical analysis in [88] of Einstein's generalization of the invariance principle (r3) to the covariance of general relativity:

- *In November 1915 Einstein completed his general theory of relativity. Almost eight decades later, we universally acclaim his discovery as one of the most sublime acts of human speculative thought. However, the question of precisely what Einstein discovered remains unanswered, for we have no consensus of the exact nature of the theory's foundations.*

- *The locus of greatest controversy has been at the core of Einstein's principle of relativity. It is routinely allowed that the special theory of relativity satisfies the principle of relativity of inertial motion simply because it is Lorentz invariant: its laws remain unchanged in form under a Lorentz transformation of the space and time coordinates. Does this formal property allow the theory to extend the relativity of motion to accelerated motion?*

- *In the tradition that is skeptical of Einstein's account of the foundations of general relativity the best known of all objections is due to Kretschmann [69], who, in brief, claims that general covariance is vacous.*

- *The reception and development of Einstein's account in the literature has been anything but a graceful evolution. It has more been a process of*

> *uncontrolled mutation, fragmentation and even disintegration...fuelled by skeptical attacks such as Synge's famous complaint that he has never been able to find a version of Einstein's principle that is not false or trivial.*

Synge [101] expresses his doubts as follows:

- *... the general theory of relativity. The name is repellent. Relativity? I have never been able to understand what the word means in this connection. I used to think that this was my fault, some flaw of my intelligence, but it is now apparent that nobody ever understood it, probably not even Einstein himself.*

Fock [44] states in the same spirit:

- *Thus we can sum up: general relativity can not be physical, and physical relativity is not general.*

In Chapter 4 below we will study a basic model problem for which the mathematical expression depends on the inertial system used, that is, which violates (r3). The analysis includes the essence of special relativity, the Lorentz transformation, so it is well worth the effort to go through the formulas with paper and pencil in hand. Before plunging into the calculations, which are very simple but illuminating, we prepare ourselves with a bit of philosophical discussion.

3.15 Two Systems

We may compare the following two systems with the key features indicated:

- many-minds: realistic: democratic: (r4): math from physics,
- one-mind: formalistic: autocratic: (r3): physics from math.

We notice in particular that (r3) is a statement of formalistic-mathematical nature asking physics to care about mathematical form and coordinate systems, while (r4) allows physics to carry on without worrying about coordinate systems. Evidently, the many-minds view represents realism or materialism while the one-mind view represents (an extreme form) of idealism.

3.16 Lenin, Gorbachev, Relativity and Star Wars

No wonder that Lenin from his marxist-materialistic stand-point was opposed to the (capitalistic imperialistic) idealism of relativity. Of course, Lenin was not a scientist and as politician catastrophic, but it may be that (ironically) his opposition to the idealism of relativity in fact was scientifically sound. Nevertheless, Lenin's opposition helped to gather support for relativity in the capitalistic West. On the other hand, Gorbachev in his perestroika seeking to liberate Soviet science from its "bureaucratic dinosaurs", resurrected Einstein's relativity, fearing that it was part of Reagan's *Star Wars.* This indicates that relativity has been connected with world politics, as part of the peace process after the 1st World War and in the nuclear arms race of the cold war after the 2nd World War into the Star Wars of Reagan and George W. Bush of our time.

3.17 What is a Vacuum?

We start listening to Born [8]:

- *The assertion that in empty space there are observable (electro magnetic) vibrations going on, goes beyond all possible experience. Light or electromagnetic forces are never observable except in connection with (material) bodies. Empty space free of all matter is no object of observation at all. All that we can ascertain is that action starts from one material body and arrives at another material body some time later. What occurs in the interval is purely hypothetical, or, more precisely, a matter of suitable assumption. Theorists may use their own judgment to attribute properties to the vacuum, with the one restriction that these serve to correlate changes of material things.*

This certainly sounds very reasonable and convincing, but is worth pointing out. We use this approach in many-minds relativity where we do not have to find out the "real nature" of the propagation of a light signal from one material body to another: We may observe a time delay of a signal, without knowing how the signal was transmitted including its "actual" speed of propagation. Whatever the "actual" speed is, an observer adjusts his length scale so that the speed is one. In other words, each observer assumes that light propagates with unit speed according to Maxwell's equations in a vacuum fixed to the observer's coordinate system.

This gives the normative role to the observer at reception; in particular the speed of propagation of a light signal relative to the source is left open, because observations come from reception, not transmission.

3.18 A Model of Many-Minds Relativity

We will below consider a model of many-minds relativity assuming each human observer is tied to a material body and assumes that light propagates between material bodies according to Maxwell's equations in a vacuum fixed to the observer. We shall see that this is a consistent model (in a sense to be defined) as long as the relative velocity between observers is small compared to the velocity of light. In this model a material body without any human observer may move with any relative speed (smaller than the speed of light), while material bodies with observers have small relative velocity (compared to the speed of light). We believe the speed limit of this model is reasonable since human observers moving with relative speed close to the speed of light, never can become a reality. Waves and particles like electrons may move with a speed close to the speed of light, but never human observers and most likely not human made material observation equipment!

3.19 Born on Many-Minds Relativity

It is interesting to see that Born in fact supports the key assumption (m2) of many-minds relativity. We read in [8]:

- *Thus, an observer perceives the same phenomenon in his system no matter whether it is at rest in the aether or moving uniformly and rectilinearly. He has no means at all distinguishing the one from the other. Thus he can assert that he himself is at rest in the aether, and no one can contradict him. It is true that a second observer on another body moving relative to the first can assert the same with equal right. There is no empirical and no theoretical means of deciding whether one or the other of them is right....If each of two observers who are moving relative to each other can assert with equal right that he is at rest in the aether, there can be no aether.*

Figure 3.3: Max Born: *Length contraction and time dilation are ways of regarding things and do not correspond to physical reality.*

We understand that Born understands that different observers with equal right can assume they are at rest with respect to a light-propagating vacuum, which is precisely (m2). But instead of simply accepting such a many-minds view as a fact of physics, Born panics following Einstein, and throws out the aether completely: If different observers cannot agree on a common aether, then no observer is allowed to have any aether of his own! This is like denying all the children to have a piece of cake, just because they cannot agree on the (precise) color of the cake. Not very nice and in fact unnecessary.

The side-effect of throwing out all aethers or vacui, is of course that now light has nothing to propagate in, and then also Maxwell's equations would seem to be in danger:

Without any vacuum you cannot motivate Maxwell's equations on physical grounds, but you have to pull the equations out of Einstein's hat containing physical laws which are invariant to Lorentz transformations. The logic now becomes reverse: Since Maxwell's equations are Lorentz invariant, they are (according to Einstein's definition) "physical laws", and of course such laws must describe "physics", right? Einstein thus requires physics to conform to the mathematical model, instead of the opposite. We believe this represents a misunderstanding of what mathematics is and what physics is. We will expand on this misconception below.

In many-minds relativity each observer derives his model from his conception of a vacuum, thus deriving the model from physics, which offers a different resolution of an apparent dilemma, without any severe side-effects.

3.20 Steven Weinberg's Praise

Steven Weinberg, Nobel Prize in Physics 1979, expresses his view on Einstein's general relativity as follows [108]:

- *I am inclined to believe that the astronomers of the 1919 expedition had been carried away with enthusiasm for general relativity in analyzing their data.....Nevertheless it gave general relativity worldwide acclaim and became cocktail party conversation everywhere.*

- **The important thing** *for the progression of physics* **is not** *the decision* **that a theory is true***, but the decision that it is worth taking seriously–worth teaching to graduate students, worth writing text books about, above all, worth incorporating into one's own research.*

- *I believe that* **the general acceptance of general relativity was due** *in large part to the attractions of the theory itself– in short,* **to its beauty***.*

- *By the beauty of a physical theory, I certainly do not mean merely the mechanical beauty of its symbols on the printed page....* **Simplicity is part of** *what I mean by* **beauty...**

- **The equations of general relativity are notoriously difficult to solve** *except in the simplest situations, but this does not detract from the beauty of the theory itself....In Einstein's theory there are fourteen equations, In Newton's three...*

We believe the reader will lift the eyebrows in surprise, as we did, reading these "slips of the mind" by a leading physicist of today. Isn't it more important to teach physics students theories which are true rather than "beautiful", and if simplicity is part of beauty, how can "equations notoriously difficult to solve" be beautiful? Is Einstein's relativity to blame for the erosion of scientific virtues represented by Weinberg's statements?

3.21 Einstein and $E = mc^2$

Einstein is generally considered to be the father of the famous formula $E = mc^2$ stating that energy E is proportional to mass m, with c the velocity of light, supposedly giving the modern man the power to control the fire of nuclear energy.

Einstein states in the (3 page) second of his 1905 articles on special relativity [24]: *If a body gives off the energy* L *in the form of electromagnetic radiation, its mass diminishes by* L/c^2*... The mass of a body is a measure of its energy content.* This can be viewed as a precursor $E = mc^2$, but was Einstein the first to suggest something like this, or did he borrow it from someone else? Let's face some facts:

Newton writes in his *Opticks* from 1704 [87]: *Are not gross bodies and light convertible into each other, and may not bodies receive much of their activity from the particles of light which enter into their composition? The changing of bodies into light, and light into bodies, is very comfortable to the course of Nature, which seems delighted with transmutations.* Evidently, Newton understood the essence long before Einstein.

In 1900 Poincaré equated radiated energy with mass through the equation $E = mc^2$ in an analysis based on Maxwell's equations of the recoil of an object emitting a burst of radiation in one direction, an idea appearing already in [94]. In 1903 the formula $E = mc^2$ was proposed by Olivier De Pretto. In 1904 Friedrich Hasenhörl [50] specifically associated mass via inertia with energy through the equation $E = \frac{3}{8}mc^2$, later recalculated to $E = mc^2$ by Cunningham correcting a small mistake.

We conclude that Einstein was not the first to propose $E = mc^2$, but the official standpoint of the physics community is that Einstein was the first to "understand the formula". We will return to this aspect of Einstein's qualities as a scientist below.

3.22 Swedish Skepticism

Swedish physicists kept a skeptical attitude to Einstein's relativity well into the second half of the 19th century, shared in particular by the Nobel Prize committee never willing to award the Nobel Prize to work on relativity theory, despite the widely accepted idea that it is a corner stone of all modern physics and has fundamentally changed the world view of the modern man. Hannes Alfvén (1908-1995), Nobel Prize in Physics 1970, expresses this sentiment below.

Figure 3.4: Hannes Alfvén: *Many people probably felt relieved when told that the true nature of the world could not be understood except by Einstein and a few other geniuses who were able to think in four dimensions. They had tried to understand science, but now it was evident that science was something to* **believe in**, *not something which should be* **understood** *[2].*

Chapter 4

Philosophy of Pseudo-Science

> To summarize, I would use the words by Jeans, who said that the "Great Architect seems to be a mathematician"...It is too bad that it has to be mathematics, and that mathematics is hard for some people...(Richard Feynman in *The Character of Physical Law*)
>
> Newton, forgive me... (Einstein [39])
>
> The acceptance of these concepts (of relativity) belongs mainly to epistemology. (Lorentz [79])
>
> Technology is a way of organizing the universe so that people don't have to experience it. (Max Frisch in *Homo Faber*)
>
> I have had to struggle here with my dearest aesthetic impressions, endeavoring to push intellectual honesty to its ultimate cruelest limits. (Marcel Proust)

4.1 Epistemology

Lorentz considers relativity theory to belong to *epistemology* or *philosophy of knowledge* or *theory of cognition*, and not physics. In other words, Lorentz considers relativity theory to be a form of pseudo-science of questionable relevance in physics, which is catastrophic Al for Einstein as physicist: Lorentz suggests that Einstein's relativity is a form of philosophy and not physics. We now seek to retrace Lorentz arguments and then need some elements of epistemology.

4.2 Synthetic and analytic propositions

Leibniz makes the distinction between *synthetic propositions*, which concern physical realities and can be decided to be true or false depending on physical facts, and *analytic propositions*, which can be decided to be true or false using rules of logical deduction, irrespective of any physical reality. Mathematical propositions (theorems) such as $2 + 3 = 3 + 2$, are analytic. Propositions in physics such as Newton's law of gravitation, are synthetic. *Definitions* in mathematics or physics, such as "a natural number divisible by 2 is an even number" or "there are 100 centimeters on a a meter", represent analytic propositions, which are true by definition irrespective of any experiments.

4.3 Euclidean Geometry

Euclidean geometry formally consists of analytic propositions derived by logic from five axioms stating relations between the undefined concepts of *point* and *straight line*. One of the axioms states that there is a unique line passing through every pair of distinct points.

If we give Euclide's axioms a physical interpretation, as lines and points on a piece of paper or on the ground, then a proposition of Euclidean geometry turns into a synthetic proposition telling us something about the lines and points of our physical interpretation. This is the power of Euclidean geometry, and what makes into an important tool in physics.

On the other hand, if we do not turn the basic axioms into synthetic propositions, then the theory derived from the axioms remains a possibly empty play with words, that is, it may represent pseudo-science.

4.4 Relativity: Science or Pseudo-Science?

We now proceed to investigate if Einstein's relativity represents science or pseudo-science. We have understood that this depends on if its basic axioms can be viewed as synthetic propositions, or not. We shall find that Einstein's Principle of Relativity is an analytic proposition in the form of a definition, which hardly can be viewed to be a synthetic proposition with a physical interpretation. This is expressed in Born's observation [8]:

- *It is hardly possible to illustrate Einstein's kinematics by means of models.*

We have seen that Einstein takes an ambiguous position oscillating between analytic formality and synthetic reality. We have understood that physicists cannot admit that relativity only consists of analytic propositions (pseudo-science), but have a hard time showing that relativity theory consists of synthetic propositions concerning real physics.

To convince a doubtful layman, or politician in charge of public funding, about the truth of relativity theory, an expert physicist may use an analytic approach arguing that relativity theory cannot be wrong (by definition), and thus must be true. To convince a doubtful layman concerning its applicability, a synthetic approach can be used claiming e.g. that traveling twins will be of different ages when they meet, even if the experiment cannot be performed. We now try to uncover this double play, taking first a couple of preparatory steps, before the final revelation.

4.5 Kant's Synthetic a Priori Propositions

The great philosopher Immanuel Kant (1724-1804) suggested the possibility of deriving true synthetic propositions by pure thinking, reflecting that our brain is constructed so as to (somehow) reflect the external world. Kant referred to such propositions as *synthetic a priori* propositions, where a priori means that a prediction is made by pure thinking without input of any observation.

Einstein expresses in a 1933 lecture on *The Method of Theoretical Physics* a similar stand-point:

- *Nature is the realization of the simplest conceivable mathematical ideas. I am convinced that we can discover, by means of purely mathematical constructions, those concepts and those lawful connections between them which furnish the key to the understanding of natural phenomena. Experience may suggest the appropriate mathematical concepts, but they most certainly cannot be deduced from it. Experience remains, of course, the sole criterion of physical utility of a mathematical construction. But the creative aspect resides in mathematics. In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed.*

Eddington takes one step further in *New Pathways of Science*, Cambridge University Press, 1934:

- *One should not put overmuch confidence in the observational results that are put forward,* **until they have been confirmed by theory**.

We see that both Einstein and Eddington believe in the possibility of discovering natural phenomena by pure thinking, which could be viewed to be similar to Kant's synthetic a priori. We understand that this is a natural conclusion in view of the obvious practical utility of e.g. Euclidean geometry and Newtonian mechanics. Sitting at the desk in room without windows and doing some mathematical calculations, we can predict the positions of celestial objects. Not bad. But we need we the initial conditions, so *some* observation is necessary. We also understand that for this activity to be physically meaningful, the basic axioms have to be given a physical interpretation, that is, the basic postulates, except for definitions, have to be (true) synthetic propositions with physical interpretation, justified by observation.

Newtonian mechanics, can be described as a set of propositions derived by mathematics and logic from Euclidean geometry combined with Newton's 2nd law. If the basic postulates are given a physical interpretation and represent true synthetic propositions, then propositions derived by logic and mathematics will also represent true synthetic propositions, because Nature cannot violate logic and analytical or computational mathematics based on logic. The power of Newtonian mechanics relies on the fact that its basic postulates can be given a physical interpretation.

4.6 Principle of Relativity: Analytic or Synthetic?

Einstein's Principle of Relativity (r3) states that *laws of nature are Lorentz invariant.* We understand that this is an analytic proposition in the form of a definition: If a law is not Lorentz invariant, then it is not a law of nature.

We further understand that since the basic principle of special relativity is not a synthetic proposition, propositions derived from this principle are neither synthetic and thus represent pseudo-science.

Einstein's use of the term "laws of nature" is (deliberately?) confusing: Suppose that we would replace "laws of nature" by say "Lorentz laws". The basic principle would then read *Lorentz laws are Lorentz invariant.*

But this can only be interpreted as a definition of what we mean by a *Lorentz law*, since we have no clue to what a Lorentz law is, except that it is Lorentz invariant. But a definition cannot tell us anything about nature, only about terminology irrespective of any reality.

However, if we rename “Lorentz laws” back again to “laws of nature”, then suddenly it seems (somewhat miraculously) to be a law about “nature” and thus it would seem to have *some* physical interpretation. Clearly, a “law of nature” must concern “nature”, right? We could then be led to believe that a Lorentz invariant law is a law of nature, so that if we find a law which is Lorentz invariant, then we could be (mis)led to believe that it must say something about nature. This idea has survived into modern physics, as we will see shortly.

Not even the young Einstein believed that it would be possible to say something about the real world from just definitions, and the crucial step in special relativity is to give the Lorentz transformation a physical interpretation. Einstein claimed that the Lorentz transformation is a transformation between two space-time coordinate systems both representing real space and time, which was heavily denied by Lorentz and Poincaré. But we have seen that Einstein was ambiguous on this critical point: The connection between coordinates was not only real but also a “matter of principle” or definition.

The main result of special relativity, the Lorentz transformation, thus according to Einstein represents *both* a synthetic and an analytic proposition. But this is not logically possible, and we shall see that in the end the analytic “true by definition” alternative will prevail.

The net result is that Einstein’s (special) relativity is not a physical theory with synthetic propositions, and thus from scientific point represents pseudo-science.

4.7 Physics from Mathematics?

We know that Einstein had a strong influence on the development of modern physics during the 20th century, replacing Newtonian mechanics by the mechanics of relativity theory. The general sentiment is expressed by Pais in [89]:

- *There are as many times as there are inertial frames. That is the gist of Einstein’s 1905 kinematics of special relativity, which rank among the highest achievements of science, in content as well in style.*

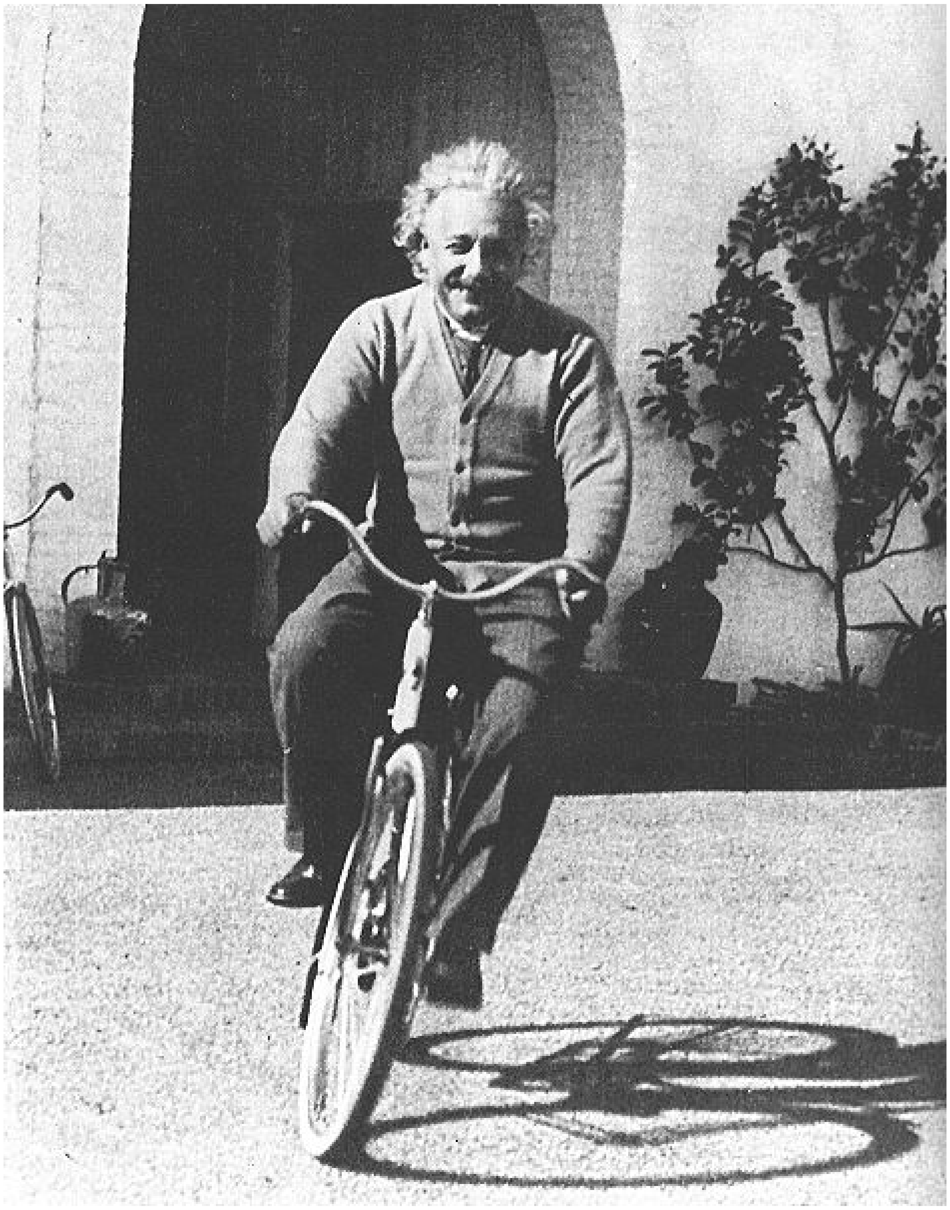


Figure 4.1: Einstein: *Look, I am testing a synthetic "law of nature" experimentally.*

However, *if* Einstein's mechanics represents pseudo-science, and we have presented strong evidence that it does, then this is (very) cumbersome for physics as the most basic of all sciences.

The analytic pseudo-scientific character of Einstein's relativity represents a form of *physics from mathematics*, which Einstein expresses as follows [39]:

- *Our experience hitherto justifies us in believing that nature is the realization of the simplest conceivable mathematical ideas. I am convinced that we can discover by means of purely mathematical constructions the concepts and laws connecting them with each other, which furnishes the key to the understanding of natural phenomena...the creative principles resides in mathematics.*

- *Maxwell's equations are the simplest Lorentz-invariant field equations that can be postulated for an antisymmetric tensor derived from a vector field.*

The famous physicist Sir James Jeans states [61]:

- *Nature seems very conversant with the rules of pure mathematics, as our mathematicians have formulated them in their studies... in some way nature is more closely allied with the concepts of pure mathematics than to those of biology or of engineering...The universe can best be pictured.... as consisting of pure thought, the thought of what, for want of a wider word, we must describe as a mathematical thinker.*

The physicist Paul Davies writes [19]:

- *...physicists have discovered that forces can be understood in a curious way: they are simply nature's attempt to maintain various abstract symmetries in the world...we live in an eleven-dimensional universe ...The world, it seems, can be built more or less out of structured nothingness....cryptic mathematics, coupled with the strong mystical flavor of the new physics, imbues the subject with a quasi-religious appeal, the professional physicists playing the role of high priests... relativity physics assaults common sense in many ways...Physicists now believe that all forces exist simply to enable nature to maintain a set of abstract symmetries in the world...It seems that only Einstein, with his superhuman insight, ever suspected such a symmetry on physical grounds...Indeed, in recent years the symmetry bonanza has proved so* *powerful that it has taken over the thinking in whole areas of the subject.. The meeting of the twain in the Lorentz-Poincaré symmetry was odd and unexpected...The detailed mathematics of supersymmetry has become so elaborate that few outside the immediate circle of cogniscenti have the slightest clue about what all the symbols mean.*

Is this the true novelty of "modern physics", the inheritance of Einstein? That somehow the Lord is a (pure) mathematician, and that the World must exist because if you write down a (Lorentz invariant) mathematical equation on a piece of paper, then a solution must exist and represent some physics and thus the World must exist? This idea of Einstein is expressed by the famous physicist Eugene Wigner (1902-95, Nobel Prize 1963), as follows:

- *It is now (after Einstein) natural for us to try to derive the laws of nature and to test their validity by means of the laws of invariance, rather than to derive the laws of invariance from what we believe to be the laws of nature, [105].*

The idea has become very popular among theoretical physicists (applauded by pure mathematicians) searching for a Grand Unified Theory: If you can only find the Equation for Everything (expressing some "symmetry" or "invariance"), then the solution (Everything) must exist! This is a bit like the old "proofs" of the existence of God, based on the logic that God must exist since God is "complete" and an aspect of completeness is existence.

But isn't this form of idealism a bit too good to be true? Just because you can say "cake" it does not mean that the cake exists: You also have to bake the cake, right?

This is precisely the essence of the Computational Calculus developed in Body&Soul series: The computational solution of differential equations can be seen as the essence of both mathematics and physics with the computation being analog in physics and digital in mathematics, and computation being a step by step constructive process. Thus the World can come to existence by construction, but does not just come out of the blue in ready-made form, neither does Calculus.

Norton [88] expresses his doubts as concerns Einstein's idealism of physics descending from mathematics as follows:

- *It is not obvious why nature would be so kind as to prefer laws we humans deem simple...the virtue of simplicity for covariant laws might merely be that they are more likely to be accepted by others...*

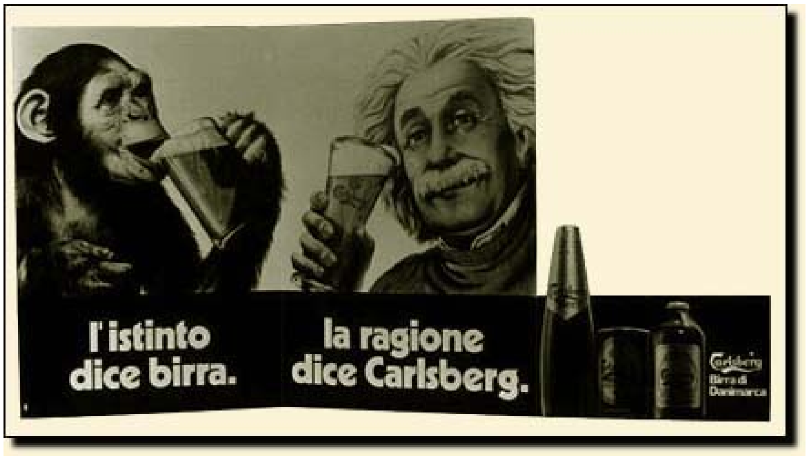


Figure 4.2: Einstein on synthetic vs analytic propositions: *Instinct says beer, reason says Carlsberg.*

4.8 Discussions with Physicists

Discussions with physicists about special relativity often lead nowhere, and the reason is that the Lorentz transformation is used as a definition, stating the relation between observations in two coordinate systems by definition, and not by real observation. This means that it is impossible to "prove that Einstein's special relativity is wrong". It cannot be wrong because it is a definition, an agreement, which cannot be falsified by any kind of experimental observation. This reflects *Einstein's principle of science* asking physics to conform with the mathematical model, and if it does not, then blame the physics and not the model.

In particular this means that it is impossible to construct a paradox in special relativity. Many paradoxes have been presented, such as the twin paradox (which we return briefly to below) and the ladder and the barn paradox, and they all really seem to exhibit very paradoxical effects of special relativity. But they can all be "resolved" by consistently going back to the definition based on the Lorentz transformation. The paradoxes arise because usual logic is used, instead of the logic of the Lorentz transformation.

Thus a trained physicist can meet every paradox presented by some amateur physicist with a supercilious smile, and be absolutely sure that there is a resolution based on a proper interpretation of the Lorentz transformation (even if he cannot come up with it). Such interpretations fill many books of physics, and they are not easy to follow because they violate conventional logic. For instance, in the Alice Wonderland of special relativity each of two twins can be strictly younger than the other, while this is not possible in the world we know. All physicist know for sure that "the twin paradox has been resolved somehow by somebody long ago", but nobody is sure about all the details, because there are so many different resolutions and they are so difficult to follow.

4.9 Einstein's Principle of Science

Einstein's principle of science of "physics from mathematics", is the reverse of the classical principle of science asking a mathematical model to conform with physics, and which with a one-mind view seemed so difficult to combine with (r1) and (r2). The scientists of the late 19th century were desperately searching for the physics of an aether which could explain Maxwell's equations, but could find no aether common to all moving observers. Then Einstein came along with the brilliant idea to reverse the classical principle and ask physics to conform with mathematics, and then there was no need for any aether physics any more, since the physics now came out from mathematics and not from nature. Genial!

Einstein uses his principle of science to formulate his Principle of Relativity (r3), which he uses not only to force physical laws to have invariant mathematical expression, but also also to derive physical laws from invariant mathematical expressions. Einstein describes the ambiguity of his position as follows:

- *The scientist must appear to the systematic epistemologist as a type of unscrupulous opportunist: he appears as realist insofar as he seeks to describe a world independent of the acts of perception; as idealist insofar as he looks upon the concepts and theories as the free inventions of the human spirit (not logically derivable from what is empirically given); as positivist insofar as he considers his concept and theories justified only to the extent to which they furnish a logical representation of relations among sensory experience. He may even be viewed as Platonist or Pythagorean insofar as he considers the viewpoint of logical simplicity as an indispensable and effective tool of his research.*

We see that Einstein oscillates between a realism and an idealism, between positivism and logic, taking one or the other position according to convenience. Can you do that as a scientist?

4.10 Popper on Pseudo-Science

From Wikipedia: *The term pseudoscience appears to have been first used in 1843 by Magendie [84] to describe phrenology as a combination of the Greek root pseudo, meaning false, and the Latin scientia, meaning knowledge or a field of knowledge. The term has negative connotations, because it is used to indicate that subjects so labeled are inaccurately or deceptively portrayed as science.[4] Accordingly, those labeled as practicing or advocating a "pseudoscience" normally reject this classification. Beyond the initial introductory analyzes offered in science classes, there is some epistemological disagreement about whether it is possible to distinguish "science" from "pseudo-science" in a reliable and objective way. Pseudo-sciences may be characterized by the use of (i) vague, exaggerated or untestable claims, (ii) over-reliance on confirmation rather than refutation, (iii) lack of openness to testing by other experts, and a (iv) lack of progress in theory development.*

The philosopher Karl Popper (1902-1994) suggested a criterion of *falsifiability* to distinguish science from pseudo-science. He gave astrology, marxism and psychoanalysis as examples of pseudo-science, while he viewed Einstein's theory of relativity as an example of science. We have given evidence that Popper concerning Einstein's relativity was misled by its mathematical dress, which is more imposing than just words and quite difficult to look through. At a closer look Popper would have understood that Einstein's relativity is true by definition, and thus cannot be falsified by experimental observations and thus represents pseudo-science exhibiting all the features (i)-(iv).

More precisely, since special relativity is nothing but the Lorentz transformation, which is just a special 2×2 linear transformation, which can be specified in many different ways, all equivalent, and conclusions drawn from one set of specifications can only reflect very simple tautologies.

4.11 The Ultimate Model

We may compare with the following simple model X of Life, Universe and Everything from *Hitchhikers Guide to the Galaxy*: $X = 42$. This is admit-

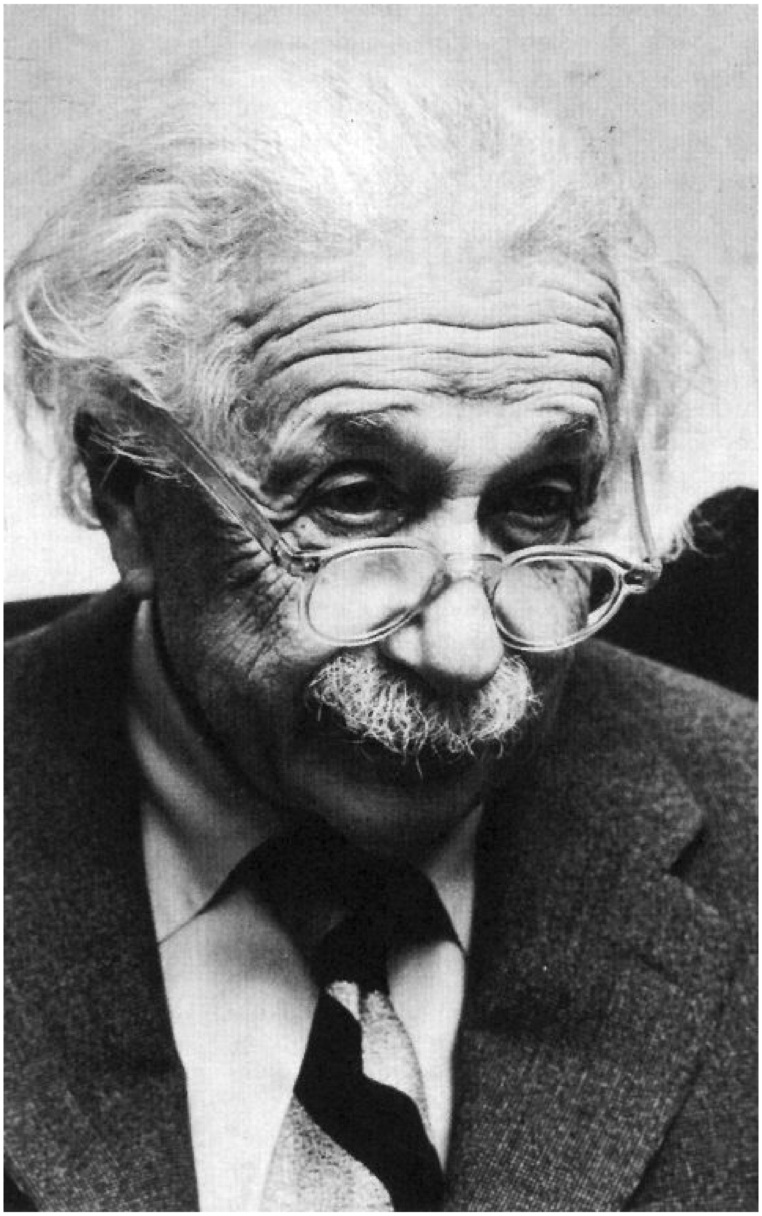


Figure 4.3: Einstein: *Science or pseudo-science, that is the question.*

tedly a simple model (even if finding it was not easy), of about the same complexity as the Lorentz transformation. From this model we can by mathematics draw the conclusion that half of Life, Universe and Everything is equal to 21. Now, the question is if this is something profound or just a trivial consequence of the model $X = 42$. What do you think?

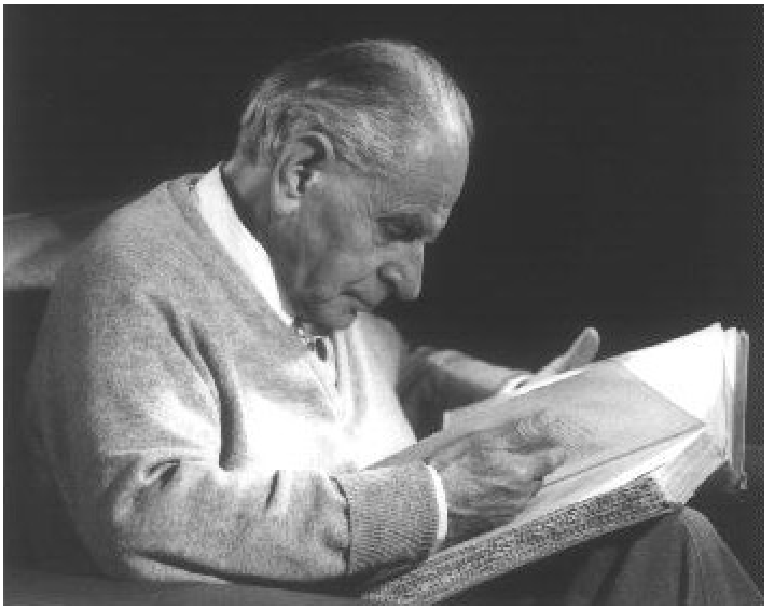


Figure 4.4: Popper: *Non-falsifiable physics represents pseudo-science.*

4.12 Kuhn on Scientific Revolution

The famous scientific philosopher Thomas Kuhn writes in his *Structure of Scientific Revolutions*:

- *To make the transition to Einstein's universe, the whole conceptual web whose strands are space, time, matter, force and so on, had to be shifted and laid down again on nature whole. Only men who had together undergone or failed to undergo that transformation would be able to discover precisely what they agreed or disagreed about....Even today Einstein's general relativity theory attracts men principally on aesthetic grounds, an appeal few people outside of mathematics have been able to feel.*

Kuhn states that Einstein's universe represents a veritable scientific revolution changing our "conceptual web", yet it can be understood only by very few mathematicians, if any. Is this convincing?

Planck states in *Scientific Autobiography*:

- *A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and new generations grow up that is familiar with it*

The question is if the new generation of today is comfortable with Einstein's relativity theory, or like previous generations cannot understand it? And what will then eventually die out?

4.13 Leibniz the Universal Genius

If the geniality of Einstein can be debated, that of Leibniz as the greatest Universal Genius all times can not. Leibniz was a master philosopher, mathematician, physicist, scientist, politician, and more, all in one person, incessantly working day and night to realize a "best of worlds". Leibniz invented Calculus and discovered the basic law of physics of conservation of momentum. His definition of space and time, with space "the order of coexistence" and time "the order of succession", is truly genial, and seemingly just the right one even today. Leibniz was the unequalled master architect of "Calculus" based on the best possible definitions and notation, including definitions of space and time! Leibniz has something interesting to say on most subjects of science even today, including philosophy, thermodynamics, quantum mechanics, artificial intelligence and politics.

We recall some of the profound revelations of Leibniz connecting to relativity theory:

- *It is, unfortunately, our destiny, that because of a certain aversion toward light, people love to be returned to darkness. We see this today, where the great ease for acquiring learning has brought forth contempt for the doctrines taught, and an abundance of truths of the highest clarity has led to a love for difficult nonsense.... These same people threaten to give us other occult qualities and thus, in the end, they may lead us back to the kingdom of darkness.*

- *I maintain that the attraction of bodies is a miraculous thing, since it cannot be explained by the nature of bodies*
- *There is nothing without a reason and no effect without a cause*
- *I admit that each and every thing remains in its state until there is reason for change.*
- *Motion ... is not a thing entirely real....But force or the proximate cause of these changes is something more real, and there are sufficient grounds to attribute it to one body rather than the other. Furthermore, it is only in that way we can know to which body the motion belongs.*
- *An whether the bodies are moving freely or colliding with one another, it is a wonderful law of nature that no eye, wherever in matter it might be placed, has a sure criterion for telling from the phenomena where there is motion, how much motion there is, and of what sort it is,* **or even whether God moves everything around it, or whether he moves that very eye itself.**

Read and contemplate!

Figure 4.5: Leibniz: *An abundance of truths of the highest clarity has led to a love for difficult nonsense...*

Chapter 5

Wave Propagation and Convection

> Space is the order of coexistence, and time is the order of succession of phenomena. (Leibniz)

> According to the *Hitchhikers Guide to the Galaxy*, researchers from a pan-dimensional, hyper-intelligent race of beings constructed the second greatest computer in all of time and space, *Deep Thought*, to calculate the Ultimate Answer to Life, the Universe and Everything. After seven and a half million years of pondering the question, Deep Thought provides the answer 42. The reaction: “Forty-two” yelled Loonquawl, “Is that all you’ve go to show after seven and a half million years?”. “I checked it very thoroughly”, said the computer, “and that quite definitely is the answer. I think the problem, to be honest with you, is that you’ve never actually known what the question is”.

5.1 An Initial Value Problem

The simplest *initial value problem* of physics involving a *partial differential equation* takes the form: Find a function $u(x,t)$ with values on the real line $\mathbb{R}$, such that

$$\begin{aligned} \frac{\partial u}{\partial t} + c\frac{\partial u}{\partial x} &= f, \quad \text{for } x \in \mathbb{R}, 0 < t \in \mathbb{R}, \\ u(x,0) &= u_0(x), \quad \text{for } x \in \mathbb{R}, \end{aligned} \tag{5.1}$$

where $u_0(x)$ is a given initial condition, and c is a positive constant and $f(x)$ is a given funtion. The solution $u(x,t)$ is given by the (simple) explicit solution formula

$$u(x,t) = u_0(x-ct) + \int_0^t f(x-cs)\,ds \quad \text{for } x \in \mathbb{R}, 0 \le t \in \mathbb{R}, \tag{5.2}$$

which shows that the equation (5.1) models *convection* in the positive direction of an x-axis with velocity c. In the case $f = 0$, which we focus on to start until indicated, the solution $u(x,t)$ takes the same value $u_0(x_0)$ along rays $x = ct + x_0$ starting at x_0 at time $t = 0$, reflecting that the value $u_0(x_0)$ is (somehow) propagated in the positive direction along the x-axis with velocity c, like a signal moving along the x-axis.

We can also view this problem as a simple model for *wave propagation* (of light) with speed c, and thus it can be viewed as a basic problem relating to special relativity, as a simpler version of the *wave equation*

$$\begin{aligned} \frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 u}{\partial x^2} &= 0, \quad \text{for } x \in \mathbb{R}, 0 < t \in \mathbb{R}, \\ u(x,0) = u_0(x), \quad \frac{\partial u}{\partial t}(x,0) &= \dot{u}_0(x) \quad \text{for } x \in \mathbb{R}, \end{aligned} \tag{5.3}$$

where u_0 and $\dot{u}_0$ are a given initial conditions. Formally, we have

$$\frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 u}{\partial x^2} = (\frac{\partial u}{\partial t} + c\frac{\partial u}{\partial x})(\frac{\partial u}{\partial t} - c\frac{\partial u}{\partial x}), \tag{5.4}$$

which indicates that in the wave equation (5.3), waves propagate with speed c in both the positive and negative direction of the x-axis. This is also shown by *d'Alembert's solution formula* for (5.3):

$$u(x,t) = \frac{1}{2}(u_0(x+ct) + u_0(x-ct)) + \frac{1}{2}\int_{x-ct}^{x+ct} \dot{u}_0(y)dy. \tag{5.5}$$

The solution $u(x,t)$ of the wave equation (5.3) represents the vertical displacement at position x and time t of a vibrating horizontal elastic string, or the horizontal displacement of a vibrating horisontal elastic rod, or the variation of pressure of sound waves in a horizontal tube of air. The elastic string can be viewed as a continuous version of a string of beads joined by small elastic springs.

We can view the space variables x and the time variable t as coordinates (x,t) in a (x,t)-coordinate system of the Euclidean plane $\mathbb{R}^2$, e.g. with the x-axis horizontal and the t-axis vertical.

5.2 Medium for Wave Propagation

In both problems (5.1) and (5.3) the x-axis, serves as *reference frame* for a *material medium* through which the waves propagate, where the medium may be an elastic string or a tube of air. The wave is carried by vibrations or oscillations of the medium around its reference configuration, which is fixed to the x-axis.

We will also allow the material medium and the x-axis to translate with respect to each other, in which case the corresponding wave equations take a different form.

We will also consider the wave equations (5.1) and (5.3) to model the propagation of light waves in a *non-material medium*, or aether, which we identify with the x-axis. In this case the medium cannot translate with respect to the x-axis, since the medium is identified with the x-axis. In particular, this means that there will be no "aether wind": the aether is always at rest with respect to the coordinate axis.

In the rest of this chapter we focus on the convection problem (5.1) viewed as a simplified model for wave propagation, the extension of the argument to the wave equation (5.3) being direct.

5.3 Essential Information

We note that in the initial value problem (5.1) the initial data $u_0(x)$ together with the convection velocity c, constitute the *essential information* required to define the unique solution $u(x,t) = u_0(x - ct)$ for $x \in \mathbb{R}$ and $t \geq 0$. Without knowing the initial condition and/or the speed of convection, the problem has no well defined solution.

We notice that in (5.1) time is identified as the independent variable for which there is an initial condition: The value of the function $u(x,t)$ is given as data for $t = 0$: $u(x,0) = u_0(x)$ for $x \in \mathbb{R}$.

5.4 What is a Wave I?

It is reasonable to define a *wave* to be a solution $u(x,t)$ of a wave equation, that is here, a function satisfying the wave equation (5.1) or (5.3) in a pointwise sense. This means that the data $u_0(x)$ is a differentiable and thus continuous function of x with support $\{x \in \mathbb{R} : u_0(x) \neq 0\}$ consisting of a set of open intervals. In other words, for each given time t, the function $x \to u(x,t)$ represents "coexistence" of the non-zero function-values $u(x,t)$, following the profound definition of space and time by Leibniz cited above.

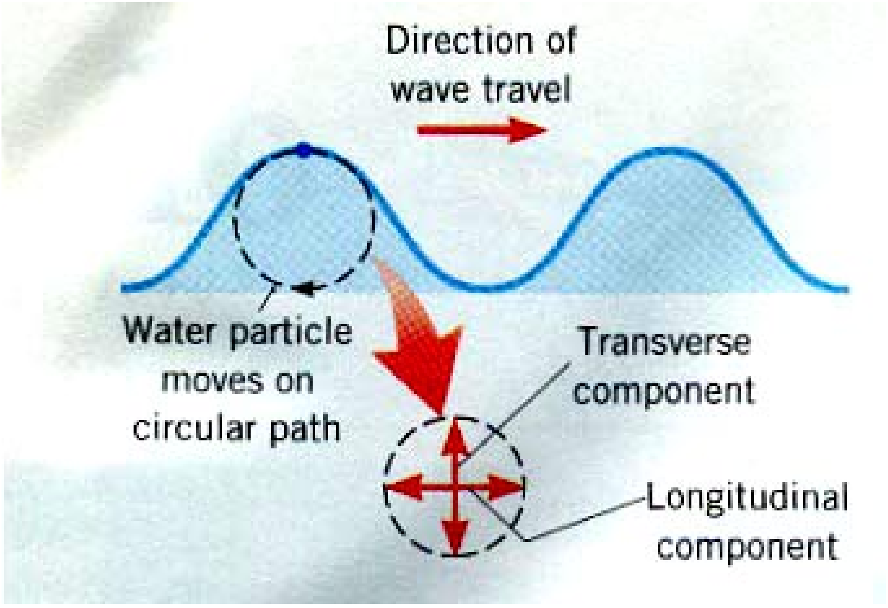


Figure 5.1: Newton: *A water wave is generated by circular motion of the water molecules.*

5.5 What is a Wave II?

We know that a progressing wave on a stretched horisontal string of beads is created by coordinated oscillatory vertical (or horisontal) motion of the beads, a wave which can be represented as a solution of a wave equation. Similarly, a progressing water wave is created by coordinated circular motion of fluid particles, see Fig. 5.1. We know that a ship is moved up and down by waves on the sea following the circular motion of the water, but is not (maybe surprisingly so at first sight) translated along with the moving waves, cf. Fig. 5.2. In both cases the waves are seen to progress or translate horizontally, while the material sustaining the wavy motion is oscillating and is not translating. We understand that we have to make a clear distinction between the the oscillatory motion of the material medium in which the wave is formed and the horizontal translatory motion of the wave, which is not accompanied by any translation of material.

To anyone claiming that a progressing translating wave must be accompanied by some kind of particles translating along with the wave, we would say that this represents a primitive confused way of thinking: The horizontal translatory motion of the wave in a horizontal string of beads is immaterial in the sense that it is not accompanied by the motion of any material, while the oscillatory motion of the beads of course is material. We would further explain that water flow in a river is represented by translating fluid material, while the motion of a sea wave is not represented by translating fluid.

Figure 5.2: Victor Hugo: *I entitle this painting of mine of a ship on a water wave:* **My Destiny**.

5.6 Light: Wave or Stream of Corpuscles?

But what about a light, which we know to be an electro-magnetic wave phenomenon described by Maxwell's wave equation (which we will return to below), generated by electric and magnetic fields oscillating perpendicularly to the direction of propagation of the light wave? By analogy with the above, we would *not* expect to find that what we perceive as a flow of light would consist of a stream of some form of light "corpuscles" or particles, right?

But this was exactly what Einstein suggested in his 1905 article on the photo-electric effect [25] earning him the Nobel Prize in 1921: Einstein suggested that light is a stream of some form of discrete light "corpuscles", later called *photons*, of some unknown material "particle nature". Einstein borrowed this idea from Newton who was the first to propose that light has a "corpuscular" material nature. This primitive idea ruled for 200 years until Maxwell formulated his wave equations describing a very rich world of electro-magnetic phenomena, including light and radio waves, in the form of a system of linear equations, essentially of the form (5.1) or (5.3).

Maxwell's wave equations represents a formidable (incomparable) success of mathematical modeling in physics, by accurately modeling a very rich world of phenomena in concise differential equation form open to both analytical and computational solution with amazing predictive capabilities: By solving his equations, Maxwell could predict the existence of radio waves and the possibility of long distance radio communication, before anybody had made any observations of such waves. Maxwell could thus with the help of mathematics see a new world which no human being had ever seen before!!

Maxwell's equations immediately put Newton's corpuscular theory into the wardrobe of scientific disasters, and opened to the electronic age of modern society.

With this perspective, it would seem impossible to award the Nobel Prize for a corpuscular theory of light as late as 1921, a theory which was proposed in the 17th century and was superceded by Maxwell's wave theory in the 19th century. An in fact it was not: The Prize motivation is "for the *law of photo-electricty*" (the very simple relation $P = h\nu + E$) and explicitly "not for its derivation nor for relativity". It is unique in the 100 year history of the Nobel Prize that the motivation explicitly states for which contributions the Prize is *not awarded*. Obviously, it expresses the mixed feelings towards the science of Einstein in the Prize Committee. In fact, it was not easy to find a good reason to give the Prize to Einstein, and the "law of photo-electricity" came out after having discared many alternatives including relativity.

We summarize our insight gained so far: A wave translating or propagating along a string of beads can be viewed as a form of non-material phenomenon, which is realized by oscillation (but not translation) of material beads. We may similarly expect a light wave carried by oscillating electric and magnetic fields to have an immaterial nature. Immaterial light waves would also seem to harmonize well with an immaterial aether.

On the other hand, viewing light to be a stream of some kind of light "corpuscles" immediately brings up the question of the material nature of these particles, which not even Einstein seems to have any good answer to. In fact, the late Einstein refrained from the photons of the early Einstein.

We thus come to the conclusion that from scientific point of view it is much more useful to view light as an immaterial wave phenomenon, than as a stream of material corpuscles. We present more evidence in a a study of Maxwell's equations below.

5.7 Galilean Transformations

We now investigate how the convection problem (5.1) is "affected" by the *Galilean coordinate transformation*

$$x' = x - vt, \quad t' = t, \quad \text{or} \quad x = x' + vt', \quad t = t', \tag{5.6}$$

where v is a given constant non-zero velocity, which connects two coordinate systems, an (x,t)-system and an (x',t')-system, where the x'-axis moves with velocity v with respect to the x-axis, or equivalently, the x-axis moves with velocity $-v$ with respect to the x'-axis.

We further note that the new time-coordinate t' is the same as the old time-coordinate t. Time does not change under a Galilean transformation, only space. An observer X fixed to the x-axis, and an observer X' fixed to the x'-axis moving with velocity v with respect to each other, would use identical clocks showing the same (absolute or universal) time.

Following Einstein we refer to coordinate systems moving in space with respect to each other with constant velocity, as *inertial systems.* The term *inertial* expresses that the systems do not accelerate with respect to each other. Thus the (x,t) and (x',t')-systems are inertial systems, connected by the Galilean transformation (5.6), with the x'-axis gliding on top of the x-axis, and vice versa. The Galilean transformation of inertial systems is a basic coordinate transformation of classical Newtonian mechanics, the other one being a rotation which however involves acceleration.

Now, by the chain rule we have

$$\frac{\partial}{\partial t} = \frac{\partial}{\partial t'} - v\frac{\partial}{\partial x'}, \quad \frac{\partial}{\partial x} = \frac{\partial}{\partial x'},$$

and thus defining $u'(x',t') = u(x,t)$ and $u_0'(x') = u_0(x')$, we find that (5.1) transforms into

$$\begin{aligned} \frac{\partial u'}{\partial t'} + (c-v)\frac{\partial u'}{\partial x'} &= 0 \quad \text{for } x' \in \mathbb{R},\, 0 < t' \in \mathbb{R}, \\ u'(x',0) &= u_0'(x') \quad \text{for } x' \in \mathbb{R}, \end{aligned} \tag{5.7}$$

which models convection with the velocity $c' = c - v$. We see that the mathematical expression changes under a Galilean transformation, as it must do, since the effective convection velocity vs the x'-axis is $c' = c - v$. In other words, the physics represents convection with velocity c with respect to the x-coordinate and velocity $c' = (c - v)$ with respect to the x'-coordinate. Simple and clear.

We have thus found that the mathematical expression of the physics of convection depends on the choice of inertial coordinate system. Following Einstein's principle (r3), we would then declare that the physical law of convection with a certain velocity with respect to some inertial system, is not a physical law. But this is absurd and it seems that we have to shift attitude to the trivial option (a). But this is of no interest.

The only reasonable standpoint from scientific point of view, is to express the transformed initial value problem in the form

$$\begin{aligned} \frac{\partial u'}{\partial t'} + c'\frac{\partial u'}{\partial x'} &= 0 \quad \text{for } x' \in \mathbb{R},\, 0 < t' \in \mathbb{R}, \\ u'(x',0) &= u_0'(x'), \quad \text{for } x' \in \mathbb{R}, \end{aligned} \tag{5.8}$$

where $c' = c - v$, and then claim that the physical law is then not affected by a Galilean transformation: Just take away the primes, and (5.1) turns into (5.8). It is then also important to notice that the essential information of the initial value u_0 naturally carries over.

We understand that the transformation is completely natural and that it is possible to choose different inertial systems with different effective convection velocity. We may sum up our experience as *Galilean invariance* of the initial value problem of convection, with the convention $c' = c - v$. In particular, two observers O' and O'' moving relative to each other, may detect the effective convection velocities $c' = c - v'$ and $c'' = c - v''$, from which their relative velocity is determined as $v' - v'' = c'' - c'$.

However, neither Einstein nor Lorentz would be very happy with this, because it would seem to violate (r1), because $c' \neq c$, and thus different observers would not agree on the convection velocity. So Lorentz looked around for some other coordinate transformation which could do a better job in this respect, and we shall now see what Lorentz came up with, and Einstein then picked up (without reference).

5.8 Lorentz Transformation

After some trial and error, Lorentz out of a hat pulled the *Lorentz transformation*:

$$x' = \gamma(x - vt), \quad t' = \gamma(t - \frac{vx}{c^2}), \tag{5.9}$$

where

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{5.10}$$

as the relation between two coordinate systems (x, t) and (x', t') used by two observers X and X'. We see that this is a linear transformation of coordinates, presumably with some particular property, which Einstein got hooked on, and which we now will uncover. Evidently, Lorentz had to assume that $|v| < c$, in order for γ to be defined as a real number. In the Galilean case we did not have to impose this restriction.

We see that (5.9) as concerns the x'-coordinate is the same as the Galilean transformation (5.6), modulo the γ-factor, and thus suggests that X and X' translate with respect to each other with the velocity v, as above. However, the time coordinate t' is quite different. Evidently, the Lorentz transformation mixes space into time, since t' depends on x. This is something new (and unexpected), indicating that the clock of an observer X' using t'-time would be affected by the position of X' in space.

This is an effect of *time dilation* and is indeed a seemingly (very) strange new phenomenon, at the heart of special relativity. We will investigate this strange phenomenon in detail below, and come to question its reality.

Let us now reformulate the convection problem (5.1) in (x', t')-coordinates using the Lorentz transformation. Solving for x and t in (5.9), we find by easy computation,

$$x = \gamma(x' + vt'), \, t = \gamma(t' + \frac{vx'}{c^2}), \tag{5.11}$$

which is the same transformation modulo the sign of v. By the chain rule we have now

$$\frac{\partial}{\partial t}=\gamma(\frac{\partial}{\partial t'}-v\frac{\partial}{\partial x'}),\quad \frac{\partial}{\partial x}=\gamma(\frac{\partial}{\partial x'}-\frac{v}{c^2}\frac{\partial}{\partial t'}).$$

Thus defining $u'(x',t')=u(x,t)$ as above, we find that (5.1) transforms into

$$\begin{gathered}\gamma(1-\frac{v}{c})(\frac{\partial u'}{\partial t'}+c\frac{\partial u'}{\partial x'})=0,\\ u'(x',0)=u_0'(x'),\end{gathered}$$

where now $u_0'(x')=u(\gamma x',\gamma\frac{vx'}{c^2})$, which after division with the factor $\gamma(1-\frac{v}{c})$ transforms into

$$\begin{gathered}\frac{\partial u'}{\partial t'}+c\frac{\partial u'}{\partial x'}=0,\\ u'(x',0)=u_0'(x').\end{gathered}\tag{5.12}$$

To our surprise, but to the great satisfaction of Einstein and Lorentz, we find that the mathematical expression of the physical law of convection with velocity c is (modulo the factor $\gamma(1-\frac{v}{c})$ which we will come back to) "not affected" by the Lorentz coordinate transformation: The convection velocity perceived by X' is still c, although X' moves with respect to X, and not as above $c'=c-v$. In a strange way, (r) and (r3) appears to survive: Both X and X' measure the same speed of propagation c, although they are moving with respect to each other.

It seems that the convection equation (5.1) thus represents a physical law in the sense of (r3), a physical law invariant under the Lorentz transformation.

However, if now the forcing $f(x)$ does not vanish, then we will obtain upon setting $f(x)=f'(x')$, the following equation in (x',t')-coordinates

$$\begin{gathered}\frac{\partial u'}{\partial t'}+c\frac{\partial u'}{\partial x'}=\frac{1}{\gamma(1-\frac{v}{c})}f',\\ u'(x',0)=u_0'(x'),\end{gathered}\tag{5.13}$$

with the factor $\frac{1}{\gamma(1-\frac{v}{c})}$ "affecting"the forcing. The presence of this factor indicates that the effect of the forcing as perceived by X' increases as the translation velocity v approaches the light speed c. The physics of this effect is not easy to rationalize, but seems to somehow express that the effect "does not blow away".

On the other hand, for the wave equation (5.3), the corresponding factor would be $\gamma^2(1-\frac{v}{c})(1+\frac{v}{c})=1$, because of the splitting (5.4) and the forcing would not be affected. We will return to the wave equation below.

The key question is now if the Lorentz transformation (5.9) really can be allowed as transformation of coordinates for the initial value problem (5.1)? Einstein says YES, Lorentz MAYBE, while we say NO! Definitely NO! We say so not only because the forcing is affected by the Lorentz transformation, but also because the nature of the initial value is affected, as we shall now see. And this is a key point, so watch now out carefully.

We will motivate our standpoint by touching the heart of Einstein's special relativity, which is nothing but a physical interpretation of the Lorentz transformation.

5.9 The Defect of the Lorentz Transformation

The important notion is now that of essential information. We noticed above that the essential information of initial value carried over from one coordinate system to the another under a Galilean coordinate transformation. But in the case of a Lorentz transformation we have for $x'\in\mathbb{R}$ with $t'=0$,

$$u'(x',0)=u_0'(x')=u(\gamma x',\gamma\frac{vx'}{c^2}).$$

Thus the initial condition for the transformed problem, requires values $u(x,t)$ not only for $(x,0)$, but also for (x,t) with $t>0$, which is information not contained in the initial value u_0. We conclude that the essential information of the initial value does not carry over under a Lorentz transformation. Our conclusion is that the Lorentz transformation cannot, from a physical information point of view, be allowed as a transformation of coordinates for the convection initial value problem.

The reason is that a wave has an extension in space, which represents an "order of coexistence", and the initial value or initial wave u_0 represents a coexistence for the initial time $t=0$, which by the Lorentz transformation is *not* transformed into a coexistence u_0' at $t'=0$. This is a key point, If you do not buy it, then you are a true believer in Einstein, and more heavy artillery is required. We offer that below.

We thus come to the conclusion that the Lorentz transformation represents a mathematical peculiarity without physical significance. In particular the restriction $|v| < c$ does not seem to have any physical significance per se, in contradiction to a basic belief of Einstein: No convection velocity v can be larger than the speed of light c, because of special relativity based on the Lorentz transformation.

5.10 The Dilemma and Its Resolution

We have seen that (r3) as concerns the physical law of convection, is not satisfied by the Galilean transformation, because it changes the convection velocity. But it is neither satisfied by the Lorentz transformation, because both the forcing and the nature of the initial condition are affected. But it is difficult to deny that convection is not a physical process described by a physical law, and thus we arrive at the trivial conclusion that the mathematical form of the physical law of convection changes with the choice of coordinate system, as it must do.

More generally, as we have already stressed, we expect that a physical law or physical problem such as an initial value problem for a differential equation, will have different mathematical expressions in different coordinate systems. By comparing these expressions we expect to be able to detect relative motion between coordinate systems: Relative motion is observable, but not absolute motion.

Chapter 6

Poincaré and Einstein

> We have not a direct intuition of simultaneity, nor of the equality of two intervals of time. (Poincaré 1898)
>
> I regard it as very probable that optical phenomena depend only on the relative motion of the material bodies, and that this is true not only for quantities of the square or the cube of the abberrative, but rigorously. (Poincaré 1899)
>
> Does the aether really exist? (Poincaré 1900)
>
> Since Einstein is probing in all directions, one should anticipate, that most of the roads he is following will lead to dead ends. (Poincaré 1911)
>
> It is apparent that Poincaré was tantalizing close to a theory of relativity. But he either did not see the all-important final step or was not bold enough to take it. (Leo Sartori in [96])

6.1 Poincaré's Relativity

Henri Poincaré (1854-1912) was the leading mathematician at the turn to the 20th century with fundamental contributions in all main areas of mathematics and also in physics as "the last universalist". In 1893 he joined the French Bureau des Longitudes, which engaged him in synchronization of time around the globe. A common view among physicists is that Poincaré presented the theory of special relativity well before Einstein, but because he was a mathematician he did not properly understand the physical relevance of his theory. So even if Einstein essentially copied Poincaré (and Lorentz), which is doubted by few, it was Einstein who understood what Poincaré was doing, not Poincaré who was doing it. Thus the official credit for special relativity goes to the physicist Einstein and not to the mathematician Poincaré.

Concerning the evidence in the priority case, we cite Poincaré from an address to an international congress at St. Louis in 1904 where he formulates his "principle of relativity" (prepared in [94]) as follows:

(p) *The laws of physical phenomena should be the same for a stationary observer as for an observer carried along in uniform motion of translation; so that we have not and can not have any means of discerning whether or not we are carried along in such a motion.*

Sartori [96] comments: *This is exactly Einstein's principle of relativity from 1905.*

In the 1904 address Poincaré also discusses the synchronization of clocks by exchange of light signals, as well as the related concept of simultaneity *in manner similar to Einstein's* according to [96], (or the other way around). Poincaré also expresses another insight: *Perhaps, we shall have to construct a new mechanics...where, inertia increasing with velocity, the velocity of light would become an impassable limit*, which is strikingly similar to Einstein's special relativity.

6.2 Poincaré's Reservation

We cite from [96]:*Poincaré never spells out how he interpreted the primed coordinates in the Lorentz transformation....and like Lorentz believes in local time. Poincaré never recognized what was immediately obvious to Einstein: the principle of relativity implies that the aether can be dispensed with.*

We understand that Poincaré hesitated to take the steps, so boldly taken by Einstein, to give the Lorentz transformation including its dilated time a physical interpretation, and to throw out any aether. This book presents evidence that Poincaré had very good reasons to hesitate, reasons that Poincaré of course was aware of, since he deliberately did not take the immediately obvious steps, which Einstein (evidently lacking Poincaré's insight) did take. To *not do* what seems obvious to do, means that either you are completely

Figure 6.1: Poincaré: *Thus, be it understood, to demonstrate a theorem, it is neither necessary nor advantageous to know what it means....*

ignorant or that you know something non-obvious beyond the obvious. We believe that Poincaré as the sharpest mathematician of his time, knew something.

When an experiment by Walter Kaufmann seemed to contradict the principle of relativity, Poincaré commented: *The principle of relativity may well not have the rigorous value which has been attributed to it*, indicating a disbelief in (r3). In contrast, Einstein knowing that (r3) was true by definition, did not show any hesitation and simply claimed that Kaufmann's observation was wrong.

Einstein is not cited in any of Poincaré's writings on relativity. Born tells of attending lectures by Poincaré in Göttingen in 1909 explaining relativity using the reasoning found in Einstein's paper, without mentioning Einstein and giving the impression that he was recording Lorentz' work.

6.3 Akademie Olympia

We cite from [96]:

- *During Einstein's first years in Bern he met reguraly with friends in a group called the Akademie Olympia for philosophical reading and discussion. Among the works discussed was Poincaré's Science and Method; in a letter cited by Pais [89], Einstein says that the book "profoundly impressed us and kept us breathless for weeks on end". This book contains many of Poincarés early thoughts related to relativity.*

Comments unnecessary.

6.4 Einstein's Working Method

Einstein writes in the introduction to a 1906 paper:

- *It seems to me to be in the nature of the subject, that what is to follow might already have been partially clarified by other authors. However, in view of the fact that the questions under consideration are treated here from a new point of view, I believed I could dispense with a literature search which would be very troublesome for me, especially since it is to be hoped that other authors will fill this gap, as was commendably done by Herr Planck and Herr Kaufmann on the occasion of my first paper on relativity".*

This seems to be an honest description by Einstein of his working method: Pick up an idea from somebody else, adopt it as your own pretending that you will add some "new point of view", and then present it to the world without reference, leaving it to others to figure out what "new point of view" you may have contributed. It seems that Einstein's method was working quite well: Poincaré's contributions to relativity have completely been over-shadowed by Einstein's.

Also Kesawani [67] refers to Einstein's use of the key phrase *principle of relativity*, as *precisely the words used by Poincaré.* Kesawani concludes that Einstein took the phrase from Poincaré. Sartori [96] comments: *The conclusion seems plausible, though not terribly significant.* The consensus seems to be that even if Einstein picked up special relativity from Lorentz and Poincaré, this is not "terribly significant", since Einstein "understood" what nobody else was capable of understanding.

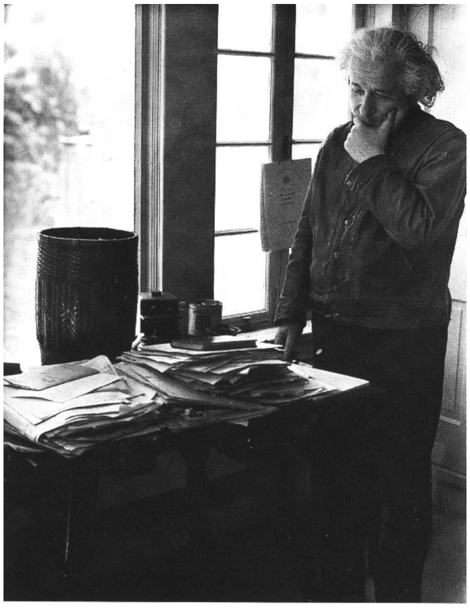


Figure 6.2: Einstein: *The secret of creativity is knowing how to hide your sources.*

6.5 The Boldness of Einstein

We cite from [59]:

- *...Nothing could reveal (space contraction) more strikingly the revolutionary boldness of Einstein's ideas compared with those of his elders Lorentz and Poincaré. All three had the Lorentz transformation in which the startling consequences were implicit. But, when interpreting it, neither Lorenz nor Poincaré dared to give the principle of relativity full trust. Poincaré, one of the greatest mathematicians of his time, ...had early sensed the probable validity of a principle of relativity. Yet when he came to the decisive step, his nerve failed him and he clung to old habits of though and familiar ideas of space and time. If this seems surprising, it is because we underestimate the boldness of Einstein in stating the principle of relativity as an axiom and, by keeping faith with it, changing our notions of space and time*

We believe Poincaré, one of the greatest mathematicians of his time, had very good reasons not taking the step that Einstein, who was not any mathematical genius, took so easily. Did really the “nerve fail” Poincaré, or was Einstein simply foolhardy?

Chapter 7

Illusion or Reality?

> I must explain to you that in the days of the Emperor thinking was a painful inconvenience and a troubling deformity. His Unexcelled Majesty, in his incessant care for the good and comfort of his subjects, never spared any effort to protect them from this inconvenience and deformity. Why should they waste the time that ought to be devoted to the cause of development, why should they disturb their internal peace and stuff their heads with all sorts of disloyal ideas? Nothing decent and comforting could result if someone decided to think restlessly and provocatively or mingle with those who were thinking. (Kapuściński in *The Emperor*)

> You imagine that I look back on my life's work with calm satisfaction. But from nearby it looks quite different. There is not a single concept of which I am convinced that it will stand firm, and I feel uncertain whether I am in general on the right track. (Einstein 1949 on his 70th birthday)

7.1 Perspectives

We collect here some citations giving perspectives on the central question whether special relativity connects to reality or is an illusion representing pseudo-science, hopefully giving more stimuli to critical thinking:

- *So I introduced the concept of local time which is different for all systems of reference which are in motion relative to each other. But I* *never thought that this had anything to do with real time.* (Lorentz 1927)

- *Time and space are modes in which we think and not conditions in which we live.* (Einstein)
- *Length contraction and time dilation are ways of regarding things and do not correspond to physical reality.* (Born)
- *In 1905 Einstein recognized that Lorentz contractions and local time were not mathematical devices and physical illusions but involved the very concepts of space and time.* (Born [8])
- *It is hardly possible to illustrate Einstein's kinematics by means of models.* (Born [8])
- *A material rod is physically not a spatial thing, but a space-time configuration.* (Born [8])
- *If we slice a cucumber, the slices will be larger the more oblique we cut them. It is meaningless to call the sizes of the various oblique slices "apparent" and call, say, the smallest which we get by slicing perpendicularly to the axis as the "real"size. (Born [8])*
- *The application of the distinction between "apparent" and "real" is no more reasonable than asking what is the real x-coordinate of a point (x, y), when it is not known which (x, y)-coordinate system is meant.* (Born [8])
- *When understood in the right way, Einstein's kinematics contain no obscurities and inconsistencies. (Born [8])*
- *The relativization of the concepts of length and intervals of time appears difficult to many, but probably only because it is strange.* (Born [8])
- *It is ironical that, in the very field in which Science has claimed superiority to Theology, for example - in the abandoning of dogma and the granting of absolute freedom to criticism - the positions are now reversed. Science will not tolerate criticism of special relativity, while Theology talks freely about the death of God, religion-less Christianity, and so on.* (Herbert Dingle)

- *In any of these systems lengths and times measured with the same physical rods and clocks appear different in any other system, but the results of measurements are connected with each other by Lorentz transformations.* (Born [8])
- *Thus from Einstein's point of view, Ptolemy and Copernicus are equally right.*(Born [8])
- *Common sense often has the tendency to lead us astray.* (Born [8])
- *Perhaps most important was Lorentz' failure to grasp the true significance of the time transformation. Only Einstein realized that a fundamental reassessment of the nature of time is required; this is the key conceptual step in relativity.* (Sartori [96])
- *The anomaly of the perihelion of Mercury is so far the only confirmation of the general theory of relativity in the domain of mechanics. But an exact agreement between theory and measurement has not yet been obtained.* (Born [8])
- *Einstein's ideas have given the physical sciences the impetus which has liberated them from outdated philosophical doctrine and made them one of the decisive factors in the modern world of man.* (Born [8])
- *Einstein analyzed the simultaneity of two events happening at different places in space and found it to be a non-verifiable notion. This discovery led him in 1905 to a new formulation of the fundamental properties of space and time.* (Born [8])
- *The special theory of relativity of 1905 can be justifiably considered as the end of the classical period or the beginning of a new era. For it uses the well-established classical ideas of matter spread continuously in space and time, and of casual or, more precisely, deterministic laws of nature. But it introduces revolutionary notions of space and time, resolutely criticizing the traditional concepts as formulated by Newton. Thus it opens a new way of thinking about natural phenomena. This seems today Einstein's most remarkable feat, the one which distinguishes his work from that of his predecessors, and modern science form classical science.* (Born [8])

- *It is certainly remarkable that these relativity concepts, also those concerning time, have found such rapid acceptance.* (Lorentz 1913 [79])

7.2 An Example of an Illusion

We present a (simple) example of illusion of observation connecting to Doppler shifts, which will play an important role below. This example is similar to two people looking at each other at distance, both having the impression that the other is smaller.

Thus, let Paul and Peter move away from each other with speed v, both sending light signals of unit frequency and both receiving red-shifted light signals of frequency $f = \frac{1}{1+v}$ according to the classical Doppler shift assuming unit speed of light. The unit frequency of the light signal sent may be viewed as a clock, and thus Paul and Peter have identical clocks of unit frequency. Paul (who is not too smart) thus receives a red-shifted clock frequency from Peter and from this observation Paul claims that Peter's clock seems to be slow, while Peter (who is not too smart either) similarly claims that Paul's clock seems to be slow. If they reverse velocities to join to compare their identical clocks, they will receive blue-shifted signals indicating that the slow clocks now run fast, so that when they meet the clocks will show the same time. After some thought, each brother realizes that the red/blue-shifted slow/fast clock of the brother is an illusion only, and that they in fact share a common time which is correctly indicated by their own clock. Does Einstein's time dilation have a similar illusionary character?

7.3 Einstein as Poker Player

A strategy in poker is to raise the bet so high that no other player is willing to meet the bet, even if your hand is lousy. This is of course dangerous but may work, at least for some time until one of the other players gets a very good hand and is willing to take the risk to meet your bet. Einstein used this strategy successfully: When his special relativity was questioned, then he kept quiet and raised the be to general relativity, and when general relativity was questioned, then he kept quiet and raised the bet to cosmology with the universe as testing ground. All the small players could be overpowered this way, and only the big player of the physics community could have a fair

Figure 7.1: Richard Feynman (Nobel Prize in Physics 1965): *I still can't see how Einstein thought of general relativity.*

chance. But the physics community stands behind Einstein in raising the bet.

So what do you say? Would you be willing to bet? You have a lot to win, and little to loose, since not even Nobel Laureates in physics claim that they understand Einstein's relativity. Maybe you have very good cards....

Part II

Einstein's Special Relativity

Chapter 8

Einstein and His Career

> The supreme task of the physicist is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction. (Einstein at Plank's 60th birthday)

> ...all of England has been taken by your theory. It has made a tremendous sensation...It is the best possible thing that could have happened for scientific relations between England and Germany. (Eddington in a letter to Einstein in 1919)

8.1 The Unknown Clerk

The theory of *special relativity* was proposed by the young unknown clerk Albert Einstein (1879-1955) at the Swiss Federal Patent Office in Bern in the manuscript *On the electro-dynamics of moving bodies* [23] submitted to Annalen der Physik in June 1905, a publication which was first met with an icy silence by the scientific community, but was then brought into light by the famous Max Planck with the motivation: *For me its appeal lay in the fact that I could strive toward deducing absolute, invariant features following from its theorems.* Einstein himself quickly turned away from special relativity to the challenge of *general relativity*, which after a long struggle with its mathematics he presented in November 1915.

Einstein was born into a Jewish family in Ulm, Würtemberg, Germany. His parents worried about both his unusually big head and his language delay with lack of fluency until the age of nine. At school he clashed with authority claiming that a spirit of creativity was missing. After the failure of his father's electro-chemical business, the family moved to Milan and then to Pavia in Italy. Young Albert quit school without a diploma at age 16, was sent to Aarau in Switzerland to catch up and after giving up his German citizenship to avoid military service, he enrolled at the Federal Polytechnic Institute in Zürich, where he met his first wife Mileva Maric. Upon graduation in 1900, Einstein could not find a teaching position, and with some help he instead obtained employment as technical assistant examiner at the Swiss Patent Office in 1902. The rest is history...

Figure 8.1: Einstein 1907: *I was sitting in a chair at the patent office at Bern when all of a sudden a thought occurred to me: "If a person falls freely he will not feel his own weight". I was startled. This simple thought made a deep impression on me. It impelled me toward a theory of gravitation.*

8.2 The Scientist

Einstein is the most well known of all physicists of all times. However, the attitude to the scientific work of Einstein is ambiguous for several reasons: First, the scientific writing of Einstein is no easy reading: Einstein's articles are definitely no masterpieces of clarity, and often contain both obscure mathematics and physics. In fact, reading his original articles was a shock to the author of this book. In addition, Einstein often includes work by others without references, seemingly coming close to plagiarism. These qualities probably result from Einstein's somewhat shaky formal scientific education lacking a constructive critical teacher during his early formative years (and therefore without model to foster students of his own during his mature career). As an autodidact with strong difficulties to get a scientific career going, Einstein could be expected to be more willing to take scientific risks, than a traditionally trained scientist. And Einstein took risks, big risks. Einstein's inclination to present big results based on small assumptions, is often viewed as the main virtue of Einstein's science: Einstein is commonly viewed as unusually bold and willing to take steps others like Lorentz and Poincare did not dare to, and thereby putting everything at stake, to win the game of scientific recognition and position.

Thus, typically Einstein starts from some innocently looking basic mathematical or physical principle, and derives by mathematical reasoning the most astounding consequences. Einstein also played a high level game by suggesting that he had been given a particular role to uncover God's secret principles, by pure thinking, as expressed in his famous *Subtle is the Lord, but malicious He is not.*

On the other hand it is well known that Einstein had severe difficulties with mathematics both in high-school and during his academic career, viewed as a "lazy dog" by his famous teacher Hermann Minkowski, which may explain Einstein's view on mathematics as a partly mystical key with the power to unlock the secrets of the Lord...

Secondly, Einstein's resistance to quantum mechanics put him outside the development of modern physics after 1925, by the scientific community excused as an early onset of senility.

Thirdly, relativity concerns very subtle effects which are exceedingly difficult to observe experimentally, and thus much of Einstein's work is supported only by Einstein's own (famous) "thought experiments", often relating to people in freely falling elevators.

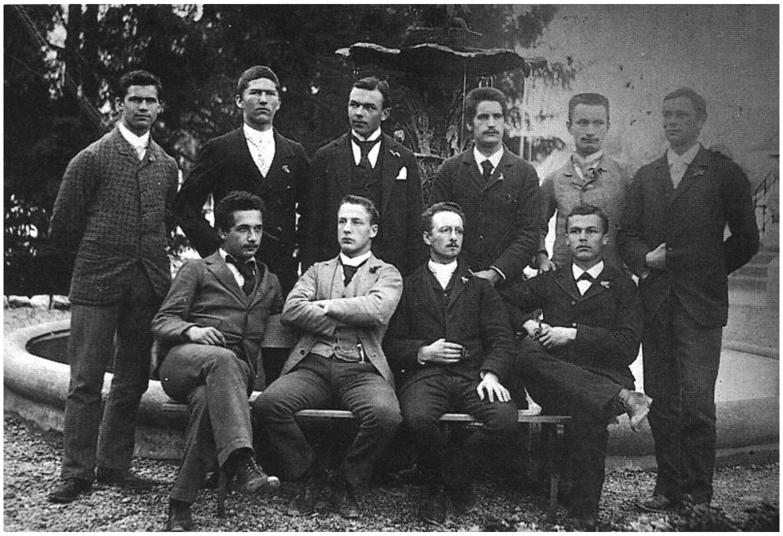


Figure 8.2: Einstein with school mates:*It is marvelous that man is capable of reaching such a degree of certainty and purity in pure thinking as the Greeks show for the first time to be possible in geometry...[39]*

Figure 8.3: Einstein: *Ooops, I am falling freely in a freely falling elevator.*

8.3 The Nobel Laureate and Pacifist

Despite these disturbing facts, Einstein developed into the scientific icon of the 20th century. His career was initiated by his five famous articles from 1905, of which one concerned the photoelectric effect and one the special theory of relativity. Eventually, with the help of Max Planck, this work opened up to Einstein's first academic position at Zürich University in 1909, at the age of 30.

Figure 8.4: Einstein in NY 1921: *I feel like a primadonna.... It is like a Circus Barnum, although I believe it would be more fun (for the people) to watch an elephant or a giraffe than an old scientist... I have become rather like King Midas, except that everything turns not into gold but into a circus.*

Einstein became world-known over night on November 6 1919, when Sir Arthur Eddington (1882-1944, pacifist and quaker) at a special meeting at the Royal Society in London, from observations at the Sun eclipse that year claimed experimental support of the general theory from barely observable shifts of barely visible dots on a photographic plate carried by camels through the deserts of Africa and through stormy waters back to England, supposedly caused by gravitational attraction from the Sun of the light from distant stars. Observations, which later were questioned by many. Nevertheless, the snowball started rolling [18]: *There was more to this than purely the scientific content of this theory. After years of war, the public embraced a moment* *that moved mankind form the horrors of destruction to the sublimity of the human mind laying bare the secrets of the Cosmos. The two pacifists the British Eddington and the German-born Einstein-were particularly pleased at the reconciliation between the nations brought about by their results.*

Subrahmanyan Chandrasekhar (1910-1995), Nobel Prize in Physics 1983, writes in [17]: *...the typhon of publicity crossed the Atlantic. From that point on, the American press played Einstein to the maximum.*

Figure 8.5: Einstein to Chaplin: *Do not worry about your difficulties in Mathematics. I can assure you mine are still greater.* Chaplin to Einstein: *People are applauding me because everybody understands what I say, and you because nobody understands what you say.*

In 1921 Einstein received the Nobel Prize for his 1905 article on the photoelectric effect taking the idea of quantum of energy presented by Planck in 1900, one step further to a (bold) corpuscular theory of light, away from Maxwell's revolutionary discovery that light is an electromagnetic wave phenomenon, and not corpuscular. The citation that accompanied the medallion sent to Einstein when he received the Prize runs as follows [42]:

- *ROYAL SWEDISH ACADEMY of SCIENCES has at its assembly held on November 9, 1921, an accordance with the stipulation in the will and testament of Alfred Nobel, decided to independent of the value that*

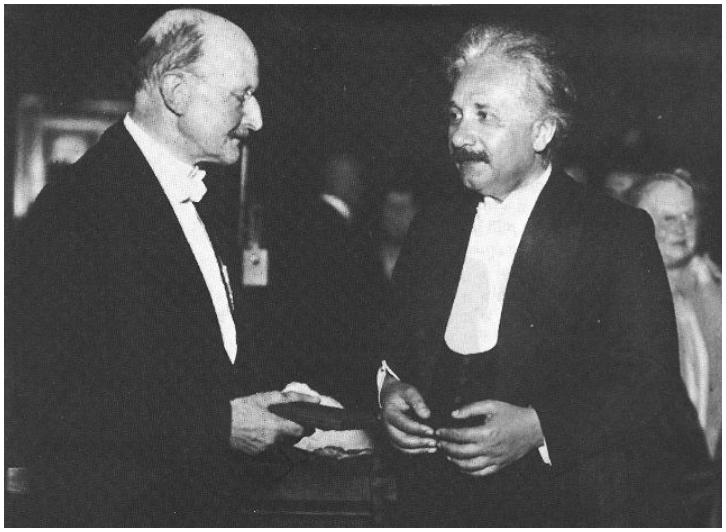
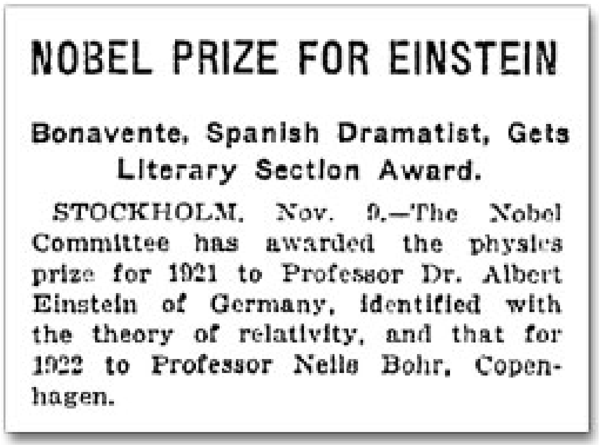


Figure 8.6: Planck to Einstein: *Like the quantum of action in the quantum theory, so the velocity of light is the absolute, central point of the theory of relativity.*

> *(after eventual confirmation) may be credited to the relativity and gravitational theory bestow the prize that of 1921 is awarded to the person in the field of physics who has made the most important discovery or invention to Albert Einstein for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect.*

The law of the photoelectric effect takes the very simple form $E + P = h\nu$ with E the energy of released electrons, P the release energy and $h\nu$ the energy of the incoming light (quanta) of frequency ν, where h is Planck's constant, and expresses that the incoming energy is partly spent to release electrons, and partly to give them momentum. We read that Einstein did *not* get the Prize for relaitivity and gravitational theory, neither for his *derivation* of the law based on corpuscular light quanta, which did not please the Prize Committee. It is unique in the history of the Nobel Prize to explicitly state for which scientific contributions the Prize is *not* awarded to Einstein: A corpuscular theory of light and relativity, his main achievements. In fact, the Committee had to search intensively to find *some* reason to give Einstein the Prize, and it was only by the ingenuity of the newly elected Carl Wilhelm Oseen suggesting the law of the photoelectric effect, that a majority could be assembled.



NOBEL PRIZE FOR EINSTEIN

Bonavente, Spanish Dramatist, Gets Literary Section Award.

STOCKHOLM, Nov. 9.—The Nobel Committee has awarded the physics prize for 1921 to Professor Dr. Albert Einstein of Germany, identified with the theory of relativity, and that for 1922 to Professor Nells Bohr, Copenhagen.

Figure 8.7: New York Times reporting Nobel Prize to Einstein on November 10 1922.

It may be said that the law $E + P = h\nu$ is extremely simple, only stating that incoming energy is equal to release energy plus released energy. What else could it be?

The negative attitude of the Prize Committee towards relativity, was expressed in the presentation speech by Svante Arrhenius, Nobel Prize in chemistry 1903:

- *There is probably no physicist living today whose name has become so widely known as that of Albert Einstein. Most discussion centers on his theory of relativity. This pertains essentially to epistemology and has therefore been the subject of lively debate in philosophical circles. It will be no secret that the famous philosopher Bergson in Paris has challenged this theory, while other philosophers have acclaimed it wholeheartedly. The theory in question also has astrophysical implications which are being rigorously examined at the present time.*

Einstein's own Nobel Lecture was delivered at the meeting of the Nordic Association for the Advancement of Science (Skandinaviska Naturforskarmötet) in Göteburg 1923, and concerned not the photoelectric effect, but of course relativity, see Fig. 8.8. It is easy to get the impression that Einstein in 1923 considers (r) to be rather a stipulation and mathematical formality than representing any physical reality.

Figure 8.8: Einstein explaining relativity on July 10 in 1923 to King Gustav V of Sweden (in the middle of the front row in a special chair) at a meeting of the Nordic Association for the Advancement of Science at the Jubileum Concert Hall of the newly opened Liseberg Amusement Park in Göteborg: *The special theory of relativity creates a* **formal** *dependence between the way in which the space coordinates on the one hand, and the time coordinates on the other,* **must** *enter into the natural laws [39].* The story goes that the new wooden benches had been freshly lacquered, and in the stifling heat of the unusually hot summer day, some of the audience found themselves glued to the their places [42], seemingly in a state of absolute rest.

Einstein spent the later half of his scientific life in isolation from the current trends in physics, incessantly seeking a general unified field theory combining relativity and quantum mechanics, however without success.

8.4 The Politician

From his position as world-famous scientist Einstein felt a need the help heal the rifts between the nations after the bitter First World War. He had high hopes for the future of the new German Republic emerging after the abdication of Kaiser Wilhelm in 1918, and to show his support he took up his German citizenship again (while remaining a Swiss citizen). However, as a Jewish pacifist with socialist leanings, he was not popular among German nationalists. In 1920 a well-financed anti-Semitic campaign was organized in Germany against Einstein and his relativity theory, which was followed up at the Congress of German Scientists in Bad Neuheim with an attack with anti-semitic overtones by the physicist Lenard, Nobel Prize 1905, once an admirer of Einstein and later an enthusiastic member of the Nazi party.

Einstein felt an obligation to support the Zionist movement led by Herzl, and accepted an invitation to a fund-raising visit to the US in 1921, where he was received with tumultuous enthusiasm led by the Mayor of New York City as kind of war hero, and was then invited to the White House and to give lectures and receive honorary degrees at Columbia and Princeton University. Einstein then returned to Berlin but met an increasingly hostile political environment. In Japan he was received by enthusiastic crowds on a six-week visit in 1922, where he received the message that he had been awarded the 1921 Nobel Prize in Physics (delayed one year), as well as in Palestine and Spain where he continued to “whistle his relativity tune” according to his diary.

When Hitler took power in 1933, Einstein directly realized that he could not stay in Germany. On March 28 he resigned from his position at the Prussian Academy in Berlin preparing to expel him, and left Germany for a couple of months in Belgium and England before taking up a position at Princeton University in October. As the clouds accumulated in Europe with the German militarization, he also gave up his pacifist position speaking out strongly against the Nazis.

We know the rest: the War, Pearl Harbor, the Manhattan Project, Hiroshima, Hitler’s bunker in Berlin, the Cold War and the nuclear arms race.

We know that Einstein's formula $E = mc^2$ stating equivalence of mass and energy, so miraculously coming out of special relativity opening the door to the atomic bomb and for ever changing the fate of mankind.

Einstein stayed in Princeton through the Second World War until his death in 1955, after having turned down an offer to become vice president in Israel in 1952 with motivation: *Politics is for the moment, an equation for eternity.* An autopsy was performed and his brain was preserved for examination by different teams through the years in search for geniality, however without any clear conclusion.

8.5 The Icon

If you consider Einstein to be the grand old father of nuclear energy/arms, then you may find it natural that he is the most famous of all scientists all times. But why are there so many funny pictures with Einstein playing fool? Newton and Leibniz didn't feel any need do that and no other scientist either of any recognition. Are nuclear blasts that funny? And after all, Einstein did not take any part in developing the bomb in the Manhattan project. In any case, Einstein is the Icon of Science, worshipped and scorned at the same time, maybe reflecting his own ambiguity. There are many layers of this image, some of which we seek to uncover below.

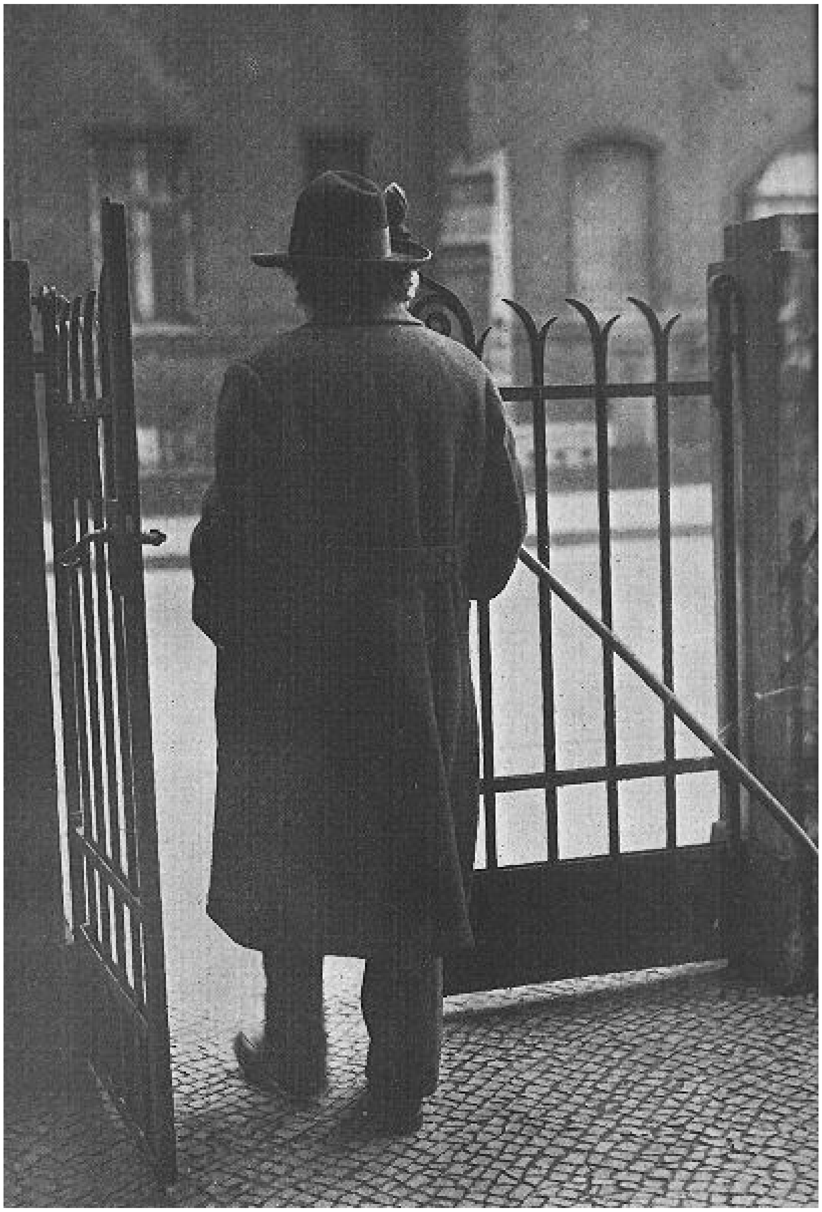


Figure 8.9: Einstein 1955: *What I wanted to say was just this: In the present circumstances, the only profession I would choose would be one where earning a living had nothing to do with the search for knowledge.* (Einstein's last letter to Born)

Chapter 9

Einstein and Modernity

> And does it not appear paradoxical that two identical clocks in two inertial systems both appear to run fast as compared to the other? To *those who have grasped* the view of modern physics with respect to the nature of space and time, *such questions will appear distinctly irrelevant....* If the common lay view proves inconvenient in the development of physics we need have no scruple in adopting a different one... We must accept the characteristics it assigns to space and time even if on first sight they seem peculiar. (Lindsay and Margenau [77], 1936)

> A kind of mania seized this mad and unpredictable world, my friends: a mania for development. Everybody wanted to develop himself! Everyone thought about developing himself, and not simply according to God's laws that a man is born, develops, and dies. No, each one wanted to develop himself extraordinarily, dynamically, and powerfully, to develop himself so that everyone would admire, envy, talk and nod his head. Where it came from, no one knows. (Kapuściński in *The Emperor*)

9.1 Collapse of Empires

Einstein's relativity is contemporary with the fall of the Austrian Empire and and the collapse of Western Europe culminating in the 1st World War, which prepared the way for political revolution with breakdown of traditional structures in politics, society, culture and science.

Relativity can be seen as a scientific revolution prepared by the collapse of the classical empire of Newtonian mechanics starting in the late 19th century. To understand the development of relativity theory, it is important to understand why classical Newtonian mechanics gradually started to collapse, against all odds, because it was firmly believed to remain true at least as long as the Earth would orbit the Sun, that is, at least another couple of billions of years, if not longer. So why then did Newtonian mechanics get into free fall in the late 19th century?

9.2 Thermodynamics as Statistical Mechanics

The reasons were two: (i) *thermodynamics* and (ii) *black-body radiation.* The key problem in thermodynamics, which a Newtonian did not seem to be able to explain, was the *2nd law of thermodynamics* stating that in all (isolated) processes in Nature, a certain quantity named *entropy* could never decrease. Entropy could stay constant, in which case the process was *reversible*, or it could increase, in which case the process was *irreversible*, but the entropy could never decrease [16].

Irreversible processes thus had a built in *arrow of time* showing a direction of time forward, which could not be reversed. Now, classical Newtonian mechanics could not explain the 2nd law, because it seemed to be time reversible and thus without any arrow of time, and thus could not explain why time always was moving forward and never backward.

This came up as a very disturbing seemingly undeniable fact, which was questioning the very heart of Newtonian mechanics. Of course, scientists were concerned, since the very credibility of rational mechanics and physics was at stake, but nobody could come up with any solution, until Ludwig Boltzmann invented a kind of pseudo-solution in his *statistical mechanics* [5, 8]. This was a new type of mechanics with particles no longer interacting according to Newton's laws of mechanics, but instead according to laws of statistics as if they were all playing little games of roulette.

Boltzmann claimed that with statistical mechanics he could explain the 2nd law and the arrow of time as effects of statistics, with physical processes always moving in forward time from *less probable* to *more probable* states by playing games of roulette. Boltzmann's ideas first met a very strong

Figure 9.1: Boltzmann: *One is almost tempted to assert that quite apart from its intellectual mission, theory is the most practical thing conceivable, the quintessence of practice as it were, since the precision of its conclusions cannot be reached by any routine of estimating or trial and error; although given the hidden ways of theory, this will hold only for those who walk them with complete confidence....besides, a man with a new idea is a crank until he succeeds...*

resistance, because giving up classical deterministic mechanics for the new statistical mechanics, seemed like a big sacrifice with questionable gains. But lacking any alternative in what seemed to be a dead-lock of classical deterministic mechanics, Boltzmann slowly gained recognition, if not much understanding, because statistical mechanics admittedly is a very difficult subject both to learn, teach and apply, almost as difficult as relativity theory [28, 29, 30, 33]. In Boltzmann's favor worked the experimental verification of the atomistic nature of matter, shortly after Boltzmann's tragic death in 1907, which to Boltzmann was only a hypothesis, even if it was not verified that atoms really do play roulette.

9.3 Black-Body Radiation as Statistical Mechanics

The other, with classical methods seemingly unsolvable problem confronting the scientists, was the problem of black-body radiation. A *black body* absorbs light of all frequencies but emits only lower frequencies with a high frequency *cut-off* depending on the temperature of the body. Classical wave mechanics had no cut-off, so it could not explain the phenomenon seen in many experiments. Max Planck had written his thesis on the 2nd law and was trained in statistical mechanics (eventually taking up Boltzmann's position in Vienna in 1907), and "in an act of desperation" he resorted to the idea of viewing light as a stream of packets of energy, so called *quanta*, which would obey certain laws of statistics borrowed from statistical mechanics, and this way he could obtain the desired cut-off of high frequencies [90, 91, 92]. Thus the other threat to science had been obviated by resorting to statistics, but Planck hesitated to give his quanta any real physical significance, because he could not make that fit with the principles of his (solid) scientific education.

In the short term, the threat thus was met, but the side effect of the statistical medication was a weakening of the immune system of rational mechanics and physics giving way to the new brave world of relativity of space and time. The process was similar to the perestroika of Gorbatchev aimed at solving only certain inconsistencies of marxist economy, but in fact leading to the complete collapse of the Soviet Union.

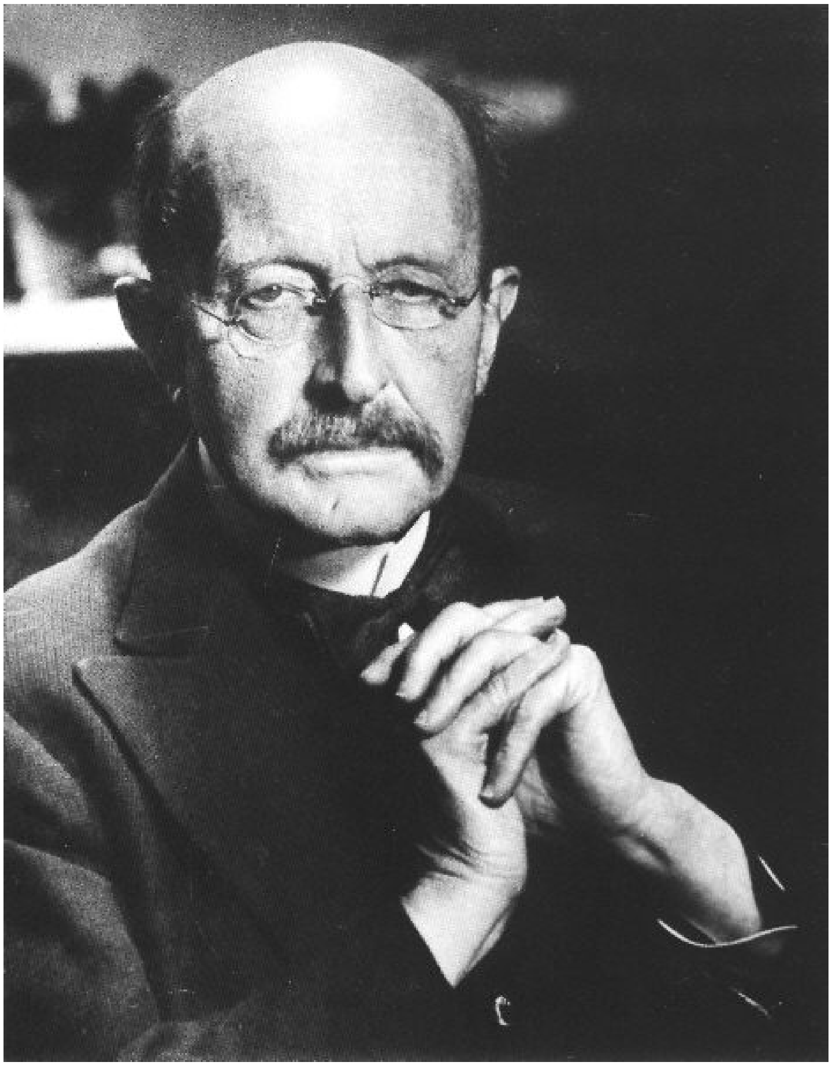


Figure 9.2: Planck: *The whole procedure was an act of despair because a theoretical interpretation had to be found at any price, no matter how high that might be...*

9.4 Quantum Mechanics

Planck's desperate 1900 resort to "quanta of energy" was picked up by Einstein and presented in his 1905 article [25] on the photoelectric effect taking Planck's upshot one step further to a new brave corpuscular theory of light with the corpuscles representing "quanta of light", or "photons" with a later terminology. Einstein's support of Planck was reciprocated by Planck, who introduced Einstein to the scientific world.

This work displays the typical traits of Einstein's scientific work: Einstein starts by freely "borrowing" a result from some famous scientist like Lorentz or Planck, usually without reference, and then presents it in different form making it appear to be new and revolutionary. Thus, Planck did not believe in the real existence of quanta of light as some form of photon particles, but Einstein did not hesitate to give the photon a particle nature, although he of course also took the opposite position that in fact there are no photons.

Planck's concept of quantum of energy prepared the way for a gradual development of a new wave theory for the atom through the work by Rutherford 1911, Bohr 1913 and de Broglie 1924, until its culmination as *quantum mechanics* based on *Schrödinger's wave equation* presented in 1925 by the young Erwin Schrödinger. Quantum mechanics gives a continuum model of matter on atomistic scales as *wave functions* of space and time satisfying Schrödinger's wave equation. Wave functions are not localized in space like corpuscular point-wise particles, but are smooth functions effectively extending in space over atomistic scales. The quanta are represented as differences of successive eigenvalues of Schrödinger's equation, and thus quantum mechanics is a wave theory, and not a corpuscular "particle mechanics of quanta".

Quantum mechanics is today an accepted theory of matter on atomistic and molecular scales, supposedly supported by massive experimental data. But the true nature of the Schrödinger equation is still today largely a mystery, because of the high dimensionality in space of the Schrödinger equation, with three independent variables for each particle leaving a problem with $3N$ independent variables for an atom with N electrons. This is a problem which is a monster from both scientific and computational point of view, as pointed out by Walter Kohn in his Nobel Lecture 1998.

The monstrosity of the Schrödinger equation made Schrödinger turn away from his equation, and Einstein did not appreciate it either. Despite these reservations, and others, quantum mechanics is viewed to be one of the two pillars of modern science [14, 9, 10, 11, 12, 13, 43, 22, 35, 6, 68, 97, 98, 99],

Figure 9.3: Schrödinger: *I am opposing not a few special statements of quantum physics held today (1950s), I am opposing as it were the whole of it, I am opposing its basic views that have been shaped 25 years ago, when Max Born put forward his probability interpretation, which was accepted by almost everybody.*

the other being Einstein's relativity theory.

9.5 An Alternative Deterministic Approach

In [55, 56, 58, 57] we present a deterministic approach to the 2nd law of thermodynamics, black-body radiation and quantum mechanics based on finite precision computation. We thus present a deterministic alternative to statistical mechanics as a basis of modern physics, in all modesty. This is important to know, since it offers an escape from the apparent dead-lock of classical mechanics concerning the 2nd law and black-body radiation preparing the collapse into (the black holes of) modern physics. We follow a principle of viewing physics as a form of analog computation, in which precision and stability are key aspects, just as in digital computation. Irreversibility can then be understood as an impossibility arising from insufficient precision to counter instability reflecting rapid growth of perturbations.

With this perspective, the impossibility of assembling an expensive Chinese vase smashed into pieces, has nothing to do with statistics, but only reflects the unattainable high precision required for the assembly. Smashing does not require much of high precision, but assembly does, and this gives time a direction. In short words, we replace statistical mechanics by finite precision computational mechanics, thus achieving a considerable simplification of scientific principles. But this is another story, although many-minds relativity also connects to finite precision, as we will see below.

9.6 Einstein vs Quantum and Statistical Mechanics

Both Einstein and Schrödinger spent the later half of their scientific lives in pursuit of a unified theory combining quantum mechanics and relativity, but none of them came any near a solution. Part of the difficulty comes from the "wave-particle" duality with a corpuscular theory living side by side with a wave theory. Part of it comes from the way Einstein's relativity is set up, which refuses combination with quantum mechanics.

Einstein's reaction to these difficulties was to reject quantum mechanics, which was not a good idea, since quantum mechanics showed to work surprisingly well, if only its high dimensionality was reduced by suitable

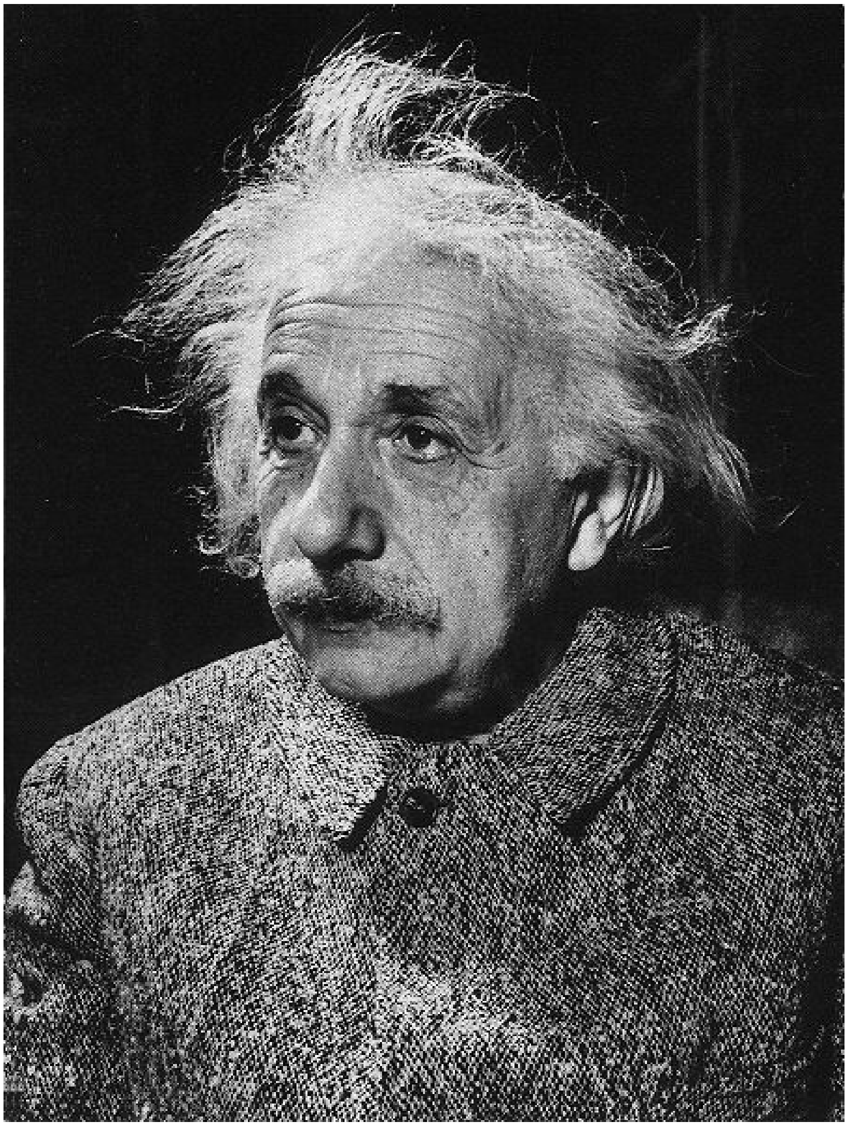


Figure 9.4: Einstein 1954: *All these fifty years of conscious brooding have brought me no nearer to the answer to the question, "What are light quanta?". Nowadays every Tom, Dick and Harry thinks he knows it, but he is mistaken.*

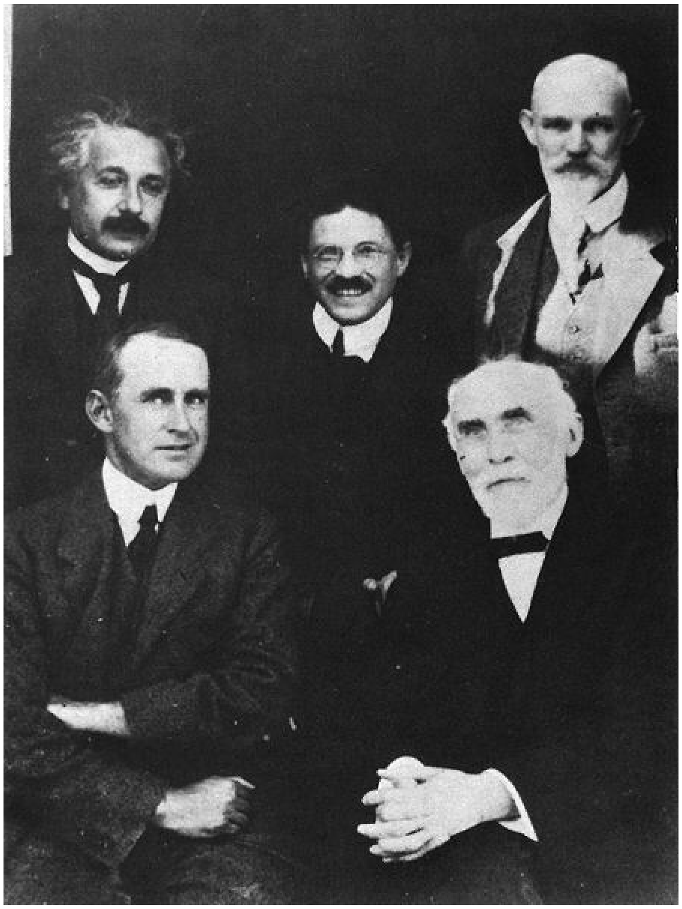


Figure 9.5: Einstein to Eddington, Eherenfest, Lorentz and deSitter: *If mechanics is to be maintained as the foundation of phyics, Maxwell's equations have to be interpreted mechanically... [39]*

approximation methods. Thus quantum mechanics continued to thrive all the way through the 20th century, while the distance from Einstein to the research front became larger and larger.

It is ironic that Einstein's corpuscular photons prepared for the anti-corpuscular wave functions of Schrödinger's quantum mechanics, which Einstein could not accept and which made him look like a fool; it thus appears that Einstein had nourished a wolf at his breast. And maybe his master-piece of relativity had similar qualities.

9.7 Born on Modernity and Progress

Born writes in [8]:

- *There must be an error in these (classical Newtonian) ideas, or at least a fallacy, due to a confusion of habits of thought with logical consistency, a tendency we all realize to be an obstacle to progress.*

Born evidently suggests that relativity requires the modern man to give up "logical consistency" to give room for "progress". But logical consistency is the first and maybe only principle of science, so how could Born require the modern physicist to give it up? This is the question, we now seek to answer.

It is natural to see a parallel between the breakdown of the classical concepts of space and time in relativity theory, and the breakdown of society during the 1st World War, and the "deconstruction" of literature, art and music giving room for modernity in the form of cubism, dadaism and atonal 12-tone styles of musical composition. To give up classical values to give room for modernity, is an important aspect of relativity; the relativistic modern scientist must be willing to replace logic and intuition by absurdities, just as the modern man must be willing to give up the classical novel (which he feels offers emotion and insight), tonal music (which he likes) and descriptive art (which he understands), and adjust to a complex, variable and often absurd relativistic "deconstructed postmodern" world.

Of course, relativity showed up also in politics, when the absolute rules of the Emperor and the Church were replaced by all the relativities of democratic parliamentarian systems and consumerism. In the modern society, everything was relative and nothing absolute, and yes it was even absurd and contradictory. Accordingly, also physics, the King of Absolute Science, could allow itself to become absurd, contradictory and fragmented, if that showed to be necessary for progress, in a modernization process similar to the fragmentation of language and human experience exhibited in James Joyce unreadable monumental masterpiece *Finnegans Wake.*

The essence of Einstein's contribution is thus the message that we have to give up the Newtonian world view with a Euclidean "flat" space clearly separated from time, for a "curved" space-time with space and time no longer separated. The most difficult aspect is that of "giving up" Newtonian mechanics, because Newtonian mechanics is so solidly built into physics and mechanics. Thus the "giving up" is felt like a big sacrifice and the inner soul of most scientists is clearly against making this sacrifice, because so much is lost and so little seems to be gained. To understand Einstein's influence it thus seems to be important to analyze, why the "giving-up" philosophy of Einstein could get such strong influence. Certainly, there was a lot of resistance to relativity during the first quarter of the 20th century, but then the resistance faded, and today everybody knows that space-time is inseparably "curved", without having the faintest clue to what the meaning could be.

The reason behind the fame of Einstein's (special) relativity, thus does not appear to be its scientific content, which is questionable, but its connection to the modernity developing starting around 1900:

- *Relativity theory formed a knife to help cut society adrift from its traditional moorings.* (Paul Johnson).

- *Einstein's theory of relativity not only upended physics, it also jangled the underpinnings of society. For nearly three centuries, the clockwork universe of Galileo and Newton–which was based on absolute laws and certainties, formed the psychological foundation for the Enlightment, with its belief in causes and effects, order, rationalism, even duty.* (Paul Johnson)

We see that relativity has moral over-tones of heroically "giving-up" classical ideas in order to open for progress into a new brave world of the modern man rising from the ashes of world wars. The size of the heroic sacrifice of giving up classical concepts of space and time developed through many thousands of years of human civilization and imprinted in the human brain, and the size of the undertaking of discovering God's Plan of the Universe, also probably helped to impress the general public, although somewhat questioned by E.H. Gombrich in *The Story of Art*:

- *Everybody knows that the ideas of modern science often look extremely abstruse and unintelligible...the most striking example is of course Einstein's relativity... Both artists and critics were and are immensely impressed by the power and prestige of science and derive from it not only a healthy belief in experiments but also a less healthy faith in anything that looks abstruse.*

And maybe by James Joyce in *Finnegan's Wake*:

- *...inearthial cowardinate syspensoir transfermentation of spass and shame cunttraction and delusion of coinawareness... they ought to told you every last word first stead of trying every which way to kinder smear it out poison long. Show that the median, hce, che ech, interecting at royde angles the parilegs of a given obtuse one biscuts both the arcs that are in curveachord behind. The family umbroglia. A Tullagrove pole to the Height of County Fearmanagh has a septain inclinaison and the graphplot for all the functions in Lower County Monachan, whereat samething is rivisble by nighttim, may be involted into the zeroic couplet, palls pell inhis heventh glike noughty times* ∞*, find, if you are not literally coefficient, how minney combinaisies and permutandis can be played on the international surd! pthwndxrclzp!, hids, cubid rute being extructed, takin anan illitterettes, ifif at a tom. Answers (for teasers only). Ten, twent, thirt, see, ex and three icky totchy ones. Form solation to solution. Imagine the twelve deaferended dummbbawls of the whole abovebeugled to be the contonuation through regeneration of the urutteration of the word pregross. It follows that, if the two antesedents be bissyclitties ....Plutonic loveliaks twinnt Platonic yearlings– you must, how, in undivided reawlity draw the line somewhawre....*

Chapter 10

Simultaneity

> Thus we are obviously moving in a vicious circle. (Born [8])
>
> If a scientist says that something is possible he is almost certainly right, but if he says that it is impossible he is probably wrong. (Arthur C. Clarke)
>
> Courtiers of all ages feel one great need: to speak in such a way that they say nothing. (Stendahl in *Racine and Shakespeare*)
>
> The goal of a true critic should be to discover which problem the author posed himself (knowingly or not) and to find whether he solved it or not. (Paul Valéry)
>
> A fundamental error is confusion of time and space.(Henri Louis Bergson)

10.1 The Initial Shock

Einstein prepared his 1905 venture into special relativity by trying to pull the carpet under the scientific community (as usual borrowing an idea, this time from Poincaré), by declaring: *"There is no such thing as absolute simultaneity"*, [8]. After this shock the community should be relieved from any misconception of Newtonian absolute time, and open its mind to a new modern world of relativity of time (and space).

Initially, Einstein's work was ignored by the scientific community, but gradually its seeds of disbelief in simultaneity started to have an effect. By the end of the 1st World War it was viewed as an accepted truth, even if it kept its mystery and very few physicists claimed they were able to follow Einstein's reasoning.

10.2 Relativity of Time

Of course, even a traditional non-relativistic Newtonian is aware of the trivial fact that time is not absolute in the sense that we have to start counting time from a certain point in time, like the birth of Christ, the beginning of the year, day or hour, or the start of a 100 meter dash. At initial time we start a clock and then we can read off the time of subsequent events. Time is always relative to a certain initial time.

That clocks can work at different pace became painfully aware to the seafarers before the modern chronometer was invented by John Harrison, a Yorkshire carpenter, in the early 18th century, since the determination of longitude relied on the time of an accurate clock brought along on the ship. Columbus thus thought he had arrived to India, when in fact he was arriving to the Carrabean. With the chronometer more exact navigation became possible, using the height of the Sun at noon to determine the latitude, and e.g. the time of sunset for the longitude. Without a clock you can decide your latitude, but not the longitude.

Now, if you mount a chronometer on top of the church tower, you can define absolute time and simultaneity in the town. You can of course widen the scope and consider a country consisting of many towns, each one with a church clock showing the local time of the town. To get business and administration working in the country properly, it is necessary to *synchronize* the clocks, so that they all show the same time. This can be done by setting each clock according a broadcasted time from one central clock, and thereby specify an absolute time and simultaneity all over the country.

If we now imagine a very large country with very long distances between the central clock and the town clocks, then we may have to take into account the finite speed of propagation of the radio waves transmitting the central time to the local clocks. This can of course readily be done if we know the distances between the central and local clocks, and the speed of propagation of the radio waves, which is the same as the speed of propagation of light. This is because both light and radio waves are electromagnetic waves, albeit with different wave-lengths but all propagating with the same speed of light.

Now a slight problem may appear, if the country is very large: How to get to know the distance between towns if we cannot for practical reasons measure it with a yard stick?

Well, it does not take much innovation to come up with a solution, if you can communicate between the towns with radio waves, which can carry the local time of transmission to the reception. This technique is used in the GPS-system which offers absolute time and simultaneity all over our Earth. We describe the principles of the GPS absolute time in more detail below as a part of many-minds relativity.

However, nothing like a GPS-synchronization technique was available to Einstein: The radio was still in its infancy, and the possibilty that a signal could carry its time of transmission to the receiver was not envisioned by Einstein, who got stuck with a much more primitive method of synchronization based on light signals, like sending an receiving flashes of light using flashlights.

Einstein then showed that with such a primitive system, it could be quite hard to achieve absolute synchronization, so hard that he felt he could confidently state that *absolute simultaneity can be ascertained in no way whatever*, [8].

To get some perspective we recall the above citation of Clarke concerning the impossibility of proving the impossible.

10.3 Impossibility of Simultaneity?

We reproduce Borns version [8] of Einsteins thought experiment supposedly demonstrating once and for all that “absolute simultaneity can be ascertained in no way whatever”. We consider three point-like bodies B_1, B_2, B_3 on an x-axis, first at rest at $x = 1$, $x = 2$ and $x = 3$. Let at $t = 0$, B_2 emit a light signal propagating with unit speed along the x-axis in both directions. The two light signals will then be received simultaneously by B_1 and B_3 at $t = 1$, according to trivial Galilean mechanics in a (x, t)-coordinate system.

Imagine now that both B_1, B_2 and B_3 instead move in the positive direction of the x-axis with speed $0 < v < 1$, and as before at time $t = 0$ with the same position as before of the bodies, B_2 again sends a light signal in both directions of the x-axis. In a (x', t')-coordinate system with the x'-axis also moving with velocity v together with the bodies along the x-axis, the light signal would again arrive simultaneously at B_1 and B_3 at time $t' = 1$.

However, and now comes the catch, if we describe the process in (x, t)-coordinates, then it would seem that the light signal would reach B_1 at a time $t < 1$, and B_3 at a time $t > 1$, because of the motion of B_1 and B_3 towards and away from the light signal. Thus what is simultaneous in (x', t') coordinates would not be simultaneous in (x, t)-coordinates, and thus Einstein though experiment would show that "absolute simultaneity can be ascertained in no way whatever".

We will understand below that in many-minds relativity, this counter-example to absolute simultaneity, cannot be posed. In many-minds relativity there is absolute time t and absolute simultaneity, and the space-time coordinates of the reception of a light signal by a body are only recorded with the space-axis at rest with the receiver. All reception takes place at rest, while emission may take place under motion. Thus, in Einstein's thought experiment only the (x', t')-coordinates are recorded (with $t' = t$) in the case with the bodies moving with respect to the x-axis; the (x, t)-coordinates would not be recorded because the moving receivers B_1 and B_3 are not at rest with the x-axis.

In many-minds relativity, we thus avoid Einstein's contradiction to simultaneity, by requiring that a receiver always is at rest on its space-axis. Simple and natural.

10.4 How Essential is Simultaneity?

In the spirit of the politics of 1968, we can pose the question:

(s) *Simultaneity for whom?*

We note first that absolute simultaneity is required in the GPS system, since it works on the time delay of signals from a set of transmitting satellites to the receiver in your hand. Since the GPS system evidently works very well, it shows that it is possible to construct a system of absolute time, at least around the globe, and probably in our Solar system and beyond. Evidently the GPS system is very useful for very many human beings for orientation on and around the Earth. But there is not yet a GPS system that covers the Milky Way Galaxy, because there is not yet any demand from space travelers for such a system. But it can probably be set up when the demand arises. So it seems that human beings are capable of setting up a system of absolute time and simultaneity, at least so far there is any need for it.

Of course, Einstein could not anticipate the GPS system, and therefore what todays is shown to be possible, to him seemed impossible.

Next, leaving human made systems, what about Nature itself, without any observers with GPS receivers in their hands? How much simultaneity is required in Nature, which only has access to some kind of "natural clocks" when evolving from one moment of time to the next. Of course, this brings in the question of cause and effect, and locality of interaction. If two objects are so far apart that they cannot interact by any means, simultaneity is not an issue: Each can use its own local time and there is no need for synchronization. If two objects are interacting locally, then both must share the local time of the locality: If two trains are to meet, they must meet at the local time of the meeting. It is impossible that train A meets train B at a certain place in space at a certain local time at that place, without B meeting A at the same place at the same local time. So, as long as local interaction is concerned, simultaneity is no issue in Nature, because it is automatic.

Next, what about "action at distance"? When the Earth orbits the Sun according to Newton's laws, in an elliptical orbit with the Sun in one of the focal points (omitting the influence of the other planets), the Earth accelerates towards the Sun as if the gravitation acted instantly without delay, just as in the case of local interaction. This means that the Earth accelerates towards the present instant position of the Sun, and not towards the 8 minute delayed position visible in the sky, because it takes 8 minutes for the light to travel from the Sun before it hits our eye. Thus, the issue of simultaneity does not arise either for action at distance as long as it is instant.

Finally, action at distance with time delay, results from a chain reaction of local instant interactions creating a propagating wave, and the chain reaction sets the sequence and thus the timing of the events. Also in this case it appears that simultaneity is automatic and thus not any issue. In Nature without observers and GPS receivers.

We conclude that the GPS system offers absolute time with absolute simultaneity for use of human beings, while in Nature simultaneity is automatic, whenever there is any need for it. Therefore Einstein's concern about the combined importance and impossibility of simultaneity seems overly sensitive. It does not seem to be any issue today, even if it was in Einstein's time. But in special relativity it is the starting point, so we have to maintain an interest in the impossibility of simultaneity and relativity of time, when we now continue recalling Einstein's theory.

10.5 Effective Scientific Argumentation

Born writes in [8, 10]

- *In 1905 Einstein recognized that Lorentz contractions and local times were not mathematical devices and physical illusions but involved the very concepts of space and time.*
- *Length contraction and time dilation are ways of regarding things and do not correspond to physical reality.*

The discussion of the question whether special relativity is illusion or reality, has been going on since the start without any conclusion. Einstein very conveniently takes on an ambiguous attitude, supported by his friend Born, making it possible to shift from one standpoint to the other when facing critique:

On criticism of lacking conformity with observation, Einstein can say that after all space contraction and time dilation are effects forced upon us by logic, that is by definition via the Lorentz transformation, and thus as such do not have to conform to anything, as long as they conform to the Lorentz transformation, which they do, by definition.

On criticism for being only an illusion as an effect of a definition, Einstein can say that there are observations conforming to special relativity, such as the Michelson-Morley experiment, and thus observations confirm the theory.

The ambiguity makes it hard to argue with physicists trained in the tactics of Einstein, and Born. If you are warned, it is easy to see when such tactics is used, but it is not easy to counter. You often meet questions like: What exactly to *you* mean by “event”, “at the point x”, “wave”, “wave equation”, “time”, “space”, “length”, “observation”, “exists”, “model”, “reality” and the like, which puts you into a defensive position. After carefully having explained exactly what you mean, you face questions on a new level like: What exactly do *you* mean by “at”,“for”, “when” and “and”, which puts you into another defensive round, and after a couple of hours you give up by pure exhaustion, without the expert physicist having answered any of your questions. Or the expert just evades any serious questions by joking referring to one of the many funny pictures of Einstein or Einstein-jokes: We all know that relativity is a joke, but it is such a good joke that there must be some truth in it, like in all good jokes.

10.6 The Hard Line of Born

We cite from [8]:

- *Since absolute "simultaneity" cannot be ascertained, science must remove this concept from its system.*

This is a tough statement by a tough scientist, who is not joking and shows no pardon as concerns what has to be done to completely eliminate "simultaneity" from the "system of science". Again, political vibrations could be felt.

Leave everything.
Leave Dada.
Leave your wife and your mistress.
Leave your hopes and your fears.
Sow your children in the corner of a wood.
Leave the prey for the shadow.
Leave if need be an easy life, what you are
offered for a future situation.
Hit the road. (André Breton)

Chapter 11

The Essence of Special Relativity

> Too many laws are made, and too few examples given. (Saint-Just)

> Relativity actually ought not to be connected with a single name or single date. It was in the air about 1900 and several great mathematicians and physicists–Larmor, Fitzgerald, Lorentz, Poincaré, to mention a few, were in possession of many of its contents. (Born [8])

> I know that most men, including those at ease with problems of the highest complexity, can seldom accept even the simplest and most obvious truth if it be such as would oblige them to admit the falsity of conclusions which they have delighted in explaining to colleagues, which they have proudly taught to others, and which they have woven, thread by thread, into the fabric of their lives. (Tolstoy)

11.1 The Lorentz Transformation Revisited

We recall that the back-bone of special relativity is the Lorentz transformation (5.9) and (5.11) connecting the space-time (x', t')-coordinates with the (x, t)-coordinates by

$$\begin{aligned} x' = \gamma(x - vt), \quad t' = \gamma(t - \frac{vx}{c^2}), \\ x = \gamma(x' + vt'),\ t = \gamma(t' + \frac{vx'}{c^2}), \end{aligned} \tag{11.1}$$

where c is the speed of light,

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}, \tag{11.2}$$

and we assume that $0 < |v| < c$. We know that this is a simple linear transformation, which can be characterized in many ways, for instance by the following conditions:

(l1) $x' = 0$ if and only if $x = vt$,

(l2) $x' = ct'$ if and only if $x = ct$,

(l3) the inverse transformation arises by replacing v by $-v$.

Here (l1) signifies that the origin $x' = 0$ of the x'-axis translates along the x-axis with velocity v, (l2) signifies that a light ray with speed c in one system is a light ray with the same speed in the other system, and (l3) signifies that we can switch coordinates and equivalently start instead with the (x', t')-coordinates considering the origin $x = 0$ of the x-axis to translate with velocity $-v$ along the x'-axis.

We understand that the Lorentz transformation is just a simple 2 × 2 linear transformation with certain properties. No more no less. It can be specified in an endless number of ways, all trivially equivalent.

11.2 Dangers of Over-Interpretation

As comparison we may consider the 1 × 1 linear transformation given by $x' = ax + b$, which is a straight line with slope a and offset b. There is an endless number of ways to specify the transformation, that is specifying the constants a and b, for example by specifying two different points (with different x'-coordinates) in an (x, x')-coordinate system, through which the straight line is required to pass. Whatever conclusion we can draw from this transformation, we should be prepared that it could not be anything beyond linearity, which is how it is defined. We cannot get more out than we put in.

Likewise, we may expect that whatever conclusion can be drawn from the Lorentz transformation, it cannot contain more than the defining conditions: If someone derives something astonishing beyond what was put in, we should be prepared that this might represent some kind of *over-interpretation*.

However, special relativity is not commonly viewed as simply an over-interpretation of the Lorentz transformation, but as nothing less than a completely new view on the basic concepts of space and time! Just as if from $x' = ax + b$ as a model of the world, we could get new deep insight beyond the very simple linearity put into the model. We know that mathematics is a powerful, but it cannot be expected it to create wonders out of nothing. Or can it? It seems that Einstein thought it could, maybe forgetting that, after all, mathematical results are tautologies with output equal to input, without possibilities to over-interpretation, of course tempting to an amateur mathematician, but not allowed to a professional.

11.3 Elementary Observations

If we are not already convinced that the Lorentz transformation should be dismissed as a peculiarity not doing what it was intended to do, and thus without physical significance, we continue noting the following facts:

- the x'-axis corresponds to the line $t = \frac{vx}{c^2}$,
- the t'-axis corresponds to the line $x = vt$,
- the x-axis corresponds to the line $t' = -\frac{vx'}{c^2}$,
- the t-axis corresponds to the line $x' = -vt'$.

We can plot the two systems in the same figure with the (x, t)-system as an orthogonal system with horizontal x-axis and vertical t-axis, and with both the x' and t'-axes tilted into the positive quadrant of the (x, t)-plane. We can alternatively plot the (x', t')-system as a translated system, with a vertical t'-axis but with the x' still pointing into the positive (x, t)-quadrant.

In particular we see that even if the origin of the x'-axis can be viewed to slide along the x-axis as in the alternative plot, *there is no way we can view the whole x'-axis to glide along the x-axis*, as is possible in a Galilean transformation. The property of the Lorentz transformation to mix space into time signifies the novelty as compared to the classical (trivial) Galilean transformation, which only mixes time into space, but not space into time.

Einstein says that the mixing of space into time is the very beauty and power of the Lorentz transformation, revealing new aspects of the very concepts of space and time to *homo modernus*.

We have already, in the setting of the convection problem, met the defect of the Lorentz transformation concerning transformation of initial data, and we now will see the same effect for the wave equation (5.3).

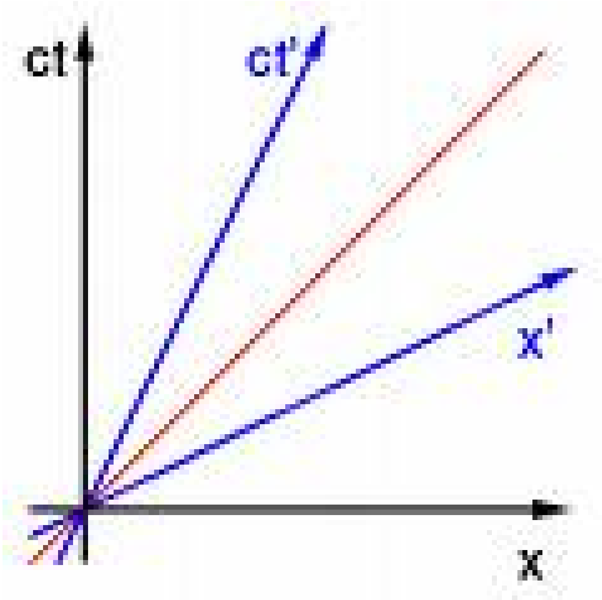


Figure 11.1: The canonical picture of the Lorentz transformation: Notice that the x'-axis points into the (x,t)-plane and is **not parallel** to the x-axis.

11.4 Lorentz Transformation and Wave Equation

Recalling that by the chain rule

$$\frac{\partial}{\partial t} = \gamma(\frac{\partial}{\partial t'} - v\frac{\partial}{\partial x'}), \quad \frac{\partial}{\partial x} = \gamma(\frac{\partial}{\partial x'} - \frac{v}{c^2}\frac{\partial}{\partial t'}),$$

we find by direct computation that the initial value problem for that wave equation

$$\begin{aligned} \frac{\partial^2 u}{\partial t^2} - c^2\frac{\partial^2 u}{\partial x^2} = 0, \quad \text{for } x \in \mathbb{R}, 0 < t \in \mathbb{R}, \\ u(x,0) = u_0(x), \quad \frac{\partial u}{\partial t}(x,0) = \dot{u}_0(x) \quad \text{for } x \in \mathbb{R}, \end{aligned} \tag{11.3}$$

where u_0 and $\dot{u}_0$ are a given initial conditions, transforms into

$$\begin{aligned} \frac{\partial^2 u'}{\partial t'^2} - c^2 \frac{\partial^2 u'}{\partial x'^2} = 0, \quad \text{for } x' \in \mathbb{R}, 0 < t' \in \mathbb{R}, \\ u'(x',0) = u_0'(x), \quad \frac{\partial u'}{\partial t'}(x',0) = \dot{u}_0'(x') \quad \text{for } x' \in \mathbb{R}, \end{aligned} \tag{11.4}$$

where

$$\begin{aligned} u_0'(x') &= u(\gamma x', \gamma \frac{v x'}{c^2}), \\ \dot{u}_0'(x') &= \gamma(\frac{\partial u}{\partial t} + v \frac{\partial u}{\partial x})(\gamma x', \gamma \frac{v x'}{c^2}). \end{aligned} \tag{11.5}$$

We essential made this computation in the chapter on Wave Propagation and Convection. We see that the wave equation itself is invariant under the Lorentz transformation, because the equation

$$\frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 u}{\partial x^2}$$

takes an identical form in (x', t')-coordinates with the same speed c of wave propagation (and no factor on the forcing if present)

However, as in the case of the convection problem, the nature of the initial conditions do change, because the Lorentz transformation mixes space into time, and we cannot express u_0' and $\dot{u}_0'$ in terms of u_0 and $\dot{u}_0$, as would be required for full invariance.

The invariance of the wave equation itself is the main virtue of the Lorentz transformation. But since it does not leave the initial conditions invariant, it has a very serious defect. Surprisingly this seems to have been overlooked by Einstein, who copied Lorentz, while Lorentz rightly hesitated to give his transformation any physical significance, maybe because of the initial value invariance defect (in one form or the other), which he probably was aware of.

11.5 Summary of Special Relativity

Special relativity can be identified with the Lorentz transformation (11.1). Using the Lorentz transformation one can (easily) derive the basics of *Einstein's kinematics* containing the *relativistic addition* of two velocities v_1 and

v_2 into the composite velocity

$$v = \frac{v_1 + v_2}{1 + \frac{v_1 v_2}{c^2}}, \tag{11.6}$$

and the following modification of Newton's 2nd law

$$m\dot{v} = f, \tag{11.7}$$

where $\dot{v} = \frac{dv}{dt}$ is the acceleration,

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{11.8}$$

is the *relativistic mass* at velocity v with m_0 the *rest mass* a zero velocity, and f is an applied force.

From his relativistic Newton's law (11.7), Einstein next derives the crown jewel of special relativity

$$E = mc^2 \tag{11.9}$$

stating that the energy E is proportional to the mass m.

We do not here recall the proofs of these consequences of the Lorentz transformation, since they are presented in very many books on relativity, and since part of our objective is to show that the Lorentz transformation does not do what it was intended to do, namely leave the wave equation (including initial values) invariant, and the other part is to develop the alternative of many-minds relative including proofs of many-minds variants of (11.7) and (11.9).

Chapter 12

Seduction of Lorentz Transformation

> The variable t' (in the Lorentz transformation) may be called the "local time". (Lorentz, [78])
>
> Lorentz had already recognized that the transformation named after him are essential for the analysis of Maxwell's equations, and Poincaré deepened the insight further...(Einstein a in letter to Seelig, 1955)
>
> Surprisingly, however, it turned out that a sufficiently sharpened conception of time was all that was needed to overcome the difficulty discussed. One had only to realize that an auxiliary quantity introduced by H. A. Lorentz, and named by him "local time", could be defined as "time" in general. If one adheres to this definition of time, the basic equations of Lorentz's, theory correspond to the principle of relativity. (Einstein 1907)
>
> In Lorentz view, the Lorentz transformation does not relate two arbitrary inertial frames but is only a mathematical relation between a physical frame and a non-physical set of coordinates. (Sartori [96])

12.1 Summary of Our Critique of Lorentz

We can summarize our main criticism of the Lorentz transformation (11.1) simply as follows:

(c1) the entire x'-axis does not glide on top of the x-axis, (c2) initial values are not invariant.

Here, of course (c2) can be seen to be a consequence of (c1). We can thus view (c1) to express the main defect of the Lorentz transformation.

12.2 Borns Clarification

We have seen that (c1) means that space is mixed into time and to explain this effect, by many considered as "strange", Einstein's friend Born comes to rescue with the following "clarification" [8]:

- *A material rod is physically not a spatial thing, but a space-time configuration. Every point of the rod exists at this moment, at the next, and still at the next, and so on, at every moment of time. The adequate picture of the rod under consideration is thus not a section of the x-axis, but rather a strip in the (x, t)-plane. The same rod when at rest in various moving systems, is represented by various strips.*

Born's statement is very illuminating and puts the finger right at the weak spot: We learn that a material rod is not a "spatial thing", that is not a "material something" or a "material rod". Thus it seems that a material rod is not a "material rod"!

This directly couples to the concept of a wave as a solution $u(x, t)$ to a wave equation, which we discussed above, as something which has an extension (or "co-existence") in space as a function $x \rightarrow u(x, t)$ for a given fixed t. According to Born's clarification, a wave would not be "spatial thing" with an extension or co-existence in space, that is a wave would not be a "wave". Instead, the different values $u(x, t)$ of a wave for a given t with x varying, would not be viewed as "co-existing", but as a collection of separate space time "events" $u(x, t)$ freely indexed by both x and t, with no particular nature of co-existence connected to events with the same t-coordinate.

12.3 Special Relativity as Deconstruction

This represents a "deconstruction" of the concept of a wave into a collection of fragments or isolated point-like events $u(x, t)$ indexed by (x, t), which as well can be indexed in terms of fragments $u'(x', t') = u(x, t)$ according to the

Lorentz transformation, without worrying about co-existence, extension in space and invariance of intial conditions.

But such a fragmentization does not fit with the nature of a wave as a solution to a wave equation, requiring co-existence in space to have any meaning. The wave equation is not defined for wave fragments, only for (differentiable) co-existing wave forms $x \to u(x,t)$.

The idea of deconstruction also appears in the cubism style of painting, with space-time fragments of an image being "scrambled" into a new "decomposed" image. Even if this in the hands of a Picasso can reveal new aspects of a motif, one may ask if "cubism physics" can open new roads to insight into physics?

12.4 Time Dilation and the Twin Paradox

The appearance of the γ-factor in the Lorentz transformation results in an effect of *time dilation* which is one of the most mystifying and confusing of all features of special relativity: Two observers X and X' will both consider the time of the other to run slow by the γ-factor.

This leads to the much debated *twin paradox*, with two twins moving with respect to each other and each of the twins considering the other to age more slowly (with some regret maybe). Since we understand that the Lorentz transformation does not describe physics, we understand that the different rate of aging is illusionary: Twin X *considers* (by the Lorentz transformation) twin X' to age more slowly, and twin X' *considers* (by the Lorentz transformation) twin X to age more slowly, and this has nothing to do with the physical rate of aging, which is the same by symmetry. It is simply the "local time" of Lorentz, erroneously taken as physical time by Einstein.

This is like two people looking at each other at distance, and both *considering* the other to be smaller, while they in fact may be equally tall. But does this observation reveal a deep new scientific insight to the "very concept of length of a person", or if it is a triviality related to elementary optics, which a child at the age of two understands very well. What do you think?

Thus, the twin paradox is not a paradox, but only an example of the illusionary character of the Lorentz transformation. But if you confuse illusion with reality, then the twin paradox becomes a real paradox, which it is the job of the physicist to "resolve". All of this can become very confusing, everything being relative and floating: faster, slower and equally fast all gets mixed into a fragmented deconstructed bouillon of relativity. To add to the confusion Einstein states:

- *There is no resolution to the twin paradox within special relativity.*

12.5 Einstein's Assumptions

To give evidence that indeed (c1) must be regarded as a defect rather than a virtue, we recall Einstein's Principle of Relativity:

(r3) *The laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of co-ordinates in uniform translatory motion.*

Einstein explains the meaning of “two systems of co-ordinates in uniform translatory motion” in [23] as follows:

- *Let us take two systems of co-ordinates and let the axes of x of the two systems coincide. Let each system be provided with a rigid measuring-rod and a number of clocks, and let the two measuring-rods, and likewise all the clocks of the two systems, be in all respects alike. Now to the origin of one of the two systems let a constant velocity be imparted in the direction of the increasing x of the other system, and let this velocity be communicated to the axes of the co-ordinates, the relevant measuring rods, and the clocks. To any time of the stationary system there will then correspond a definite position of the axes of the moving system, and from reasons of symmetry we are entitled to assume that the ... axes of the moving system are at time t (of the stationary system) parallel to the axes of the stationary system*

It seems hard not to get the impression that Einstein requires the x and x'-axes to be parallel and glide on top of each other, as in a Galilean transformation. But we just convinced ourselves (fully) that the x and x'-axes are not parallel. We conclude that whatever physical interpretation the Lorentz transformation may have, it does not seem to be be the situation so well described by Einstein.

Now, a defender of special relativity may counter by saying that we have misunderstood the meaning of the x'-axis: Of course, in a plot we can put it on top of the x-axis if we just agree to put at $x' = 1, 2, 3, ...$, not $t' = 0$, but instead $t = 0$ to get the corresponding retarded time instances $t' = -\gamma v, -2\gamma v, -3\gamma v, ...$ Thus, we have a new type of x'-axis not defined by $t' = 0$ according to the conventional definition, but by $t = 0$. This would represent the fully fragmented view we discussed above, where both the x and x'-axis have lost their meaning of co-existence, with the world simply being a collection of points (x, t) or "events" in space-time.

12.6 Einstein's Confessions

We recall Einstein's 1911 confession cited in the introduction:

- *The question whether the Lorentz contraction does or does not exist is confusing. It does not really exist in so far as it does not exist for an observer who moves (with the rod); it really exists, however, in the sense that it can as a matter of principle be demonstrated by a resting observer.*

And also his statement (confession) in his *Autobiographical Notes* [39]:

- *The special theory of relativity creates a* **formal** *dependence between the way in which the space and time coordinates* **must** *enter into natural laws*

We understand that to Einstein the Lorentz transformed coordinates (x', t') are assigned to the moving observer by the resting observer as a matter of definition, and not observation: Whatever the clock/rod of a moving observer may show, a resting observer will (without looking at the moving clock/rod) assign to it the dilated time/length of the Lorentz transformation. It seems that Einstein here admits that special relativity reduces to a definition adopted by an observer, without any physical real correspondence. Apparently Einstein kept this for himself, in order not to disturb his academic career was eventually taking off: Sometimes it may be better to say nothing, and be suspected to be a novice, than to open the mouth and remove any doubt.

In the introductory Einstein citation, we read that Einstein confesses that his contribution to special relativity consisted in replacing literally "local time" (with quotation marks) with "time" (with quotation marks), with the quotation marks indicating that another meaning than the usual is intended. But if you say "time" instead of "local time" (with quotation marks), and if you do not explain what you mean by the quotation marks, then what is the meaning of what you are saying? Quotation marks indicating irony or an unusual meaning, are dangerous to use in scientific arguments, because irony in science may easily be misunderstood, as well as unusual non-specified meanings of the words being used, indicated by “quotation marks”.

12.7 Lorentz’ Regret

Lorentz writes in a note added to the second edition of his Columbia lectures [80] from 1915 and in a lecture from 1927:

- *The chief cause of my failure (in discovering special relativity) was my clinging to the idea that only the variable t can be considered as true time and that my local time t' must be regarded as no more than an auxiliary mathematical quantity.*
- *A transformation of the time was necessary. So I introduced the conception of a local time which is different for all systems of reference which are in motion relative to each other. But I never thought that this had anything to do with real time. This real time for me was still represented by the old classical notion of an absolute time, which is independent of any reference to special frames of coordinates. There existed for me only this true time. I considered my time transformation only as a heuristic working hypothesis.*

Of course the first statement can be understood as a reaction to the surprising success of Einstein’s relativity, while the second expresses Lorentz’ original reluctance to give his local time a physical meaning, because it was questionable scientifically. We share Lorentz’ reservations completely. But Einstein did not, for him “local time” was the same as “time” without any reservation (but with quotation marks).

12.8 Born’s Summary of Special Relativity

We cite for reference Born’s summary of special relativity from [8]:

- *Not only the laws of mechanics but those of all physical events–in particular, of electromagnetic phenomena–are completely identical in an*

> *infinite number of systems of reference which are moving with constant velocity relative to each other and which are called inertial systems. In any of these systems lengths and times measured with the same physical rods and clocks appear different in any other system, but the results of measurements are connected with each other by Lorentz transformations.*

Born here states, seemingly as an irrefutable truth, that the laws of mechanics are Lorentz invariant. But we saw above that this is in fact not so clear, since the Lorentz transformation changes the nature of initial conditions. At least we can pose the question if Born is right? And how should we interpret “are connected with each other”? Is it simply a definition or is a real claim that factual observations always conform to the Lorentz transformation? What do you think? Or is it just the usual ambiguity of special relativity allowing the expert physicist to freely choose the relevant option to counter criticism? Unfortunately, Born cannot inform us about the meaning of his statement.

12.9 Critique by Others

Special relativity has been criticized seriously by many scientists over now more than 100 years. In the 1950s the physicist Herbert Dingle [20, 21] returned to the old twin paradox which resulted in a long heated debate in the scientific journal *Nature*, without any reconciliation. Mueller [86] has compiled a list of 3700 critical publications in a furious crusade against special relativity available from www.ekkehard-friebe.de. The physics community generally has met the criticism with silence and instead claims that special relativity serves as a theoretical basis of everything from the atomic physics of nuclear weapons over the GPS-system to the large scale structure of the Universe, and thus cannot be questioned by the physics community and certainly not by non-physicists.

The *Relativity Priority Dispute* on Wikipedia presents a war between attackers accusing Einstein for plagiarizing both physicists like Lorentz and mathematicians like Poincaré and Hilbert, and defenders claiming that even if Einstein so did, which is questioned by few, Einstein “understood” the physical relevance of the results much better than at least the mathematicians.

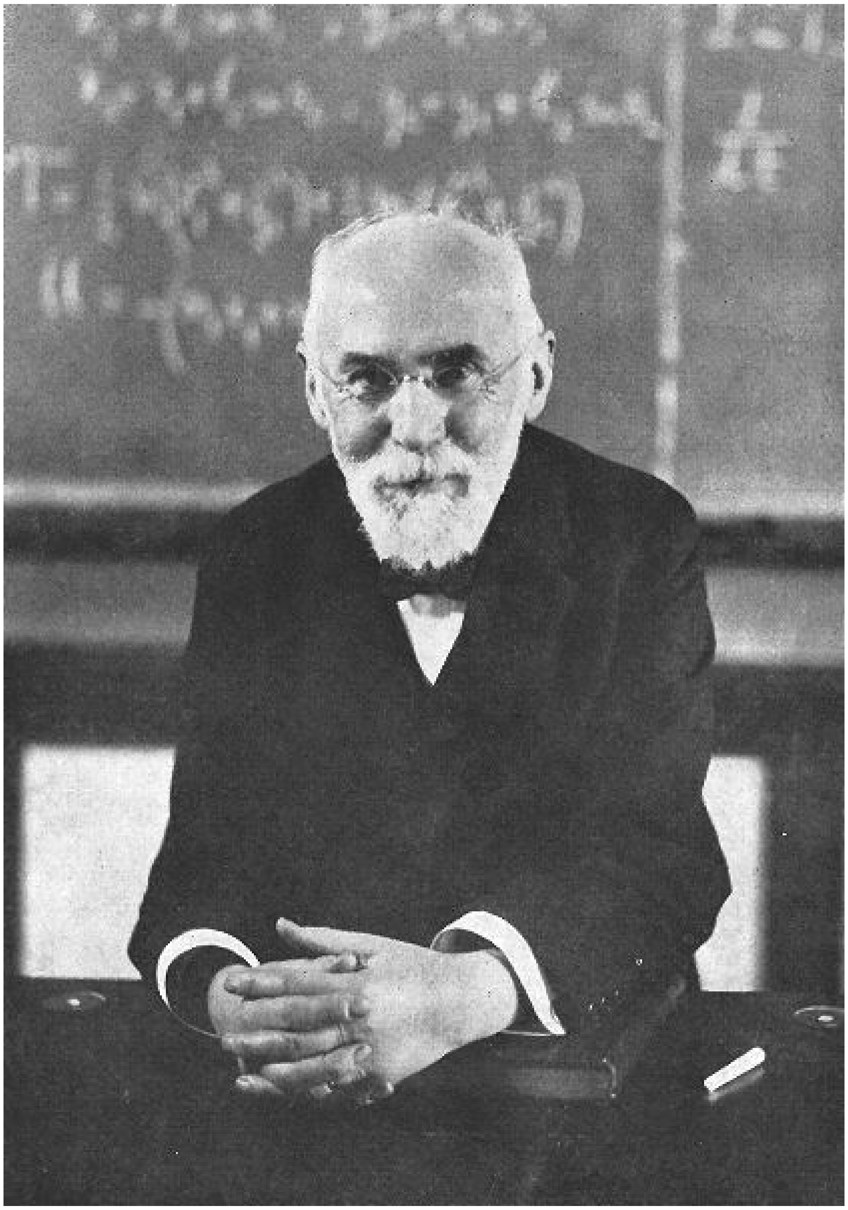


Figure 12.1: Lorentz: *I call the variable t' "local time" and emphasize that it should* **not be confused with real time***.....Is the ether an elastic medium...or frictionless fluid...or kind of a jelly, half liquid, half solid?* (from Nobel Lecture 1902)

12.10 Maurice Allais and Einstein

Maurice Allais is one of the most brilliant Leibnizian spirits of our time with a broad interest from physics over economy to politics. He received the Nobel Prize in Economy in 1988.

Allais has formulated a serious critique of Einstein, as plagiarist and pseudo-scientist, and accuses the physics community for dogmatism preventing progress during a century. We refer the reader to his very informative web site maintained by his students on *http://allais.maurice.free.fr*.

Figure 12.2: Maurice Allais: *De lá a résulté une incroyable situation sans aucun précédent dans toute l'histoire : la domination dogmatique et intolérante pendant un siécle d'une théorie fausse, la Théorie de la Relativité, résultant elle-même du plagiat indiscutable d'une incontestable erreur. Les conséquences néfastes qui en ont résulté pour la science ont été incalculables, l'orientation totale pendant un siécle de la science dans une voie erronée, et une régression de la pensée scientifique qui n 'a cessé de constituer un obstacle insurmontable sur la voie du progrés.*

Chapter 13

Time Dilation vs Experiments

> Es braucht kaum hervorgeben zu werden, dass diese neue Affassung des Zeitbegriffs an die Abstraktionsfähigkeit und an die Einbildungskraft des Physikers die allerhöchsten Anforderungen stellt. Sie übertrifft an Kühnheit wohl alles, was bisher in der spekulativen Naturforschung, ja in der philosophischen Erkenntnistheorie geleistet wurde; die nichteuklidische Geometrie ist Kinderspiel dagegen. (Max Planck in *Acht Vorlesungen über Theoretische Physik*, 1909)
>
> This implies that the foundation of the space-time world, on which rests all the arguments we have made so far, collapses. It seems now as if the ground beneath us is giving away. Everything is tottering, straight is curved, curved is straight. But the difficulty of this undertaking did not intimidate Einstein... (Born in [8])
>
> It is often simpler to work in a single frame, rather than hurry after each moving object in turn. (John Bell [3])
>
> Time will tell you I told you so. (W.H. Auden)

13.1 Reality of Time Dilation

We have understood that special relativity represents pseudo-science for which experimental support is irrelevant: If an experiment result does not fit with the theory of special relativity, in so far it is really possible to compare experiment with theoretical prediction, which seldom is the case, it is always possible to say that this is because the assumptions of special relativity were not fulfilled in the experiment, and therefore instead the general theory of relativity should be used. It is then assured that the experiments would nicely fit with the general theory, even though this comparison is impossible to make because Einstein's equations of general relativity are so complicated that they cannot be solved in any generality. In any case, the experiment would be seen as a confirmation of special relativity, which anyway does not need any confirmation, because it is true by definition.

We now take a look at some of the observations often presented as experimental confirmation of the reality of the time dilation of special relativity.

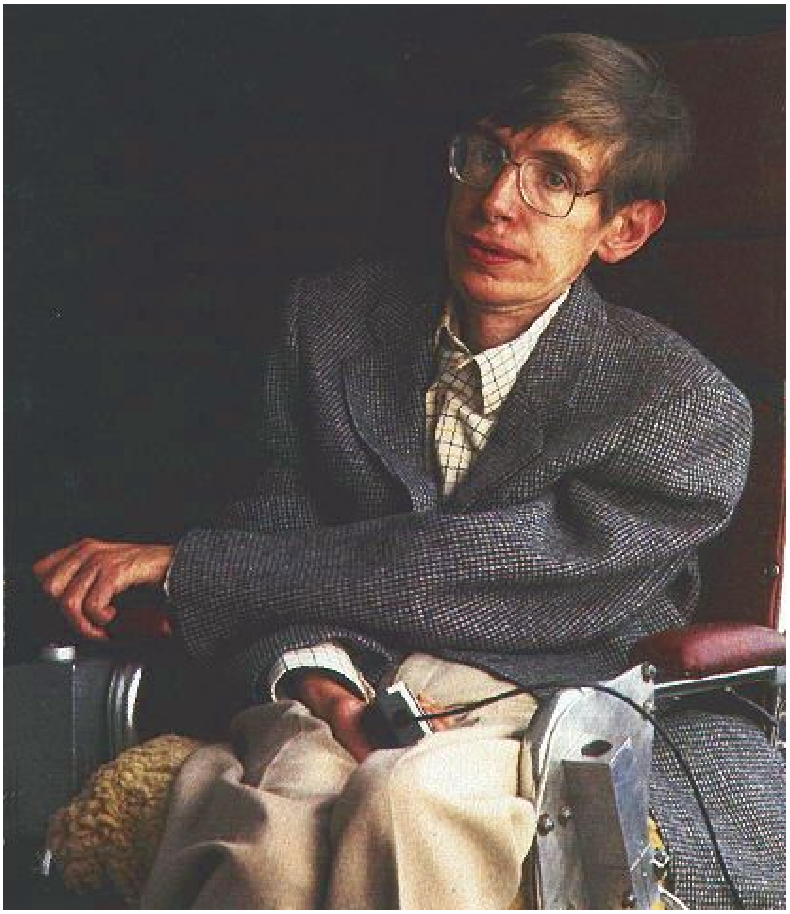


Figure 13.1: Hawking: *My goal is nothing less than a complete description of the universe we live in.*

13.2 Hawking, GPS and Special Relativity

The famous physicist Stephen Hawking, the present holder of Newton's chair in Cambridge, claims in his best-seller *The History of Time* that the GPS system (obviously) builds on both special and general relativity: Hawking claims that without *both* special and general relativity, the GPS-coordinates would be off by hundreds of kilometers or more and the GPS-system would be completely useless. Who would dare to question such a statement in a best-seller by the successor of Newton?

Let us anyway face the facts: The GPS system uses an absolute time common to all satellites orbiting the Earth all with different velocities, but *there is no time dilation*: All clocks run at the same rate and the synchronization does not have to be updated. According to special relativity there should be some time dilation because all satellites are moving with respect to each other, but there is none.

What to say? Well, first of all the assumptions of special reltivity are not fulfilled because the satellites don't move rectilinearly, and secondly the effects of time dilation are anyway too small to be noticable. All in all, GPS certainly confirms special relativity (which by the way does not need any confirmation), right?

With a closer look we find that the GPS-satellites carry identical atomic clocks with the clock rate adjusted at launch to 10.22999999543 MHz from 10.23 MHz, corresponding to 38 nano-seconds a day. Physicists claim this results from a combination of a gravitational effect by general relativity making the clocks tick 45 nano-seconds fast, and an effect in the opposite direction by special relativity of 7 nano-seconds with the net result of $38 = 45 - 7$. Voila! Both special and general relativity thus confirmed by GPS! But isn't this a little bit too good to be true? Let's dig deeper:

We recall that the current GPS configuration consists of a network of 24 satellites in orbits around the Earth at an altitude of about 20,000 km with an orbital speed of about 14,000 km/hour and orbital period of roughly 12 hours (contrary to popular belief, GPS satellites are not in geosynchronous or geostationary orbits). The satellite orbits are distributed so that at least 4 satellites are always visible from any point on the Earth at any given instant (with up to 12 visible at one time). A GPS receiver on ground or in an airplane receives signals from at least 4 satellites encoding the position and clock-time of the satellite at the moment when the the signal was sent out. From this information the distances to the satellites can be computed including synchronization of the receiver clock with the satellite clocks, from which the position of the receiver can be computed to within 5 to 10 meters in only a few seconds. With differential techniques involving at least two nearby receivers, the precision can be improved to centimeters.

Evidently, GPS requires that the satellite clocks all run at the same rate and thus show the same time, and evidently they do since GPS works. The remarkable fact is now that GPS works without any individual adjustment of the clocks, although they are all in relative motion and thus by special relativity should suffer from time dilation and run at different rates. But they don't, and thus GPS cannot be viewed to give any experimental support of special relativity. If anything, GPS shows that any effect by special relativity in GPS is negligible, according to R. Hatch chief engineer of the GPS-system [48]. Who should we believe, Hawking or Hatch?

The satellite clocks are subject to different physical conditions, as compared to ground clocks, such as gravitation, temperature and pressure, all which potentially could affect the clock rate even in Newtonian mechanics. Thus it is not clear that the required 38 nanosecond adjustment is an effect of general relativity, or is it?

13.3 The Ives-Stillwell Experiment

Herbert Ives was an ardent opponent of special relativity, who performed Doppler shift experiments in 1938 together with Stillwell to show that Einstein was wrong. However, to the dismay of Ives, the experiments rather gave evidence supporting Einstein's relativistic version of the classical *Doppler shift* formula:

$$f = \gamma^{-1}\frac{1}{1-v} \tag{13.1}$$

with an additional factor of $\gamma^{-1} = \sqrt{1-v^2} < 1$ (assuming $c = 1$ and unit source frequency) supposedly accounting for time dilation. The received signal thus showed a slightly smaller frequency than that predicted by the classical formula without the γ^{-1} factor.

The factor γ^{-1} brings in a second order effect in the velocity v, and the "explanation" of this effect as time dilation by special relativity, may just be a happy coincidence in a very complex phenomenon, which the standard simplistic Doppler formula does not capture. The mere fact that a very simple formula derived using a very simple classical model of wave propagation, does not exactly conform with experiments for velocities close to the speed of light, cannot be taken as evidence that time dilation of special relativity is a real phenomenon; it only shows that the simple formula is too simple.

The Ives-Stillwell experiment is often presented as the key indication that time dilation is a real effect, but we believe this attitude can easily be questioned. If time dilation is real it should be able to support this effect by many many experiments; not just one or two.

13.4 The Myon Decay Experiment

The other experiment often presented as support of the reality of the time dilation of special relativity, is a *myon decay* experiment with myons entering the atmosphere of the Earth at high speed and succeeding to survive without decay down to the surface of the Earth, even though due to their short decay-time, they should not reach the surface. The standard argument is now that the myon clock runs at a slower rate because of the time dilation of special relativity, which supposedly could account for their longer survival.

Again, a very complex phenomenon of high speed myons interacting with the atmosphere, is found to not fit with a very simple classical decay formula, and this is taken as experimental support of special relativity. Of course, the logic is weak: Just because simplistic classical physics does not well describe a complex phenomenon, cannot be taken as evidence of another simplistic theory, which happens to fit a little bit better.

13.5 The Sagnac Effect

Georg Sagnac was another ardent opponent of special relativity. Sagnac designed in 1913 an experiment where a light signal from a source mounted on a rotating disc was sent around the disc and received again at the moving source. By interference the difference in time sending the light in the direction of the rotation and in the opposite direction, was determined and found to be proportional to the difference in the distance traveled by light due to the rotation, in full conformity with classical non-relativistic mechanics. Sagnac considered his experiment to be difficult (impossible) to explain by special relativity, a standpoint which has (of course) been disputed by trained physicists.

Part III

Many-Minds Relativity

Chapter 14

Basics of Many-Minds Relativity

> An unending pleasure is derived from the exploration of the new and unvisited regions...the morrow's journey is longed for in the hope that something new will be discovered... (Henry Morton Stanley)

> The Doppler effect depends only on the relative motion of the source of light and of the observer, if quantities of second order are neglected. (Born [8])

> One thing is good to remember: *Vacuum has properties.* (Lars Gustafsson in *The Dean*)

14.1 Basic Assumptions for One Observer

We now turn to a basic model of many-minds relativity offering a reconciliation of (r1) and (r2). Below we will present a full model based on Maxwell's equations.

We consider a space consisting of an x-axis, and a (point-like) body B moving along the x-axis according to some physical laws. We introduce an observer X positioned at the origin O of the x-axis with the task of surveying the motion of B including its position and velocity as functions of time. Below we will as a main feature of many-minds relativity introduce several observers and study to what degree their observations agree, while the extension to several bodies is direct.

We equip X with a standard cesium clock showing t-time, and we assume that X receives light signals emitted from B. We let X operate under the assumption that light signals propagate with unit speed according to the linear wave equation (5.3) in a (x, t)-coordinate system describing wave propagation in t-time in a vacuum fixed to the x-axis. In particular, X thereby follows the 1983 SI standard of using lightsecond as length scale.

We assume that X can observe either

(o1) *the frequency of a received signal*,

or

(o2) *the time of emission of a received signal*,

or both of (o1) and (o2). We now discuss relevant aspects of (o1) and (o2).

14.2 Aspects of (o1)

Concerning (o1) we recall that by the classical *Doppler shift*, a light signal emitted at unit frequency from a source moving with velocity v with respect to an observer, assuming that light propagates with unit speed in a vacuum at rest with the observer, is received by the observer at the shifted frequency

$$f = \frac{1}{1+v}. \tag{14.1}$$

The Doppler shift gives a *red-shift* in recession (with $v > 0$) and a *blue-shift* in approach (with $v < 0$). We understand that for $v < 0$, we have to enforce the restriction $-1 < v$, but in recession, we may allow $v > 1$, that is a speed larger than that of light.

We note that we always assume the observer receiving the signal to be at rest, while the source is moving; with the opposite roles, the shifted frequency would instead be $1 - v$ differing from (14.1) to second order in v.

From the frequency f of a received light signal from B given by (14.1) , X can determine the velocity $v = \frac{1}{f} - 1$ of B at the time of the emission of the signal. Recording the velocity $v(t)$ over time, X can determine the position $x(t)$ of B on the x-axis over time, by solving the initial value problem $\dot{x}(t) = v(t)$ for $t > t_0$ with $x(t_0)$ a given initial position at a given initial time t_0. We may think of B as a celestial body emitting light at a known frequency, and X as an astronomer on Earth recording the frequency of the received light (knowing the frequency of the emitted signal), and then determining the position of the body in a coordinate system fixed to the Earth.

We also note that to make the observation (o1), X does not have to specify a choice of space-axis, since (o1) is an observation of frequency, only requiring specification of time. But to specify position from velocity, X needs to specify the space-axis.

14.3 Aspects of (o2)

In the case of (o2), we assume that B is equipped with a cesium clock synchronized with the clock of X to a common standard time. This allows a light signal emitted from B to encode its time of emission, from which X can determine the time lag and thus the distance in lightseconds to B at the time of emission. We may think of B as one of the 24 GPS satellites equipped with a cesium clock showing standard GPS-time, and X as an Earth-based central GPS-control, which surveys the positions of the satellites. We recall that indeed the signal from a GPS-satellite encodes its time of emission, and thus we understand that (o2) expresses a basic feature of the GPS-system, allowing X to determine signal time lag and thus the position of the source, again in a coordinate system fixed to X.

From either of the observations (o1) and (o2), the observer X can thus survey the motion of the body B in his (x, t)-system. The observations (o1) and (o2) are consistent and result in the same position and velocity, since they both conform to propagation of light at unit speed in a vacuum at rest with the x-axis.

We thus have three different but consistent models, based on (o1) or (o2) or both (o1) and (o2)), for the survey of a body B by an observer X, under the assumption that light propagates with unit speed in a vacuum fixed to the x-axis of X. Since there is only one observer, this represents a one-mind view allowing survey without any contest.

We understand that in these models, the velocity v of B in approach to X, necessarily satisfies $v > -1$. We will below formulate a many-minds relativistic form of Newton's 2nd law in which acceleration of a body to a velocity $v \leq -1$, shows to be impossible. This is because the inertial mass of the body appears to increase with the factor $\frac{1}{1+v}$ as $v \rightarrow -1$, effectively limiting the acceleration.

We may compare the factor $\frac{1}{1+v}$ with the apparent increase of mass in special relativity with the factor $\frac{1}{\sqrt{1-v^2}}$, which qualitatively is similar in approach with $v < 0$, but different in recession with $v > 0$.

14.4 Basic Assumptions for Several Observers

We now introduce a second fully analogous observer X' positioned at the origin O' of an x'-axis with O' moving along the x-axis with a certain velocity w, and thus O moving with velocity $-w$ along the x'-axis. The observer X' has also taken on the task of surveying the motion of B by observation of (o1) or (o2) or both. We may think of X' as an independent (competing) observer, or the observer X in a different state of motion.

By analogy X' assumes that light signals propagate along the x'-axis with unit speed in a vacuum fixed to the x'-axis. The observers X and X' thus have a (somewhat) different perception of the propagation of light, each observer claiming with equal right that light propagates in a vacuum fixed to the observers coordinate system, without any common vacuum serving the needs of both observers.

With several analogous observers we have the set-up of *many-minds relativity*, which thus is based on the following assumptions:

(m1) *all observers share a common standard time*,

(m2) *each observer assumes that light propagates with unit speed in a vacuum fixed to the observers space-axis.*

We shall below present a technique to accomplish (m1). We have seen that (m2) effectively is the same as using lightsecond as length scale.

We recall the important aspect that the unit speed of light for all observers amounts to an agreement or definition, for which experimental verification is irrelevant. We also emphasize that since all observers assume they are at rest in their respective vacuum, the question of motion of an observer with respect to an aether, does not come up. We thus handle the apparent contradiction of (r1) and (r2), by avoiding to go into the Einstein trap, that is by replacing (r1) and (r2) by:

(r1') *all observers use lightsecond as length scale*,

(r2') *there is not one aether, but many*, which are not contradictory.

All observers thus share a common standard time denoted by t, but each observer X uses his own x-axis with all observations by X consistent with propagation of light with unit speed in a vacuum fixed to the x-axis. Obvioulsy, the space-axes of all the observers can be viewed to move on top of each other. This is because all observers share a common standard time, and thus can make a clear separation between space and time. We recall that this feature makes life (and science) much simpler than with special relativity, where space is mixed into time in a very strange and confusing way, at least to people without a special training in physics.

We emphasize that each observer is at rest on his space-axis, when receiving signals. Thus all signal reception takes place with the observer at rest on the observers space-axis (typically located at the origin).

Apparently, different observers rely on different models for the propagation of light, and the central question in many-minds relativity is to what extent different observers using different coordinate systems, agree, that is to what extent the observations are *invariant*. We now proceed to address this question, taking first some preparatory steps.

The possibility of many-minds or many-aethers was suggested by Ebenezer Cunningham (1881-1977) in his *The Principle of Relativity* from 1914, the first English book on relativity.

14.5 Relative Speed of Different Observers

Let X and X' be two observers moving with respect to each other with velocity w, with $-1 < w < 0$ in approach while allowing recession at any velocity $w > 0$. We distinguish the following three basic cases:

(w1) w *small* ($|w| < 10^{-4}$),

(w2) w *intermediate* ($10^{-4} \leq |w| < 10^{-2}$),

(w2) w *large* ($10^{-2} \leq |w|$),

where typical values are indicated, comparing the relative speed $|w|$ of the two observers with the unit speed of light.

For comparison we recall that the speed of the Earth relative to the Sun is of size 10^{-4}, and the speed of GPS-satellites with respect to the Earth are less than 10^{-5}, indicating that human observers would fall into the (w1)

Figure 14.1: Ebenezer Cunningham: *Why not many-aethers, one for each inertial coordinate system?*

category with w small. Category (w3) seems to require observers in different galaxies, and thus would belong to science fiction as long as observers are human.

However, observers do not have to be human, but may consist of human-made equipment of some form, or more generally, could be any physical object capable of receiving some form of information. With this perspective all categories (w1)-(w3) may be of relevance.

14.6 Approximate Invariance of Order q

We shall harmonize the observations by two observers X and X' moving with the relative velocity w, in the following different ways:

(i1) Galilean transformation: $O(w)$,

(i2) many-minds composite Doppler: $O(w^2)$,

(i3) restricted many-minds information: exact,

where we indicate the observation discrepancy as a function of w, with $O(w^q)$ as usual indicating that the discrepancy (in position and velocity) is proportional to $|w|^q$.

We shall say that if the observation discrepancy between two observers with relative speed w is $O(w^q)$, then then we have *approximate invariance of order* q.

We note that the idea of approximate invariance falls into the general approach of finite precision physics we have used in our work on the 2nd law of thermodynamics [56] and black-body radiation [58] and will also show up in many-minds quantum mechanics [57]. In this work we give evidence that viewing physics as some form of analog computation of necessarily finite precision, opens new possibilities to insight in cases where exact physics leads into impossibilities.

14.7 First Order Galilean Invariance

We consider the case (i1) to be trivial, recalling that the wave equation under a Galilean transformation $x' = x - wt$ changes the wave speed from $c = 1$ to

$1 \pm w$, and thus the observation discrepancy is $O(w)$. We conclude that classical Newtonian/Galilean mechanics is approximately first order invariant, which may be accurate enough if the relative speed between two observers is small as compared to the speed of light. For Earth-bound human observers, we may typically have $w < 10^{-6}$, which thus normally could be covered by Galilean invariance.

We now proceed to second-oder many-minds relativity, which exhibits non-classical effect based on composite Doppler shifts with relativistic addition of velocities.

Figure 14.2: Doppler: *Also light is subject to a Doppler effect.*

14.8 2nd Order Many-Minds Invariance

We consider a situation for which first-order Galilean invariance is not accurate enough. We consider then a situation where observer X may receive light signals from B, while X' is not able to do so, but has to rely on information transmitted via X. We may think of X as a space-ship or probe in the outer parts of the Solar system receiving light from a distant celestial body B, and X' as an Earth-bound human observer, who can see X but not B. In this case we assume that X can make the observation according to (o1), that is determine the velocity v of B by observing the frequency $f = \frac{1}{1+v}$. In this case (o2) is not realistic since supplying B with a synchronized clock is not practically feasible.

We may also think of a two-step physical process, such as that of cosmic rays of protons entering the atmosphere of the Earth and colliding with oxygen and nitrogen molecules producing π-mesons penetrating through the atmosphere to observation at the surface of the Earth, both steps occurring at a relative speed very close to the speed of light.

We now assume that X emits a light signal of the same frequency f as that received from B, a signal which is received by X' at the frequency f' with an additional Doppler shift $\frac{1}{1+w}$ resulting from the relative motion of X and X' with velocity w, that is, f' is given by the *composite Doppler shift*:

$$f' = \frac{1}{1+w}\frac{1}{1+v}, \tag{14.2}$$

as always assuming that the receiver X' is at rest (and the source X is moving with speed w). From this information X' decides that the velocity v' of B relative to X', assuming that $f' = \frac{1}{1+v'}$, is given by

$$v' = v + w + vw, \tag{14.3}$$

where thus v is the velocity of B with respect to X, w is the velocity of X with respect to X' and v' is the velocity of B with respect to X'. This represents a form of *relativistic addition of velocities* resulting from repeated Doppler shifts. We shall find this form of addition of velocities to be of particular interest when formulating a relativistic form of Newton's 2nd law below.

We understand that the composite Doppler shift (14.2) represents a many-minds view with each observer at rest in his vacuum, and no vacuum common to all observers. In classical mechanics, assuming a common aether fixed to the x'-axis, we would have instead

$$f' = \frac{1}{1+w}\frac{1+w}{1+(v+w)} \quad \text{and } v' = v + w,$$

with the usual (non-relativistic) addition of velocities.

Changing now the roles of X and X', we would analogously have

$$v = v' - w - v'w, \tag{14.4}$$

which compared to (14.3) gives the discrepancy

$$(v - v')w = O(w^2), \tag{14.5}$$

which is second order as desired.

We conclude that if two observers X and X' agree to harmonize their velocity observations through composite Doppler shifts according to (14.3)-(14.4), and compute distances from velocities, then the observations by X and X' will be approximately invariant to second order. This is the main case of interest to many-minds relativity: The relative velocity is so large that first order invariance is not accurate enough, while second order approximate invariance may be viewed to be enough. With $w \approx 10^{-4}$, second order invariance may be accurate enough for most practical purposes.

14.9 Exponential Doppler Shifts

For an n-times repeated Doppler shift, dividing the velocity v into n pieces $\frac{v}{n}$ each, we would have as n tends to ∞,

$$\frac{1}{1+v'} = \frac{1}{(1+\frac{v}{n})^n} \to \exp(-v)$$

and thus

$$v' = e^v - 1, \tag{14.6}$$

with in particular $v' > -1$ for all v.

14.10 Restricted Many-Minds Invariance

If the relative velocity is so large that not even second oder invariance is accurate enough, then we may have to give up the democratic many-minds view with all observers agreeing on all information, to either (i) agreement only on certain restricted information, or (ii) to a one-mind view giving one observer the priority to the truth.

In the case (i) we would require two observers X and X' to agree only on their mutual distance and velocity, and we would allow disagreement on other distances and velocities. We understand that agreement of mutual distance and velocity can be seen as reflecting *symmetry*, allowing with equal rights X and X' to claim to be at rest in a vacuum. In the context of a system of gravitating bodies, standard time and mutual distance (and direction) represents the essential information, for the mere physics or computational simulation to function.

In the case (ii) there is only one observer, who may rely on a model for propagation of light in a vacuum at rest with the observer, and there is no need to harmonize the observations of different observers.

14.11 Clock Synchronization

We now describe a simple method for clock synchronization in many-minds relativity, assuming observation of both (o1) and o(2), through which a a system of absolute time shared by all observers, can be accomplished. Synchronized clocks define simultaneity, and thus a system of absolute simultaneity can be realized.

Let A and B be two observers, to start with not moving with respect to each other, each equipped with a cesium clock, which are to be synchronized. Let A emit a light signal with the time of emission t_A according to the clock of A encoded in the signal, and let this signal be received by B at time t'_B according to the clock of B. Let similarly, B emit a light signal at time t_B which is received by A at time t'_A. Let the time of the signal to pass from A to B be t_{AB}, which by symmetry is the same as the time from B to A. We then have

$$t'_A - t_B = t_{AB} + S, \quad \text{and } t'_B - t_A = t_{AB} - S,$$

where S is the offset of the clocks of A and B, which upon addition gives:

$$t'_A - t_B + t'_B - t_A = 2t_{AB}.$$

Assuming $t_B = t'_B$ so that B returns the signal from A without delay, we have $t'_A - t_A = 2t_{AB}$, from which A can determine t_{AB} and then from knowledge of t_B compute S and synchronize the clock of A with that of B.

If A and B are moving with velocity w with respect to each other, then we have instead

$$t'_A - t_A = 2t_{AB} + w(t'_B - t_A)$$

because of the relative motion during the passage of the signal from A to B before return to A. Again A can determine the offset S.

We conclude that a group of observers having access to (o1) and (o2) may synchronize their clocks pairwise and thus set up a common universal time.

14.12 Simultaneity

With synchronized clocks showing a common standard time, simultaneity poses no problem: Two events are simultaneous if they have the same t-coordinate. We recall that we circumvented Einstein's counter-example to simultaneity, by requiring receivers to be at rest, thus refusing to receive light signals under motion. We see no real disadvantage adopting this restriction.

14.13 Agreement and Disagreement

We consider two observers X and X' moving with respect to each other with relative velocity w, who receive light signals from a moving source B and observe (o2). Suppose that at $t = 1$ X and X' happen to be at the same spot and there both receive a light signal from B with encoded emission time $t = 0$. Both X and X' will then consider the distance to B at emission time to be 1 lightsecond. However, since X and X' are moving with relative velocity w, at emission time $t = 0$ they are at a distance w apart, and thus they agree to assign the length of 1 lightsecond to a distance which differs by w. Effectively, this means that X and X' agree to first order in w on distances to third parts.

If only (o1) is observed, and X and X' decide to share information by composite Doppler shifts, then they will agree to second order in w. If X and X' make independent observations of Doppler shifts, then the accuracy will drop to first order.

Finally, X and X' always agree exactly on their mutual distance and velocity, by symmetry.

14.14 The Michelson-Morley Experiment

Many-minds relativity is consistent with the observed null results in a Michelson-Morley experiment. In the simplest such experiment the times it takes for a light signal to go in both directions between two points with fixed distance d moving along the x-axis with a certain speed v, are compared. If there was a material aether fixed to the x-axis through which light did propagate with velocity 1 according to classical mechanics, then the times would read $\frac{d}{1-v}$ and $\frac{d}{1+v}$ and thus would give a non-null result, first order in v. In many-minds relativity the times in both directions will be the same, by symmetry, which is consistent with the observed null result and non-existence of any material aether.

14.15 Transversal Length Contraction

Suppose an observer O equipped with an x-axis and a perpendicular y-axis seeks to measure the length of a stick parallel to the y-axis, which is being translated with one of its ends sliding along the x-axis with velocity v. Suppose this is done by measuring the time it takes for a light signal emitted at one end of the stick to return after reflection in a mirror at the other end. Suppose the time as measured by an observer O' fixed to the stick is 2s, from which O' concludes that the length of the stick is 1 lightsecond. Now, from the point of view of the observer O, the time of the light signal is also 2s and thus O must assign the length $d = \sqrt{1-v^2}$ lightseconds to the stick, since O must assign the length 1 to the hypothenuse of the triangle with sides d and v along which O considers the light signal to pass. This means that O may perceive a length contraction with the factor $\sqrt{1-v^2}$ in the y-direction as a result of the translation in the direction of the x-axis.

14.16 Transversal Doppler Shift

For transversal (plane) waves, emitted in a direction perpendicular to the velocity of a light source, the standard Doppler shift is zero, while Einstein predicts a red shift of $\sqrt{1-v^2}$ because or time dilation. Thim [104] reports on zero-shift observations for a 33-GHz microwave signal received by rotating antennas, which thus contradicts Einstein relativistic shift and supports the standard zero shift for transversal waves.

It is (with some stretching of the argument) possible to motivate a transversal Doppler red shift with the factor $1/\sqrt{1+v^2} \approx \sqrt{1-v^2}$, taking into account that the distance from an observer to a light source changes during the passage of time from emission to reception, also when the emission is transversal to the velocity of the light source.

14.17 A Check of Consistency

Consider a body B approaching an observer X' with speed v' and assume X' approaches an observer X at the origin O with speed w, all along the x-axis of X. Assume the distance at time $t = 0$ of B to X' is v' and the distance of X' to X is w, so that all meet at time $t = 1$ at the origin O. If X computes the velocity v of B according to the composite Doppler shift $v = v' + w - v'w$, X would then compute the distance from O to B to be

$$d = v' + w - v'w.$$

Alternatively, it is conceivable that X may observe the time lag of a light signal from B to be

$$v' + w - v'w$$

as the sum of the time required for the signal to first reach X' from B and then reach X from X', where during the time v' from B to X', X would approach X' by $v'w$. X would thus find the distance to B to be d, as desired from consistency point of view.

However, X' would estimate the distance between O and B to be $v{+}w > d$ and the velocity of B relative to O to be $v' + w > v$, and thus the observers X and X' would have different opinions on the velocity and distance of O vs B, thus disagreeing on distance/velocity of third parts.

14.18 Sum-Up

We consider a situation with different observers surveying a moving body. All observers use identical synchronized clocks showing a common standard time. Each observer operates under the assumption that light propagates with unit speed in a vacuum fixed to the observers space-axis. Each observer receives light signals emitted at unit frequency from the body with possibly the time of emission encoded. From the frequency and/or time lag of received signals, each observer determines the instantaneous velocity and position of the body.

We have seen that (o1) and (o2) observations by two observers fixed to two coordinate systems moving with (constant) velocity w with respect to each other, will be $O(w)$ first order invariant under Galilean transformations, and (o1) observations will be $O(w^2)$ second order invariant under many-minds composite Doppler shifts. Finally, observations will be restrictedly invariant for all velocities satisfying $w > -1$ in approach.

We understand that there is no (known) model of light propagation which is common to all the observers; each observer is at rest in his own vacuum and thus we have a genuine many-minds model without any common vacuum.

Chapter 15

Relativistic Form of Newton's 2nd Law

> If we feel worried by this result (time dilation of a π-meson) and call it paradoxical, we simply mean that is is unusual, or "peculiar"; time will help us to conquer this strange feeling....The aim of scientific research is to determine criteria for distinguishing its results from dreams of fancy. (Born [8])

> It is one thing for the human mind to extract from the phenomena of nature the laws which it has itself put into them; it may be a far harder thing to extract laws over which it has no control. It is even possible that laws which have not their origin in the mind may be irrational, and we can never succeed in formulating them. (Sir Arthur Eddington)

15.1 Relativistic Addition of Velocities

We have seen that many-minds composite Doppler shifts leads to a relativistic addition of two velocities v and w according to (14.3):

$$v' = v + w + wv, \tag{15.1}$$

instead of the classical sum $v + w$. It is important to understand that the Doppler factor $\frac{1}{1+w}$ for two observers X and X' moving with velocity w with respect to each other, is *symmetric* in the sense that it is the same whether X acts as source or receiver of signals, and only depends on the relative velocity

w. Thus a single Doppler shift shows no preference for the vacuum of any of the observers and thus is exactly invariant. We saw above that a composite Doppler factor is second order invariant, while classical velocity addition is only first order invariant.

We note that if $-1 < w < 0$ and $-1 < v < 0$, then $v' > v + w$ and also $-1 < v' < 0$. Thus it is impossible to reach a speed larger or equal to the speed of light in approach. For example, with $v = w = -3/4$, we do not obtain as the classical $v + w = -3/2 < -1$, but $v' = -3/2 + 9/16 = -15/16 > -1$.

We see that if $v > 0$ and $w > 0$, then $v' > v + w$ and there is no limit to the speed in recession.

We may compare (15.1) with the addition of velocities of special relativity:

$$v' = \frac{v + w}{1 + vw}, \tag{15.2}$$

which is qualitatively similar in approach but different in recession.

15.2 The Classical Form of Newton's 2nd Law

We will now use the relativistic addition of velocities (15.1) to formulate a relativistic form of Newton's 2nd law. We first recall the standard (non-relativistic) form of Newton's 2nd law for a body B of *inertial mass* m with coordinate $x(t)$ on an x-axis and velocity $v = \dot{x}$, under the action of a *force* $F(t) = F(x(t), t)$ like gravitation, which reads (modulo initial conditions)

$$m\dot{v} = F, \tag{15.3}$$

where $\dot{v} = \frac{dv}{dt}$ is the acceleration. We here assume that the motion of B along the x-axis is observed by the observer X at rest on the x-axis.

15.3 Relativistic Form of Newton's 2nd Law

Let X' be another observer, at a given time $\bar{t}$ taking on the same position and velocity as B, thus with the origin O' of an x'-axis moving with the constant velocity $w = v(\bar{t})$ with respect to the x-axis for $t > \bar{t}$, and let v' be the velocity of B with respect to the x' axis. The classical Newton's 2nd law at the time instant $\bar{t}$ in the (x', t) system takes the form:

$$m\dot{v}' = F.$$

Now, the relativistic velocity $\bar{v}$ in the (x,t)-system resulting from the relative motion of X' with respect to X with velocity $w = v(\bar{t})$ combined with the relative velocity v' with respect to X', is according to (15.1) given by

$$\bar{v} = v' + w + v'w,$$

and thus since $\dot{w} = 0$,

$$\frac{d\bar{v}}{dt} = \dot{v}'(1+w) = \frac{1+w}{m}F.$$

We are thus led to the following form of Newton's 2nd law in the (x,t)-system

$$\frac{m}{1+v}\dot{v} = F, \tag{15.4}$$

where we replaced w by the momentary velocity $v(t)$. We see that in the 2nd law (15.4) expressed in the fixed (not co-moving) x-system, the inertial mass m is modified to $m/(1+v)$. We see that if $v > 0$ then the inertial mass appears to be smaller than the nominal mass or *rest mass* m , and if $v < 0$ it appears to be the larger than the rest mass m.

We note that the (apparent) change of mass in the relativistic form of Newton's 2nd law, is a consequence of the relativistic addition of velocities, which is based on composite Doppler shifts.

We may compare with the relativistic mass $m/\sqrt{1-v^2}$ of Einstein's special relativity, which is always larger than the rest mass.

Choosing $F/m = 1$, we obtain for an object approaching or receding from an observer at the origin following (15.4), or satisfying the standard 2nd law (15.3):

$$v(t) = 1 - \exp(-t), \quad v(t) = \exp(t) - 1, \quad v(t) = t, \tag{15.5}$$

all similar for small t, but not else. We see that very large speeds can be obtained in recession, while in approach only speeds smaller than 1 can be attained.

15.4 The Exponential Doppler Shift

Differentiating the exponential Doppler shift (14.6) with respect to time, Newton's law $m\dot{v} = F$, would take the form

$$m\dot{v}' = m\exp(v)\dot{v} = \exp(v)F,$$

that is

$$\frac{m}{1+v'}\dot{v}' = F, \tag{15.6}$$

which effectively is the same as (15.4).

15.5 Which Newton's 2nd Law is More Accurate?

Which form of the 2nd law is now the more accurate one, the standard (15.3) or the relativistic (15.4)? Accelerator experiments seem to favor (15.4), since acceleration seems to be more demanding as the velocity increases, at least in approach, as if the mass was increasing with velocity. We note that both the standard (15.3) and (15.4) allow any speed to be reached in recession, while with (15.4) only speeds smaller than the speed of light can be reached in approach.

15.6 Is Travel Faster than Light Possible?

The relativistic Newton's 2nd law (15.4) allows the relative speed of two objects/observers to be arbitrarily large in recession, while it is limited by the speed of light in approach. Thus, two observers X and X' can part from each other with any speed but may not be able to rejoin equally fast. This makes an expanding universe to seem more likely than a contracting one. Maybe. Of course, all of this is very speculative, and based on the very simple idea of composite Doppler shifts.

15.7 A No-Mind Gravitational Model

We consider a set (galaxy) of N point-like objects (stars) S_i of mass m_i with $i = 1, ..., N$, interacting by gravitational forces in three-dimensional Euclidean space $\mathbb{R}^3$. We adopt the no-mind view letting the galaxy evolve without the concern of any human observations, assuming that star S_j (somehow) is capable of inducing a gravitational force F_{ij} on star S_i with $i \neq j$. We assume each S_i changes velocity (and then position) according to Newton's 2nd law formulated in a coordinate system with origin at the position of S_i

at time t, that is,

$$m_i\dot{v}_i(t) = \sum_{j\neq i} F_{ij}(t), \quad i = 1, ..., N,$$

where according to Newton's law of gravitation

$$F_{ij}(t) = Gm_im_j\frac{x_i(t) - x_j(t)}{|x_i(t) - x_j(t)|^3}$$

with $x_i(t) \in \mathbb{R}^3$ the position of S_i at time t in the fixed universal coordinate system represented by $\mathbb{R}^3$, and G is the gravitational constant. We note that the consistency $F_{ij} = -F_{ji}$ is satisfied if S_i and S_j both use a length scale of lightseconds.

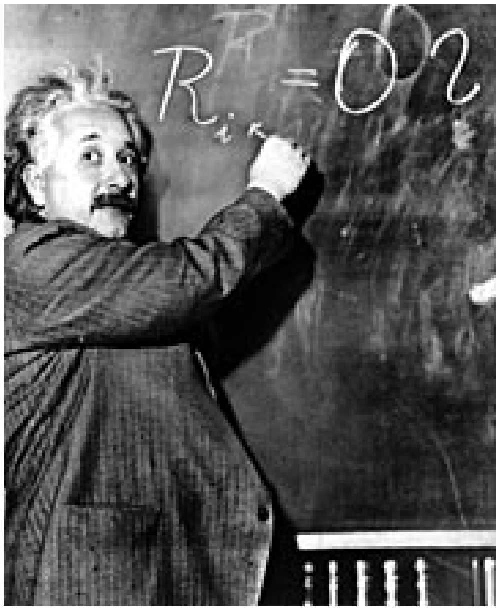


Figure 15.1: Einstein: *I write my equation of general relativity in the form* $R_{ik} = 0?$. *Does anyone understand what I mean?*

Figure 15.2: Dart Vader: *I am now traveling faster than light. No problem.*

Chapter 16

Momentum $\sim$ Mass: $P = mc$

> The law of inertia of energy $E = mc^2$, is perhaps the most important result of the theory of relativity. (Born [8])
>
> The mass energy relationship $E = mc^2$ is considered by Einstein to be the most important result of the special theory of relativity. Strictly speaking, it is not a deduction from the theory, but it is suggested by and consistent with it. (Lindsay-Margenau [77])
>
> When the velocity approaches the velocity of light, the vis viva, the amount of momentum, increases beyond all limit. (Poincaré in Science and Method)

16.1 Einstein's Formula

Einstein's famous formula $E = mc^2$ states that energy is proportional to mass. This formula can be viewed to be a consequence of the law of addition of velocities in special relativity.

16.2 A Many-Minds Formula

We can motive an analogous relation in many-minds relativity indicating that momentum $P = -mv$ of a body of mass m moving with velocity v, augments the mass by P: Using that $1/(1+v) \approx 1 - v$ for sufficiently small v, we see that Newton's law takes the form

$$F \approx m\dot{v} - mv\dot{v} = (m + P)\dot{v},$$

which suggests that P can be seen as a contribution to the mass, so that, without the normalization that $c = 1$,

$$P = mc. \tag{16.1}$$

This formula appears to be another (seemingly equivalent) form of Einstein's famous $E = mc^2$: An observer X at O will consider the inertial mass of a body B approaching the origin with velocity v to increase by $\frac{P}{c}$, reflecting that acceleration will be increasingly demanding requiring the accelerating force F to be increased by the factor $\frac{1}{1+v}$ as compared a non-relativistic law. The inertial mass of a body approaching an observer X, would thus to X seem to increase as the velocity v approaches -1, with the factor $1/(1+v)$ in a fixed coordinate system, while the inertial mass in a co-moving system remains constant.

Figure 16.1: Newton, Poincaré, De Pretto, Hasenhörl and Einstein: *The Formula*

Chapter 17

Maxwell's Equations

> We can scarcely avoid the conclusion that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena. (James Clerk Maxwell 1831-1879)

> Not only the laws of mechanics but those of all physical events–in-particular, of electromagnetic phenomena–are completely identical in an infinite number of systems of reference which are moving with constant velocity relative to each other and which are called inertial systems. (Born [8])

17.1 Einstein on Electro-Magnetics

Einstein starts his 1905 article [23] on special relativity by discussing the elementary problem of a magnet and coil (conductor) in relative motion:

- *The observable phenomenon here depends only on the relative motion of the conductor and the magnet...if the magnet is in motion and the conductor at rest, there arises an electrical field producing a current in the conductor. But if the magnet is stationary and the conductor is in motion, no electrical field arises...but instead an electro-motive force giving rise to the same current. Examples of this sort, together with the unsuccessful attempts to discover any motion of the earth relatively to the "light medium" or "luminiferous aether", suggest that the phenomenon of electrodynamics as well as of mechanics possesses no properties corresponding to the idea of absolute rest.*

Here Einstein seems to want to remind us about the elementary fact that the electrical fields E and E' in two coordinate systems, one connected to the magnet and the other to the coil, are related by $E' = E + v \times B$, where B is the magnetic field and v the relative velocity. We understand that this explains why $E = 0$ and $E' \neq 0$ is possible. We also understand that this has nothing to do with anything like special relativity, only elementary Galilean relative motion. But evidently Einstein thought it had, and the question presents itself: Does the opening of Einstein's 1905 article on special relativity reflect the inspiration of a genius, or just confusion?

Nevertheless, because of Einstein's strong influence in the physics community, there is a common belief that there is a strong connection between Maxwell's equations and special relativity, embodied in the invariance of Maxwell's equations under the Lorentz coordinate transformation. Thus it is common to explain various electromagnetic phenomena using arguments from special relativity, even if the phenomena concerns velocities much smaller than the velocity of light (as in the magnet-coil problem) in which special relativity plays no role. Often the argument is turned around by viewing special relativity as coming out of Maxwell's equations.

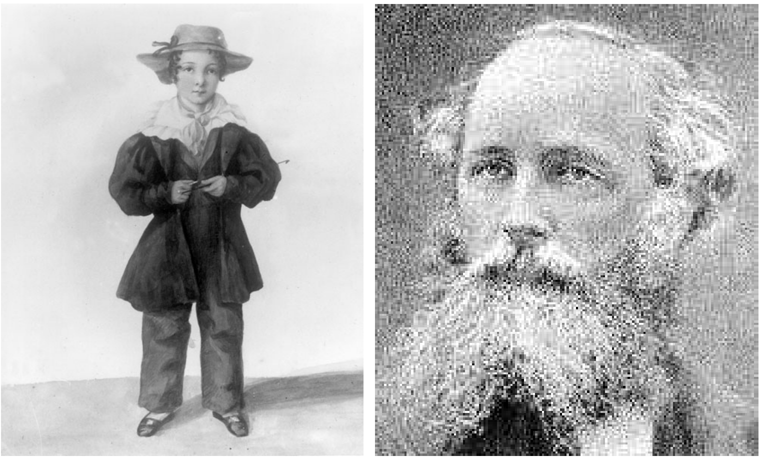


Figure 17.1: Maxwell as a young boy: *The only laws of matter are those that our minds must fabricate and the only laws of mind are fabricated for it by matter.* Maxwell in 1864: *The agreement of the results seems to show that light and magnetism are affections of the same substance, and that light is an electromagnetic disturbance propagated through the field according to electromagnetic laws.*

17.2 Maxwell without Lorentz

We shall now make a fresh start at the point of departure of Einstein in 1905. We thus consider Maxwell's equations describing in concise form a very wide variety of electromagnetic phenomena including the propagation of electromagnetic waves, which we perceive as light in a certain (narrow) frequency band, see Fig. 17.4.

We are prepared by our study of the wave equation above, which naturally extends to Maxwell's equations to give the same basic results: (i1) first oder Galilean invariance, (i2) second order many-minds invariance and also (i3) restricted exact invariance.

By the same arguments as those presented for the wave equation above, we shall not allow us to use the Lorentz transformation, which relieves us from the (hopeless) task of giving this transformation any physical meaning (following a suggestion of Lorentz himself), and thus relieves us from the illusions or paradoxes of Einstein's special relativity.

We now proceed to study Galilean invariance of Maxwell's equations. We will see, as is well known, that a quasi-steady version applicable to the coil-magnet problem, is exactly Galilean invariant, and that the full version including the electric displacement describing the propagation of light, is first order Galilean invariant. We then extend to many-minds relativity for Maxwell's equations.

17.3 Maxwell's Equations

Maxwell's equations express (in suitably normalized form) the laws of electromagnetics of *Faraday*, *Ampére* and *Gauss* in a vacuum filling a domain Ω of $\mathbb{R}^3$, as follows: Find the *electric field* $E(x,t)$ and the *magnetic flux* $B(x,t)$ such that for $x \in \Omega$ and $t > 0$,

$$\begin{gathered}\frac{\partial B}{\partial t} + \nabla \times E = 0, \quad \frac{1}{c^2}\frac{\partial E}{\partial t} - \nabla \times B = -J, \\ \nabla \cdot B = 0 \quad \nabla \cdot E = \rho,\end{gathered} \tag{17.1}$$

where c is the speed of light in vacuum, ∇ denotes differentiation with respect to x, J is the *current* and ρ the *charge density.* Maxwell's equations are complemented by initial conditions B^0 and E^0 for B and E at $t = 0$, and with suitable boundary conditions on the boundary of Ω if $\Omega \neq \mathbb{R}^3$. For simplicity, we assume that $\Omega = \mathbb{R}^3$ with suitable conditions at infinity. We note that Maxwell's equations (17.1) express the laws of Faraday, Ampére and Gauss in an x-coordinate system at rest with the vacuum of Ω.

We recall that Gauss law $\nabla \cdot B = 0$ follows by taking the divergence of Faradays's law $\frac{\partial B}{\partial t} + \nabla \times E = 0$ resulting in $\frac{\partial}{\partial t}\nabla \cdot B = 0$, combined with an initial condition $\nabla \cdot B^0 = 0$. Further, Gauss Law $\nabla \cdot E = \rho$ can alternatively be expressed in time differentiated form by taking the divergence of Ampere's law $\frac{1}{c^2}\frac{\partial E}{\partial t} - \nabla \times B = -J$, as the continuity equation

$$\frac{1}{c^2}\frac{\partial \rho}{\partial t} + \nabla \cdot J = 0 \tag{17.2}$$

combined with the initial condition $\rho^0 = \nabla \cdot E^0$.

We can thus express Maxwell's equations alternatively in the form

$$\frac{\partial B}{\partial t} + \nabla \times E = 0, \quad \frac{1}{c^2}\frac{\partial E}{\partial t} - \nabla \times B = -J, \quad \frac{1}{c^2}\frac{\partial \rho}{\partial t} + \nabla \cdot J = 0, \tag{17.3}$$

combined with suitable initial conditions for E, B and ρ, together with a constitutive equation such as Ohm's law

$$J = \sigma(E + v \times B), \tag{17.4}$$

where σ is a conductivity coefficient, and v the velocity of the conducting medium. This gives 8 linear equations in 8 variables allowing a unique solution.

Maxwell's equations are complemented by *Lorentz Law*:

$$F = E + u \times B \tag{17.5}$$

expressing the force F on a unit charge moving with velocity u with respect to the x-coordinate system, in terms of the electric field E and magnetic field B.

17.4 Electro-magnetic Waves

In the case of empty space or a vacuum with $\rho = 0$ and $J = 0$, Maxwell observed that the electric field E satisfies the (vector) wave equation

$$\frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} - \Delta E = 0,$$

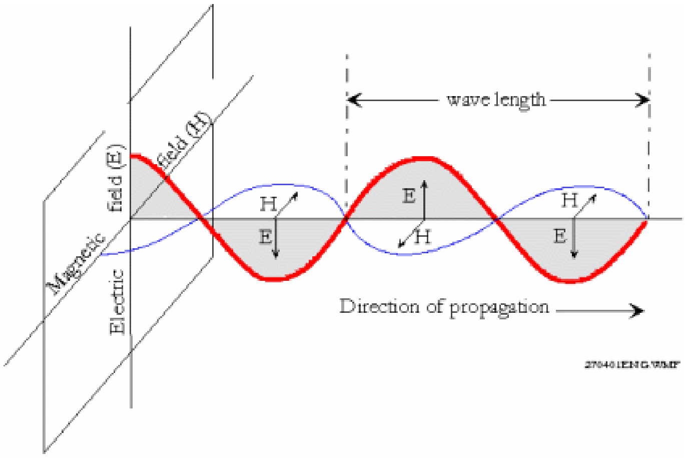


Figure 17.2: Maxwell: *An electro-magnetic wave propagating with speed c is generated by oscillating (orthogonal) electric and magnetic fields.*

which follows by differentiating Ampére's law with respect to time t, applying the curl $\nabla\times$ to Faraday's law, and using the vector calculus identity $\nabla \times \nabla E = -\Delta E + \nabla(\nabla \cdot E) = -\Delta E$. Maxwell saw similarly that the magnetic flux B satisfies the same wave equation, from which he immediately understood that Maxwell's equations admit solutions corresponding to waves propagating with velocity c and being generated by oscillating electric and magnetic fields (which turn out to be orthogonal), see Fig. 17.2.

Maxwell thus predicted in 1864 the existence of electro-magnetic waves propagating with the velocity of light, long before such waves were observed and it was understood that visible light is nothing but electro-magnetic waves in a certain frequency band. This was a formidable success of mathematical physics, surpassing even Newtons theory of gravitation.

17.5 Maxwell's Equations and Galilean Invariance

We now want to study the effect on Maxwell's equations (17.3) of a Galilean coordinate transformation $(x', t') = (x - vt, t)$ with $v \in \mathbb{R}^3$ a given constant translation velocity. We have by the chain rule with obvious notation

$$\nabla' = \nabla, \quad \frac{\partial}{\partial t'} = \frac{\partial}{\partial t} + v \cdot \nabla.$$

We thus consider an observer X expressing Maxwell's equations in a vacuum fixed to the x-system and another observer X' expressing Maxwell's equations in a vacuum fixed to the x'-system, assuming that X' moves with velocity v with respect to the x-system, and we want to find out to what extent X and X' may agree.

17.6 The Quasi-Steady Case

We start assuming that the terms with the factor $\frac{1}{c^2}$ in (17.3) can be neglected because c^2 is very large, which formally corresponds to assuming the speed of light to be infinite. We know that $c \approx 300.000$ km/second, which makes the quasi-steady case a reasonable approximation in a good metallic conductor for frequencies up to $10^{18} Hz$, and in a poor conductor up to $10^6 - 10^{12} Hz$, while for wave propagation in vacuum the approximation is not acceptable. We then obtain the following *quasi-steady* version of Maxwell's equations, which was formulated before the full version (17.1) was proposed by Maxwell in 1865:

$$\frac{\partial B}{\partial t} + \nabla \times E = 0, \quad \nabla \times B = J, \quad \nabla \cdot J = 0, \tag{17.6}$$

where now $\nabla \cdot J = 0$ is a consequence of Ampere's law $\nabla \times B = J$, and thus can be eliminated.

Defining now

$$E'(x', t') = E(x, t) + v \times B(x, t), \quad B'(x', t') = B(x, t), \tag{17.7}$$

we have with u the velocity of a moving charge or the conducting medium, setting $u' = u - v$,

$$\begin{aligned} F &= E + u \times B = E' - v \times B + u \times B = E' + u' \times B' = F', \\ J &= \sigma(E + u \times B) = \sigma(E' + u' \times B') = J', \end{aligned}$$

and also

$$\frac{\partial B'}{\partial t'} + \nabla' \times E' = 0, \quad \nabla' \times B' = J', \quad \nabla' \cdot J' = 0, \tag{17.8}$$

because

$$\begin{aligned} \nabla \cdot B = \nabla' \cdot B', \quad \nabla \times B = \nabla' \times B', \\ \nabla' \times E' = \nabla \times E + \nabla \times (v \times B) = -\frac{\partial B'}{\partial t} - v \cdot \nabla B' = -\frac{\partial B'}{\partial t'}. \end{aligned}$$

We conclude that under the correspondence (17.7), Maxwell's equations (17.6) including Lorentz' and Ohm's laws are exactly invariant under a Galilean coordinate transformation. We note that defining $\rho = \nabla \cdot E$, we have $\rho = \rho' = \nabla' \cdot E'$, as desired from consistency point of view. Note further that in this setting the continuity equation is not satisfied exactly (since we have neglected the term $\frac{1}{c^2}\frac{\partial \rho}{\partial t}$).

We see that with the connection (17.7), the magnetic field B, the current J and the Lorentz force F remain the same under a Galilean change of coordinates, while the electrical E field changes according to $E' = E + v \times B$.

The magnet-coil problem can naturally be analyzed and understood using the quasi-steady model, without any special relativity, as a special case with $E = 0$ and $E' = v \times B \neq 0$.

We remark that by $\rho = \nabla \cdot E$, we may *define* the charge ρ in terms of the electrical field E. We suggest below a similar connection defining the mass density $\rho = \Delta\varphi$ in terms of a gravitational potential φ [56], and not vice versa as usual.

We conclude that in the quasi-steady case, the two observers X and X' will agree exactly if they decide to coordinate their observations according to (17.7). In particular, we notice that letting X and X' share information of their respective electric and magnetic fields, each observer can (from the relation $E' = E + v \times B$) determine the relative velocity v.

17.7 The General Case

We now consider the effect of a Galilean coordinate transformation on the full Maxwell's equations in the form (17.3) complementing (17.7) by the relation $\rho' = \rho$. We first notice that the continuity equation transforms into:

$$\frac{1}{c^2}\frac{\partial \rho'}{\partial t'} + \nabla' \cdot J' = \frac{v}{c^2} \cdot \nabla \rho',$$

where the new term $\frac{v}{c^2} \cdot \nabla \rho'$ in a natural way reflects translation with the velocity v, because it is natural to view a point-charge as a material point with a specific location in space.

We further have

$$\frac{\partial E}{\partial t} = (\frac{\partial}{\partial t'} - v \cdot \nabla')(E' - v \times B') = \frac{\partial E'}{\partial t'} + v \cdot \nabla'(v \times B'),$$

and thus Ampère's law $\frac{1}{c^2}\frac{\partial E}{\partial t} - \nabla \times B = -J$ transforms into

$$\frac{1}{c^2}\frac{\partial E'}{\partial t'} - \nabla' \times B' + \frac{v}{c} \cdot \nabla'(\frac{v}{c} \times B') = -J' \tag{17.9}$$

with the new term $\frac{v}{c} \cdot \nabla'(\frac{v}{c} \times B')$. For the special case with $v = (v_1, 0, 0)$, we have

$$\frac{v}{c} \cdot \nabla'(\frac{v}{c} \times B') = \frac{v_1^2}{c^2}(0, -\frac{\partial B_3'}{\partial x_1'}, \frac{\partial B_2'}{\partial x_1'}).$$

We conclude that Ampère's law is first order invariant under a Galilean coordinate transformation, just as the wave equations above. This means that X and X' will agree to first order in $|v|/c$.

This case covers problems with v representing velocities of material bodies, such as the relative velocity of two human observers or of a magnet and a coil in an electrical motor, in which the effects of a finite (instead of an infinite) speed of light are small because $|v|/c << 1$.

17.8 Approximate Galilean Invariance for Maxwell

We have seen that the quasi-steady version of Maxwell's equations is exactly Galilean invariant, while the full version is first order Galilean invariant in $|v|/c$. We have seen that the case $|v|/c << 1$ typically covers cases with moving observers and material bodies with $J \neq 0$ and also possibly $\rho \neq 0$.

Cases with $|v|/c$ not (very) small, typically concern propagation of light in vacuum with $J = \rho = 0$, in which case Maxwell's equations can be formulated as the usual wave equation for electric and magnetic fields or potentials. We can then use many-minds relativity with lightsecond as length standard as developed above.

We summarize many-minds relativity with each observer using Maxwell's equations in a vacuum fixed to the observers space-coordinates and all observers sharing a common time, as follows:

- For $|v|/c$ very small, use exact Galilean invariance for the quasi-steady Maxwell's equations, or first order approximate Galilean invariance.
- For $|v|/c$ moderately small, use second order approximate Galilean invariance based on composite Doppler shifts.
- For $|v|/c$ not moderately small, use restricted many-minds invariance.

We notice in particular that we do not use the invariance of Maxwell's equations under Lorentz coordinate transformation and we thereby avoid the problem of giving the Lorentz transformation a physical interpretation.

17.9 Maxwell Equations and Lorentz Invariance

Using instead a Lorentz transformation with respect to x_1 with velocity $(v, 0, 0)$, we obtain the following modifications of the connection (17.7) between the electrical and magnetical fields in the two systems

$$E_1' = \gamma(E_1 + vB_2), \quad B_1' = \gamma(B_1 - \frac{\gamma v}{c^2}E_2). \tag{17.10}$$

Maxwell's equations are Lorentz invariant and thus take identical forms in the two systems, but the relation between the fields depend on the translation velocity v. A common view in the physics community is that there is a strong connection between Maxwell's equations and special relativity. It goes so far as to claim that electromagnetic phenomena exist because Maxwell's equations are Lorentz invariant, in a form of physics from mathematics as discussed above. It is thus common to explain electromagnetic phenomena using arguments from special relativity even if the phenomena concerns velocities much smaller than the velocity of light. For example, it is common to explain the transformation of the continuity equation under translation which we met above, as an effect of space contraction of moving electrons due to special relativity. We see no reason to resort to arguments of this type.

17.10 Summary of Many-Minds Maxwell

We consider a many-minds situation with set of different observers moving with respect to each other, each observer being tied to a material object and formulating Maxwell's equations in an x-coordinate system and vacuum in which the observer is at rest. An analysis of the resulting *many-minds Maxwell model* shows approximate first order Galilean invariance, second order invariance for composite Doppler shifts, and restricted exact invariance. We have pointed to the immaterial nature of both the electro-magnetic waves/fields and the vacuum, and we have been led to view the immaterial electric and magnetic fields as primary physical quantities, while currents and charges secondary quantities of material nature derived from the primary quantities by Ampér's and Gauss' laws. We consider below a similar approach to gravitation with the (material) mass of a gravitating body defined by its (immaterial) gravitational field, and not the usual way around with the (immaterial) gravitational field of a body defined by its (material) mass.

Figure 17.3: Faraday with a coil and Ampere.

Gin a body meet a body
Flyin' through the air.
Gin a body hit a body,
Will it fly? And where?

(Maxwell after Robert Burns *Comin' through the rye*)

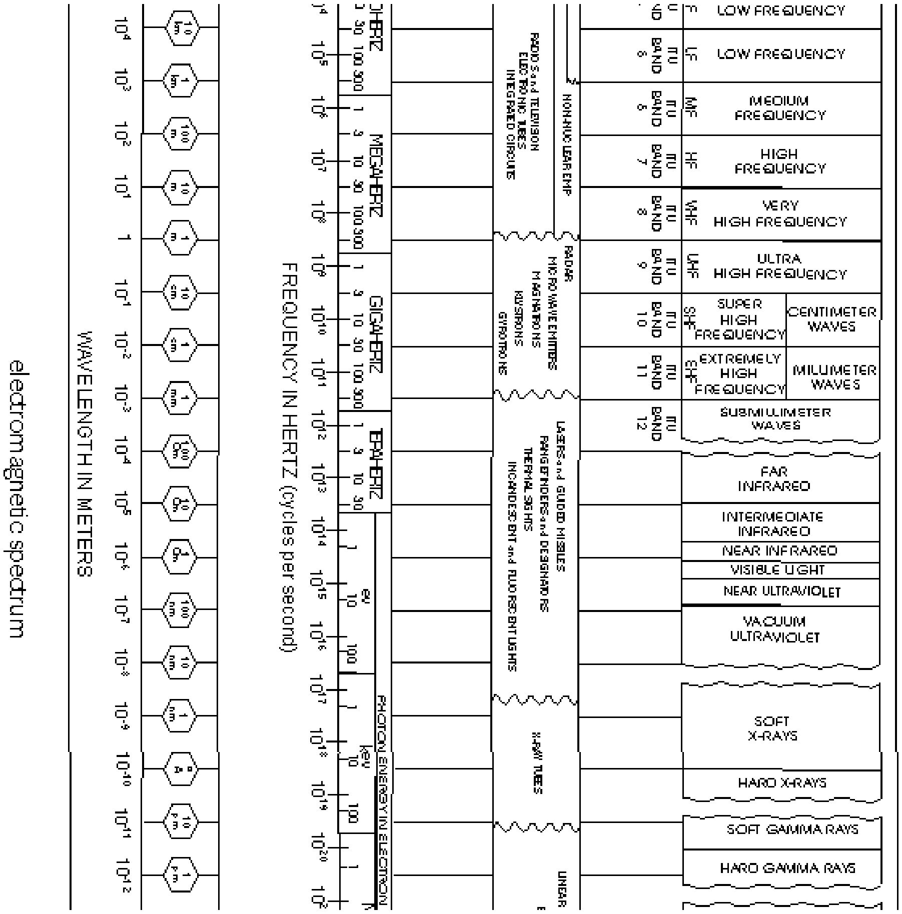


Figure 17.4: Maxwell: *The spectrum of electromagnetic waves*

Chapter 18

Galileo's Principle: Inertial = Gravitational Mass

> Thus the two phenomena of inertia and (gravitational) attraction, which are so different in Newton's formulation, must have a common root. This is the great discovery of Einstein. (Born [8])

> Special relativity was exactly that–special. (Bartusiak [4])

18.1 Inertial Mass

We recall that Newton's classical 2nd law for a body B moving with velocity v along an inertial x-axis, states that

$$m_i\dot{v} = F,$$

where m_i is the *inertial mass* of the body, and F is a force acting on the body.

18.2 Gravitational Mass

If F is a *gravitational force* acting on B, then $F = m_g f$, where f is a normalized gravitational force, which we assume to be constant, and m_g is the *gravitational mass* of the body. We can thus express Newton's 2nd law for a body subject to a constant normalized gravitational force f, in an inertial system as follows:

$$\dot{v} = \frac{m_g}{m_i} f.$$

18.3 Galileo's Equivalence Principle

We now want to establish a relation between the inertial mass m_i and the gravitational mass m_g as a function of the velocity v, starting with v small, so that relativistic effects are negligible. We then consider a different x'-axis in free fall under the normalized gravitational force f, that is, in the x-system, the origin x'_O of the x'-system with velocity v'_0, satisfies

$$\dot{v}'_0 = f.$$

Let us now write $x = x'_0 + x''$ with $v = v'_0 + v''$, and note that

$$\frac{m_g}{m_i} f = \dot{v} = \dot{v}'_0 + \dot{v}'' = f + \dot{v}''.$$

Now, we want to argue that $\dot{v}'' = 0$, which reflects that in the x'-system the body is not acted upon by any gravitational force because both the body and the x'-coordinate system are in free fall under the gravitational force. We conclude that $m_i = m_g$, that is that the inertial mass is equal to the gravitational mass, which is supported by the observation that all bodies in free fall, independent of their mass, follow the same law $\dot{v} = f$. The first such experiments were performed by Galileo dropping different objects from the tower of Pisa, see Fig. 18.1.

Born states that the insight that $m_i = m_g$ is Einstein's "great discovery" and it is commonly referred to as *Einstein's Equivalence Principle*. We just saw that this principle reflects that the motion of an object in free fall does not depend on its mass, which was very well understood already by Galileo. It therefore appears to be more correct to refer to the equivalence of inertial and gravitational mass as *Galileo's Equivalence Principle*. Did Einstein "understand" also this principle better than all the others including Galileo, and is this the reason it is commonly referred to as Einstein's principle, cf. Fig. 22.1?

Next, for larger velocities v, we have by the previous section the relativistic variant

$$m_i = \frac{m_g}{1+v}$$

stating that the inertial mass m_i increases with the velocity in approach and decreases in recession. The different inertial mass in approach and recession is phenomenon not present in classical special relativity. We conclude that in relativistic mechanics the inertial mass depends on the velocity, while the gravitational mass does not (seem to do that).

Objects of Different Mass Fall at the Same Rate

A cannon ball and a musket ball, dropped from the Leaning Tower of Pisa, would hit the ground at the same time.

Figure 18.1: Galileo: *Inertial mass is equal to gravitational mass.*

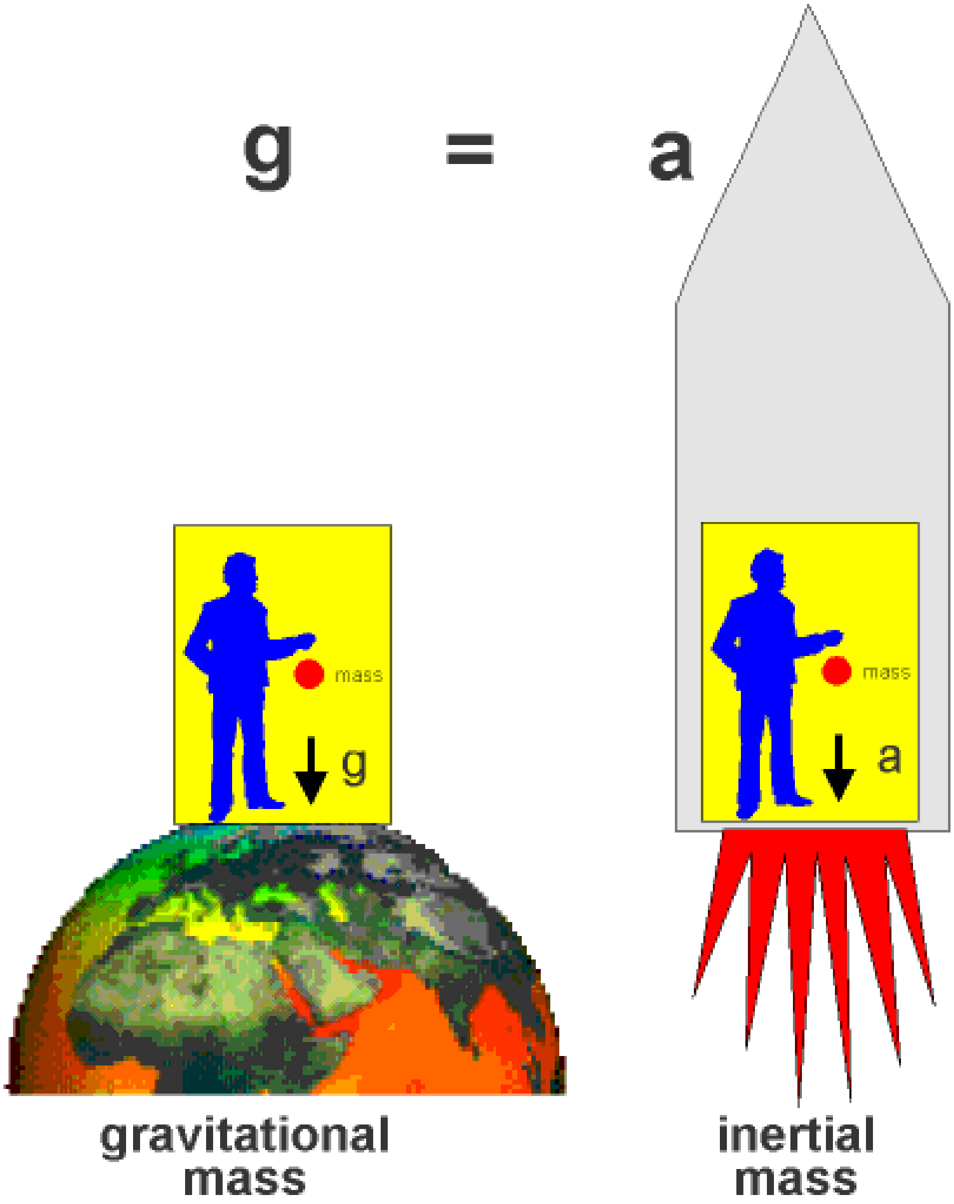


Figure 18.2: Einstein: *Inertial mass is equal to gravitational mass.*

Chapter 19

Mach's Principle

> Inertia originates in a kind of interaction between bodies. (Einstein [40])
>
> For me only relative motions exist, and I can see, in this regard no distinction between rotation and translation. (Ernst Mach)

19.1 Does the Universe Turn Around the Earth?

We have understood that all translatory motion is relative, but what about rotation? Is also rotation relative? Can we decide if he Earth is spinning around with the stars being fixed, or if the stars spin around the Earth with the Earth fixed?

To take a more mundane example, can we decide if the merry-go-round is spinning or the world is spinning around the it? Of course, you would say yes, because on the merry-go-round you would feel a centrifugal force. More precisely, if your inertial mass is m and you move in a circle of radius r with speed v in a fixed x-coordinate system of the plane, then you are subject to the *centripetal acceleration* $\frac{v^2}{r}$, because if $x(t) = r(\cos(\frac{vt}{r}), \sin(\frac{vt}{r}))$, then $\ddot{x} = \frac{v^2}{r}(\cos(\frac{vt}{r}), \sin(\frac{vt}{r}))$. Thus, by Newton's 2nd law you will be subject to the centrifugal force $F = \frac{mv^2}{r}$, which you would have to balance in order not be thrown off a merry-go-round. you would say that if $F > 0$, then the merry-go-round would be turning, and if $F = 0$, then it would stand still, right?

Likewise, if the Earth is spinning, it would be subject to a centrifugal force, making the shape of the Earth slightly oval or ellipsoidal with a flattening at the poles. And yes, the Earth is slightly flattened at the Poles, as predicted by Newton and experimentally verified by Pierre Bouguer and Charles-Marie de la Condamine in the 18th century, and so the Earth must be spinning relative to the fixed stars, and not the other way around, right?

Newton considered a variant of the merry-go-round experiment with a bucket of water suspended in a twisted rope and spinning around. Newton observed that the top surface of the water was plane when the water initially was at rest, while it became curved with the water at a higher level at the rim than in the middle of the bucket, when the water after a while had been accelerated to the speed of the spinning bucket. From the curvature of the water surface, it would thus be possible to determine the (absolute) rotational speed of the water bucket, right?

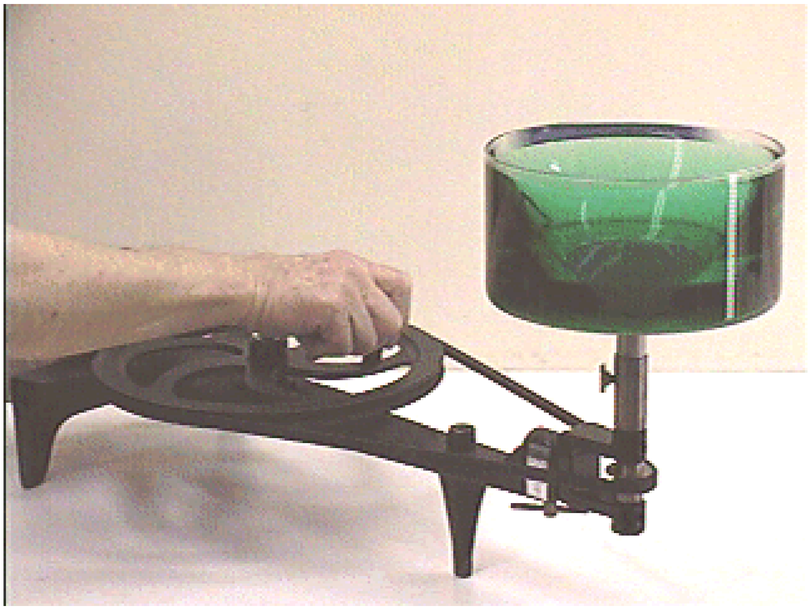


Figure 19.1: Newton: *Look at the curved water surface of the spinning bucket of water caused by inertial forces. Do you think that it is the bucket of water which is spinning, or do you (like Mach and Einstein) believe that (possibly) the Universe is spinning around the bucket subjecting the water to some mysterious gravitational pull?*

19.2 Einstein's Obsession

So far so good. However Einstein, obsessed with the idea of relativity of all motion in his general theory of relativity including acceleration, pointed out that instead of the water spinning around at a certain velocity determined by the curvature of the top surface, or the Earth spinning around with a certain flattening at the poles, one could as well argue that the water or the Earth was rest and the whole Universe was spinning around the water bucket or the Earth, or the merry-go-round. The centrifugal force causing the curved water surface and the flattening of the Earth at the poles, or threatening to throw you off the merry-go-round would then result from some effect of gravitation pull from the spinning Universe, presumably following from Einstein's general theory of relativity.

Einstein had picked up the idea of the relativity of all motion, with no distinction between translatory and rotational motion, from Ernst Mach [82] as formulated in *Mach's Principle*.

Who is right, Newton or Mach-Einstein? Or are both right or wrong? A decisive test would be to remove all the fixed stars and check if the Earth would remain flattened at the poles, but this is impossible, so what are then the theoretical arguments?

Newton would say that the Earth is spinning and the Universe not, because work is required to put an object into spin from an initial state of rest, whether it may be a merry-go-round, the Earth or the Universe. Now the work to get the Universe spin around the Earth, or the whole amusement park around the merry-go-round, would be frantically large as compared to the work required to get the Earth or the merry-go-round spinning. Newton would now say that Nature, always seeking some economy, would go for the cheaper solution.

Einstein argues, copying Mach, that all motion is relative including rotation, as expressed in his Principle of Relativity, which Einstein motivates by a tendency of Nature to seek mathematical simplicity.

We see that Newton uses a synthetic argument, which can be experimentally verified, while Einstein as usual uses an analytic argument, which cannot be tested. Einstein also would have to explain how a spinning Universe can generate a centrifugal force on an Earth or merry-go-round at rest. Presumably, Einstein would say that this follows from his field equations of the general theory of relativity, which however nobody can solve to find out what they predict about the effect of a spinning Universe. Abraham Pais writes in his biography [89]:

- *I am told that the Zeitschrift für Physik no longer accepts papers on general relativity on the gorunds that articles on Mach's Principle provokes too many polemical replies...It must be said that, as far as I can see, Mach's Principle has not brought physics decisively farther.*

Einstein writes in a letter to G. Murray in 1924:

- *As a matter of fact, one should no longer speak of Mach's Principle.*

Mach was initially quite positive to Einstein's relativity, but in his later years turned his back on relativity and stated in 1913 [83]:

- *I must assuredly disclaim to be a forerunner of the relativists ...who seem to be growing more and more dogmatical.*

Einstein explained Mach's change of attitude as an expression of senility in a letter to E. Weiner in 1930, well after Einstein himself had been judged to suffer from the same dysfunction:

- *There can hardly be any doubt that this reaction of Mach was a consequence of an absorption capacity diminished by age, since the whole thinking of relativity is in concordance of that of Mach, so that it is justified to consider Mach as a precursor of the general theory of relativity.*

We see that (as usual) Einstein oscillates between supporting and denying Mach's Principle, depending on circumstances.

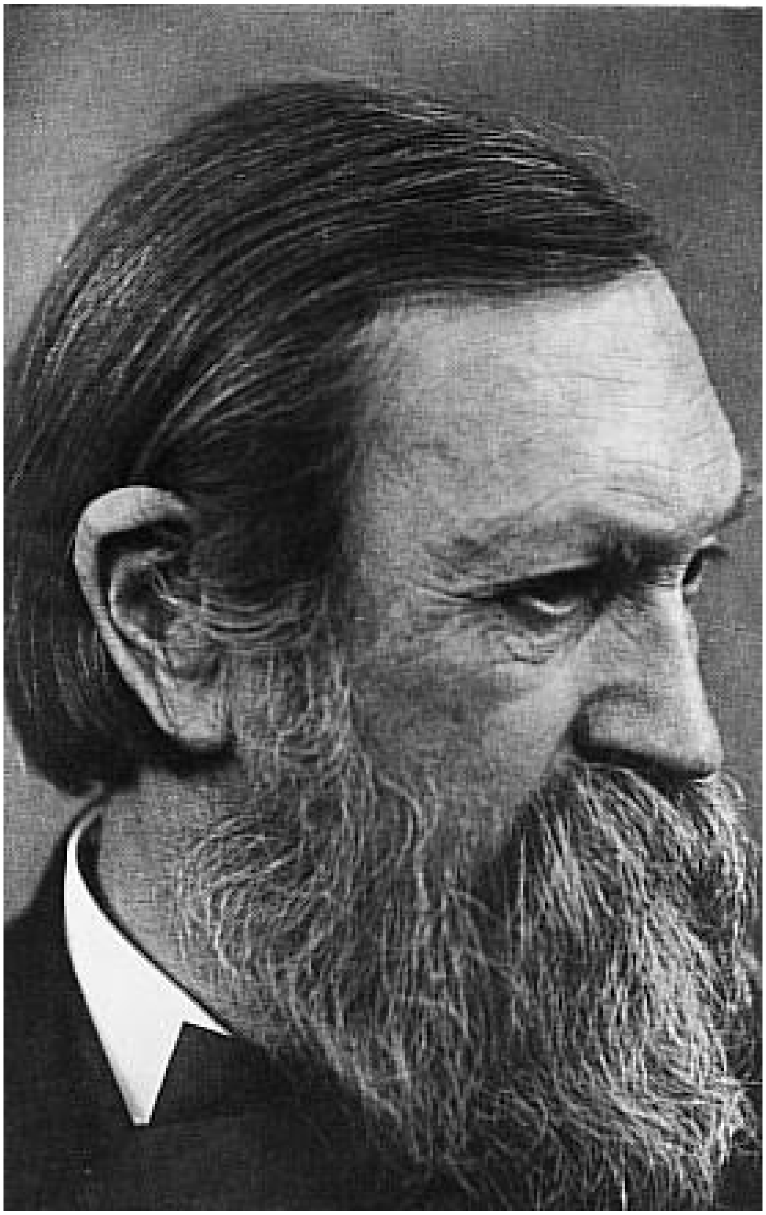


Figure 19.2: Ernst Mach: *L'objectif que la physique s'est fixé est l'expression abstraite la plus simple et la plus économique des faits... En réalité, une loi contient moins que le fait lui-même, parce qu'elle ne reproduit pas le fait dans son ensemble mais seulement dans son aspect qui est le plus important á nos yeux, le reste étant ignoré intentionnellement ou par nécessité.*

Chapter 20

Cosmological Models

> That term (with the cosmological constant) is necessary only for the purpose of making possible a quasi-static distribution of matter, as required by the fact of the small velocities of the stars. (Einstein [27])

20.1 A Very Simple Model

We now present a simple cosmological model motivated by the observation that all galaxies we can observe appear to move away from us with a speed (red-shift) proportional to the distance from our own galaxy.

We start at time $t = 0$ with a collection of $2N + 1$ unit masses (galaxies) positioned at i/N with velocity $v_i = i/N$, $i = 0, \pm 1, ..., \pm N$. This initial state may be attained from acceleration from zero velocity over the time span $[-1, 0]$ due to the gradient $-x$ of a pressure $p(x) = 1 - x^2/2$ satisfying $-\frac{d^2p}{dx^2} = f \equiv 1$ for $-1 < x < 1$ together with the boundary condition $p(-1) = p(1) = 0$. Here $f = 1$ represents the intensity of a heat source acting over the time interval $[-1, 0]$, p couples to f through a heat equation, and by the state equation of an ideal gas, p is proportional to temperature. We thus may obtain the initial condition from the Euler equations for an ideal gas with a heat source from a Big Bang nuclear reaction.

Assuming now that the pressure force disappears for $t > 0$ and that no other forces such as gravitation are of importance, the unit masses will then move away from the origin with constant velocity $v_i = i/N$ to reach the positions $x_i(t) = tv_i$ for $t > 0$. Thus, the galaxies will move away from the origin with a velocity proportional to the distance from the origin, as observed by Hubble (see below).

20.2 An Ideal Gas Cosmological Model

As a more complete cosmological model we now consider the *Euler equations* including gravitational forces expressing conservation of mass, momentum and total energy of a *ideal (inviscid) perfect gas* in three-dimensional space $\mathbb{R}^3$ over a time interval $[0,\hat{t}\,]$ with initial time zero and final time $\hat{t}$, assuming that there are no viscous forces (in-viscid flow) and that there is no heat flow from conduction (zero heat conductivity). We remark that the Euler equations for an ideal gas may be viewed to represent a *Hamiltonian system.*

We seek the *density* ρ, *momentum* $m = \rho u$ with $u = (u_1, u_2, u_3)$ the *velocity*, the *heat (internal) energy* e and the *gravitational potential* φ as functions of $(x,t) \in \mathbb{R}^3 \cup \Gamma \times [0,\hat{t}\,]$, where $x = (x_1, x_2, x_3)$ denotes the coordinates in $\mathbb{R}^3$ and u_i is the velocity in the x_i-direction. The Euler equations for $\hat{u} \equiv (\rho, u, e, \varphi)$ read with $Q = \mathbb{R}^3 \times I$ and $I = (0,\hat{t}\,]$:

$$\begin{array}{rcll}
\dot{\rho} + \nabla\cdot(\rho u) & = & 0 & \text{in } Q, \\
\dot{m}_i + \nabla\cdot(m_i u) + p_{,i} - G\varphi_{,i} & = & 0 & \text{in } Q, \quad i = 1,2,3, \\
\dot{e} + \nabla\cdot(eu) + p\nabla\cdot u & = & 0 & \text{in } Q, \\
\Delta\varphi & = & \rho & \text{in } Q, \\
\hat{u}(\cdot,0) & = & \hat{u}^0 & \text{in } \Omega,
\end{array} \qquad (20.1)$$

where $v_{,i} = \frac{\partial v}{\partial x_i}$ is the partial derivative with respect to x_i, $\dot{v} = \frac{\partial v}{\partial t}$ is the partial derivative with respect to time t, $p = (\gamma - 1)e$ is the *pressure* with $\gamma > 1$ the gas constant, G is a gravitational constant, and $\hat{u}^0$ an initial condition. Further, $\nabla \cdot v = \sum_i v_{i,i}$ denotes the divergence of $v = (v_1, v_2, v_3)$, $\nabla w = (w_{,1}, w_{,2}, w_{,3})$ is the gradient and Δ the Laplacian. We also assume suitable decay conditions as $|x|$ becomes large.

For a more detailed presentation of this model including simulations starting with a very hot dense high pressure and concentrated initial state at rest showing the gas expanding, cooling off and concentrating into spiral galaxy structures, see [56].

In the Euler model (20.1) we may solve the Laplace equation for the gravitational potential φ in terms of the density ρ, and put the result into the momentum equation, thus formally eliminating the potential φ. This would reflect the idea that (somehow) a mass distribution "creates" its own gravitational field (e.g. by emitting "gravitons").

20.3 A Model with Mass "created" by Potential

It may be of interest to turn this around and instead eliminate the density, letting the gravitational potential (somehow) "create" the mass. This approach would lead to the following model: Find (φ, m, e) satisfying

$$\begin{array}{rcll} \dot{\varphi} + \Delta^{-1}(\nabla \cdot m) & = & 0 & \text{in } Q, \\ \dot{m}_i + \nabla \cdot (m_i u) + p_{,i} - G\varphi_{,i} & = & 0 & \text{in } Q, \quad i = 1, 2, 3, \\ \dot{e} + \nabla \cdot (eu) + p\nabla \cdot u & = & 0 & \text{in } Q, \\ \hat{u}(\cdot, 0) & = & \hat{u}^0 & \text{in } \Omega, \end{array} \tag{20.2}$$

where the density is given by $\rho = \Delta\varphi$, $u = m/\rho$ and as before $p = (\gamma - 1)e$.

With this perspective the tendency of "mass lumping" from very small initial density variations, would reflect that application of the Laplacian may enhance density variations. In this model, it is thus the gravitational force field or gravitational potential, which is given initially and evolves in time and from which the mass density is "created". With this approach the mystery of how gravitational forces are generated from a mass distribution, may be replaced by the mystery of how a gravitational field can "generate mass", which may be easier to resolve because no effects have to be transmitted: All interaction is local and there is no "action at distance".

20.4 Hubble Red Shift

As a measure of Doppler red shift it is common to use $z = \frac{1}{f} - 1$, which with the standard Doppler shift $f = \frac{1}{1-v}$ gives $z = v$. The largest observed red shift (for the galaxy farthest away from the Earth, which is visible), is given by $z \approx 6.3$, which would indicate a velocity $v \approx 6.3 \approx 1,890,000$ km/sec, or $v \approx 0.99 \approx 285,254$ km/sec. Einstein's Doppler shift in special relativity would give about the same speed. However, these values are not considered to be correct [103]: The actual recession velocity depends on the cosmological model; for an OmegaM= 0.3 vacuum-dominated flat model the velocity is estimated to $585,611$ km/sec, which is faster than light and at least seemingly in contradiction with Einstein's special relativity.

We recall that Hubble's law relating the recession velocity v of a galaxy to its distance d, reads $v = Hd$, where H is the Hubble constant. Knowing the Hubble constant and the velocity v, the distance to a galaxy can thus be estimated by $d = v/H$.

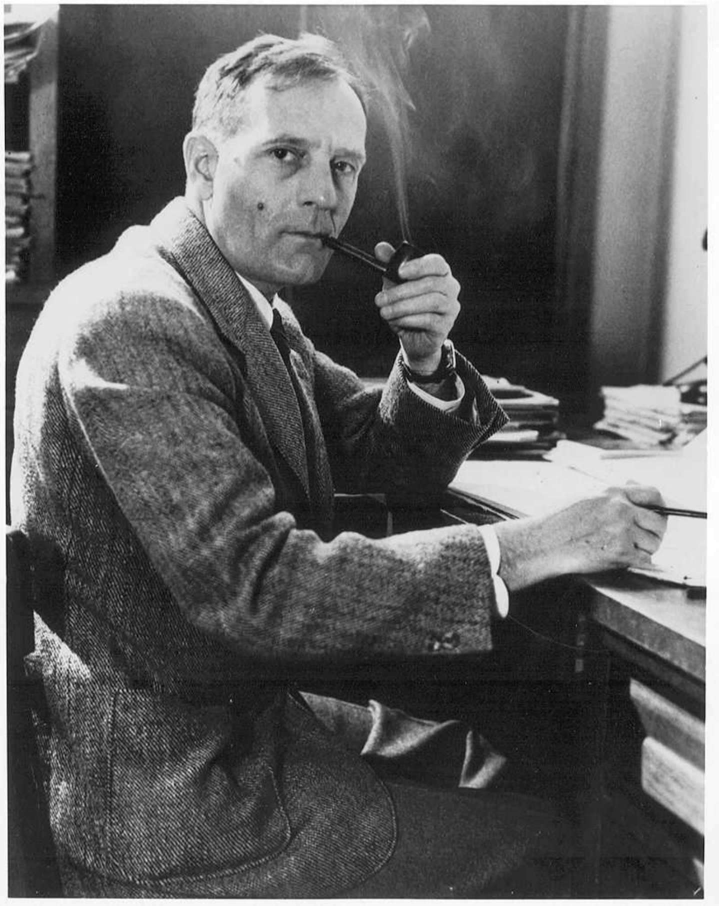


Figure 20.1: Hubble: *The red-shift increases linearly with distance.*

Part IV

Many-Minds Quantum Mechanics

Chapter 21

Quantum Mechanics

> I prefer a realist way of looking at quantum mechanics, in terms of a wave function that can describe laboratories and observers as well as atoms and molecules, governed by laws that do not materially depend on whether there are any observers or not. (Steven Weinberg in [108])
>
> Niels Bohr brainwashed a whole generation of theorists into thinking that the job of interpreting quantum theory was done 50 years ago. (1969 Nobel Laureate Murray Gell-Mann)
>
> In general the many-electron wave function $\psi(x_1, ..., x_N)$ for a system of N electrons is not a legitimate scientific concept when $N \geq N_0$, where $N_0 \approx 10^2 - 10^3$. (Walter Kohn Nobel Lecture 1998)
>
> Dont forget that the reason a physicist can really calculate from first principles is that he choses only simple problems. He never solves a problem with 42 or even 6 electrons in it. So far, he has been able to calculate reasonably well accurately only the hydrogen atom and the helium atom. (Feynman, The Feynman Lecture notes on Physics.)

21.1 Schrödinger and his Equation

Quantum Mechanics based on the *Schrödinger equation* was developed by Erwin Schrödinger in four revolutionary articles in the *Annales de Physique* 1926 in an outburst of creativity (inspired by the ingenious thesis of de Broglie [14]), which gave Schrödinger the Nobel Prize in 1933, shared with Paul Dirac. Solutions to the Schrödinger equation are referred to as *wave functions.* It appears that a vast amount of physics on atomic scales can be described by wave functions, but the physical interpretation of Schrödinger's wave functions has remained a mystery. In the *Copenhagen Interpretation* proposed by Born, and propagated by Bohr and Heisenberg, the square of the modulus of the wave function is interpreted as a probability density indicating the probability of a certain configuration of electrons and atomic kernels viewed as "point particles" without extension in space, an interpretation never accepted by the inventor Schrödinger himself.

21.2 The Copenhagen Interpretation

We have above argued that statistical considerations in thermodynamics create more problems than they solve, and thus run the risk of representing pseudo-science in the sense of Popper. The same argument applies to the Copenhagen Interpretation of quantum mechanics, and both Schrödinger and Einstein passed away without being convinced, despite a (very) strong pressure from the physics community [6, 9, 10, 11, 12, 13, 22, 33, 34, 35, 51, 90, 91, 92, 97, 98, 99, 106]. However, lacking an alternative, the Copenhagen Interpretation has become an accepted "truth" presented in (almost) all text books in quantum mechanics, although a recent poll (at a 1997 UMBC quantum mechanics workshop) gave it less than half of the votes [102].

Stimulated by the failing belief in statistical quantum mechanics indicated by the poll result, we now proceed to present an alternative to the Copenhagen interpretation, which is free of statistics, and which we will refer to as *Many-Minds Quantum Mechanics (MMQM)*, in a paraphrase to the *many-worlds interpretation* proposed by Everett in 1957, which scored second in the poll. MMQM is closely related to the Hartree-Kohn *electron density* approach [68], and connects to Kohns standpoint that a many-electron wave function is not a "legitimate scientific concept", in other words, simply does not exist. The term *many-minds quantum mechanics* was used by Albert and Loewer [1] in an interpretation of Everett's many-worlds interpretation, while we use it with a different meaning.

Figure 21.1: Schrödinger: *With very few exceptions (such as Einstein and Laue) all the rest of the theoretical physicists were unadulterated asses and I was the only sane person left…The one great dilemma that ail us… day and night is the wave-particle dilemma… So unable is the good average physicist to believe that any sound person could refuse to accept the Copenhagen oracle..* (Schrödinger in a letter to Synge 1959)

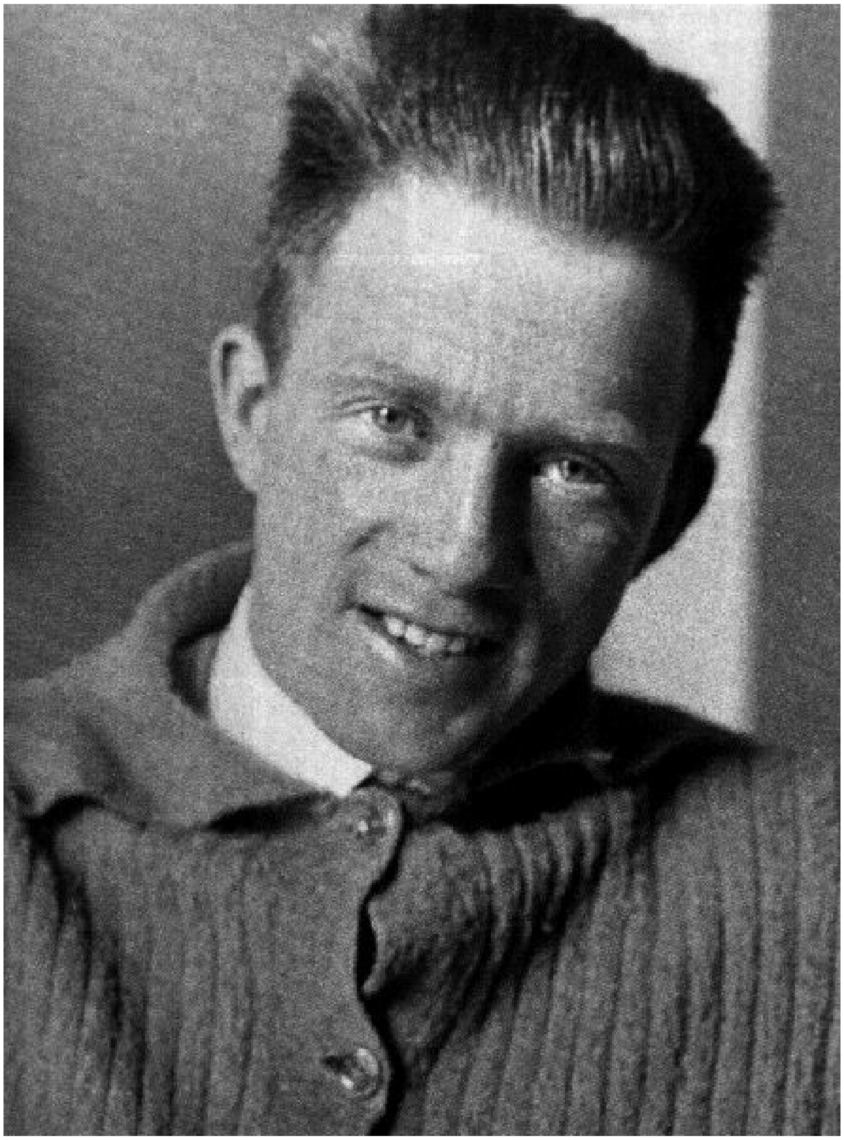


Figure 21.2: Heisenberg: *I am not uncertain about my uncertainty.*

21.3 Information Flow of Quantum Mechanics

MMQM connects to the many-minds idea of a physical system as a flow of (essential) information, in a new approach to the quantum mechanics of a system of electrons with negative charge evolving in time subject to electrostatic Coulomb forces from mutual interaction and from a set of positively charged atomic kernels (to start with assumed to be fixed as in the Born-Oppenheimer model). We thus attribute to each electron a (very simple) “mind” through which each electron can register electric potentials and move accordingly. We thus do not give any outside observer or surveyor the job of telling the electrons what to do, or simply prescribe that the Schrödinger wave equation should be obeyed no matter how, but allow the system to evolve “freely” with each electron doing its best registering electric potentials and moving accordingly.

We may compare with Adam Smith’s model of an economy as an interacting system of “free economical men”, each one seeking to maximize his own profit or happiness by taking into account the action of all the others. Smith’s “invisible hand” would then establish an “equilibrium” (representing maximal total happiness), which we could view as the analog of Schrödingers equation. Of course, the question of the nature and even existence of the “invisible hand” directly presents itself, but after some reflection we understand that the idea of an “invisible hand” represents pseudo-science, of little interest. We would then view the economy simply as a system of interacting “minds”, each mind doing its best.

In the MMQM model the electron system is described by a set of wave functions, one for each electron, each of which represents an average of the classical complete wave function containing all possible particle interactions, and which satisfies a one-electron version of the Schrödinger equation. We will argue that the complete wave function is fictional and as such “does not exist” (in the same sense as the “invisible hand” does not exist), while the set of individual averages thereof in MMQM, do exist as a reflection of the existence of the (freely) interacting electron system.

21.4 The MMQM Interpretation

MMQM invites to a natural deterministic physical interpretation (of the square of the modulus) of the wave function for each electron as the density or "presence" in space time of the electron. Together the electron wave functions thus form a deterministic electron density in the spirit of Hartree and Kohn. In contrast, the complete wave function seems impossible to interpret deterministically and the only way out seems to be the statistical Copenhagen Interpretation with all its complications. We avoid all these difficulties simply by not at all speaking of the (probably non-existent) complete wave function, following Wittgenstein's device to keep quite of which you cannot speak.

MMQM is like a many-minds interaction of a group of human beings, with each human mind having its own perception of the full interaction, as a form of blurred average of a fictional unknown complete "wave function" expressing the totality of all interactions. We can also interpret MMQM as representing a "free democratic society" of individuals taking individual decisions based on individual experience, as compared to a totalitarian society with each individual required to (somehow) follow the dictate of one Leader (having full information of all interactions through an ideal KGB or Stazi). Evidence of the existence of democratic societies is abundant, while totalitarian systems seem to be in quick transition to non-existence (or have already ceased to exist).

21.5 Schrödinger's Cat

Classical quantum mechanics is based on the existence of complete wave functions as solutions to the *Schrödinger equation*, with the linearity of the equation playing an important role, in particular suggesting that quantum states can be linearly superimposed. This led to the famous *Schrödinger cat paradox* with a cat in a box being in a combined superimposed state of both life and death, until a final verdict is given by simply an observation by opening the box. The cat would thus be neither dead nor alive prior to observation, but sort of half-dead and half-alive and only by the act of observation would become fully dead or fully alive in what Heisenberg called a "collapse of the wave function". Schrödinger constructed his cat paradox to show that a careless use of quantum mechanics could lead to absurdities, way beyond the supposed 9 lives of a cat.

21.6 Quantum Computers?

Today Schrödinger's cat has come back in the form of projected *quantum computers* supposedly being able to perform many parallel computations by superimposing many quantum states and using a final observation to select useful information. Quantum computers are based on the existence of complete wave functions, which may not exist for many-electron systems, and therefore it is not (at all) clear that a quantum computer can be brought to existence, (except very simple ones consisting of a few so called quantum bits or qubits).

Figure 21.3: Hartree: *Why not let each electron solve its own version of Schrödinger's equation?*

21.7 The Hartree and Kohn-Sham Methods

In the classical *Hartree method* [49] the Schrödinger equation is replaced by a system of one-electron equations, which may be viewed as a form of MMQM (with central field approximations). The individual wave functions represent different mean value approximation in space of a (possibly non-existent) full wave function, and together form an approximate solution to the Schrödinger equation, from which typical macroscopic outputs such as energy levels and electron densities can be computed. The Hartree method has been used extensively apparently with good results. A related successful method is the electron-density method by Kohn-Sham, for which Walter Kohn got the Nobel Prize in 1998 [68].

21.8 Many-Minds Quantum Mechanics

We now proceed to present a MMQM model for a multi-electron system, starting with the Schrödinger equation for the one-electron Hydrogen atom and the two-electron Helium atom. We also present a model for radiation which is a quantum mechanical analog of the model for black-body radiation considered above. For simplicity we do not take electron spin into account. (It may be that spin can be left out altogheter from the discussion, as well as the Pauli exclusion principle not allowing two electrons with the same spin to have overlapping wave functions).

21.9 Hydrogen Atom

The *Schrödinger equation* for the Hydrogen atom takes the form:

$$\begin{aligned} i\bar{h}\dot{\psi} + (\frac{\bar{h}^2}{2m}\Delta + V)\psi = 0 \quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3, \\ \psi(0,\cdot,\cdot) = \psi^0 \quad \text{in } \mathbb{R}^3. \end{aligned} \tag{21.1}$$

where $\psi(t,x)$ is the (complex-valued) *wave function*, Δ is the Laplacian with respect to x, and

$$V(x) = \frac{e^2}{|x|}$$

is the *Coulomb potential* modeling the interaction of the negative electron with the positive proton kernel. Here $\bar{h}$ is Planck's (reduced) constant, m is the electron mass, and e the elementary charge. We normalize to $\bar{h}^2/m = 1$

and $e^2 = 1$ using customary *atomic units* in which case (21.1) takes the form:

$$\begin{aligned} i\dot{\psi} + (\frac{1}{2}\Delta + V)\psi = 0 \quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3, \\ \psi(0,\cdot,\cdot) = \psi^0 \quad \text{in } \mathbb{R}^3. \end{aligned} \tag{21.2}$$

with $V(x) = \frac{1}{|x|}$.

Seeking solutions of the form $\exp(iEt)\psi(x)$ leads to the eigenvalue problem

$$-(\frac{1}{2}\Delta + V)\psi = E\psi.$$

where the eigenvalue E represents the total energy as the sum of kinetic and potential energy:

$$E = \frac{1}{2}\int_{\mathbb{R}^3} |\nabla\psi(x)|^2 dx - \int_{\mathbb{R}^3} \frac{|\psi(x)|^2}{|x|} dx,$$

and the eigenfunction ψ can be assumed to be real-valued with the normalization

$$\int_{\mathbb{R}^3} \psi(x)^2 dx = 1.$$

The *ground state* of Hydrogen with minimal energy is given by a spherically symmetric wave function

$$\psi(x) = \frac{1}{\sqrt{\pi}} \exp(-|x|)$$

with corresponding eigenvalue $E = -\frac{1}{2}$ representing the *ground state energy*. Exited states of Hydrogen corresponds to eigenfunctions for larger energies E. This is because in polar coordinates with r the radius and ψ radial

$$\frac{1}{2}\Delta\psi = \frac{1}{2}\frac{\partial^2\psi}{\partial r^2} + \frac{1}{r}\frac{\partial\psi}{\partial r}.$$

21.10 Radiating Hydrogen Atom

A Hydrogen atom absorbing energy from a given forcing f and radiating energy into a surrounding vacuum, can in the spirit of the model for black-body radiation above, be modeled by

$$\begin{aligned} i\dot{\psi} + (\frac{1}{2}\Delta + V)\psi - \gamma\dddot{\psi} - \delta^2\Delta\dot{\psi} = f \quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3, \\ \psi(0,\cdot) = \psi^0 \quad \text{in } \mathbb{R}^3, \end{aligned} \tag{21.3}$$

Figure 21.4: Walter Kohn: *The Schrödinger wave function does not exist for a many-electron system.*

where the term $-\gamma\dddot{\psi}$ represents radiation with dissipation intensity $\gamma|\ddot{\psi}(x,t)|^2$, $-\delta^2\Delta\dot{\psi}$ represents a G2 stabilization with dissipation intensity $\delta^2|\nabla\dot{\psi}|^2$, and we assume that $\gamma << \delta^2 \sim 1$. We note the basic energy balance (with $f = 0$):

$$\frac{1}{4}\frac{d}{dt}\int_{\mathbb{R}^3}|\nabla\psi|^2 dx + \int_{\mathbb{R}^3}\gamma|\ddot{\psi}|^2 dx + \int_{\mathbb{R}^3}\delta^2|\nabla\dot{\psi}|^2 dx = 0,$$

exhibiting the radiation and G2 dissipation.

21.11 Schrödinger's Equation for the Helium Atom

The Schrödinger equation for the two-electron *Helium atom* takes the form: Find $\psi(t, x_1, x_2)$ such that

$$\begin{aligned} i\dot{\psi} + (\frac{1}{2}\Delta_1 + \frac{1}{2}\Delta_2 + V_1 + V_2 - V_{12})\psi = 0 \quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3 \times \mathbb{R}^3, \\ \psi(0,\cdot,\cdot) = \psi^0 \quad \text{in } \mathbb{R}^3 \times \mathbb{R}^3, \end{aligned} \tag{21.4}$$

where Δ_j is the Laplacian with respect to x_j, and

$$V_j(x_j) = \frac{2}{|x_j|}, \quad V_{12}(x_1, x_2) = \frac{1}{|x_1 - x_2|}, \quad j = 1, 2,$$

are the Coulomb potentials modeling the interaction of the two electrons with the kernel (consisting of two protons and two neutrons), and with each other.

We note that the wave function $\psi(t, x_1, x_2)$ has two space variables x_1 and x_2 both ranging over $\mathbb{R}^3$, and thus has a space dependence over $\mathbb{R}^6$. For N electrons the space variables range over $\mathbb{R}^{3N}$, which makes computational (and also analytical) solution of the Schrödinger equation impossible for a a many-electron system.

21.12 MMQM for the Helium Atom

MMQM for the Helium atom takes the form of the following system of equations in $\mathbb{R}^3$: Find $\psi_j(t,x)$ for $j = 1, 2$, such that

$$\begin{aligned} i\dot{\psi}_1 + (\frac{1}{2}\Delta + V - W_1)\psi_1 = 0, &\quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3, \\ i\dot{\psi}_2 + (\frac{1}{2}\Delta + V - W_2)\psi_2 = 0, &\quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3, \end{aligned} \tag{21.5}$$

where

$$\begin{aligned} W_1(t,x) &= \int \frac{|\psi_2(t,y)|^2}{|x-y|} dy, \\ W_2(t,x) &= \int \frac{|\psi_1(t,y)|^2}{|x-y|} dy, \end{aligned}$$

Δ is the Laplacian with respect to x, and $V(x) = \frac{2}{|x|}$. Here electron j is described by the wave function $\psi_j(t,x)$ with $|\psi_j(t,x)|^2$ a weight representing the "density" of electron j at (t,x). Note that $W_1(t,x)$ can alternatively be defined as the solution to the Poisson equation

$$-\Delta W_1 = 4\pi |\psi_2(t,\cdot)|^2 \quad \text{in } \mathbb{R}^3, \tag{21.6}$$

with a suitable decay to zero at infinity, and simililarly for W_2.

We notice that the MMQM model (21.8) is a non-linear "multi-species" system of wave functions $\psi_j(t,x)$ defined $\mathbb{R}_+ \times \mathbb{R}^3$ and $t > 0$, where each electron solves its own equation integrating over the influence of the other electron in the spirit of the Hartree method. We compare with the Schrödinger equation, which is a linear equation in a scalar wave function $\psi(t,x_1,x_2)$ defined on $\mathbb{R}_+ \times \mathbb{R}^3 \times \mathbb{R}^3$. We understand that the computational complexity of MMQM is much smaller than that of the full Schrödinger equation. If each space dimension is discretized into n cells, MMQM requires $2n^3$ and Schrödinger n^6 cells, and for large n the difference is large.

Since the potentials V and W_j are real, the solutions of (21.8) are easily seen to satisfy

$$\frac{d}{dt} \int |\psi_j(t,x)|^2 dx = 0 \qquad \text{for } t > 0,$$

which justifies the interpretation of $|\psi_j(t,x)|^2$ as a weight indicating the "presence" of electron j, with the normalization

$$\int |\psi_j(t,x)|^2 dx = 1 \qquad \text{for } t > 0. \tag{21.7}$$

We may view the MMQM model (21.8) as a an alternative to Schrödinger's equation (21.4), where the equation for ψ_1 formally is obtained by multiplication by $|\psi_2(t, x_2)|^2$ and integration with respect to x_2.

There is thus a connection between the Schrödinger wave function and the set of MMQM one-electron wave functions, but the relation is by no means simple. In particular, a MMQM-solution does not offer a full wave-function satisfying Schrödinger's equation (21.4).

Since Schrödinger's equation is an ad hoc model, which is not derived from a more basic model, it may as well be possible to start from an ad hoc model of the MMQM form. If (as we expect) the MMQM system can be solved, while Schrödinger's equation cannot, the question of the relation between solutions of the two models does not come up in practice. We may check to what extent a product of MMQM one-electron wave functions satisfies the Schrödinger equation, and take the residual as a measure the existence of full wave function (which may not exist).

21.13 MMQM for the Ground State of Helium

The ground state of helium is the state of least total energy E as the sum of kinetic and potential energy. Experiments show that (in atomic units) the ground state energy is $E = -2.904$. The wave functions of *parahelium* are the spherically symmetric analogs to the Hydrogen ground state, for which $E = -2.75$, see e.g. [72], which shows that parahelium is not the ground state of helium, nor is *ortohelium* with one electron in a spherically symmetric state in an outer shell. The most accurate computation by perturbation methods reported is $E = -2.903724377034119598311159$.

To find the ground state, we time-step to stationary state the following system

$$\begin{aligned}\dot{\psi}_1 - (\frac{1}{2}\Delta + V - W_1)\psi_1 = 0, \quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3,\\ \dot{\psi}_2 - (\frac{1}{2}\Delta + V - W_2)\psi_2 = 0, \quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3,\end{aligned} \tag{21.8}$$

where we assume that the ψ_j are real, and we rescale in each time step to maintain (21.7):

$$\int_{\mathbb{R}^3} \psi_j(t, x)^2 dx = 1 \quad \text{for } t > 0.$$

The total energy, as the sum of kinetic and potential energies, is given by

$$E = \sum_{j=1}^{2}(\frac{1}{2}\int_{\mathbb{R}^3}|\nabla\psi_j|^2dx - \int_{\mathbb{R}^3}\frac{2\psi_j^2}{|x|}dx + \frac{1}{2}\int_{\mathbb{R}^3}W_j\psi_j^2dx), \tag{21.9}$$

where the interaction energy is given by

$$\int_{\mathbb{R}^3}W_j\psi_j^2dx) = \int_{\mathbb{R}^3}\frac{\psi_1^2(x_1)\psi_2^2(x_2)}{|x_1 - x_2|}dx_1dx_2, \quad j = 1, 2.$$

For spherically symmetric wave functions

$$\psi_j(x) = \frac{2\sqrt{2}}{\sqrt{\pi}}\exp(-2|x|)$$

we have

$$\frac{1}{2}\int_{\mathbb{R}^3}|\nabla\psi_j|^2dx = 2, \quad \int_{\mathbb{R}^3}\frac{2\psi_j^2}{|x|}dx = 4, \quad \int_{\mathbb{R}^3}W_j\psi_j^2dx = 1.25$$

which gives $E = -2.75$.

In computations using FEniCS we restrict to a finite computational domain with homogeneous Dirichlet boundary conditions. We obtain non-spherically symmetric wave functions with with ψ_1 primarily localized to one side of the kernel and ψ_2 to the other, with $E = -2.90????$, in accordance with experiments and the above computational result.

We conclude that MMQM offers a non-symmetric ground state of helium corresponding to experiments different from both parahelium and ortohelium.

21.13.1 Spherical coordinates and Azimuthal Independence

Using spherical coordinates $x = (r\sin(\varphi)\cos(\theta), r\sin(\varphi)\sin(\theta), r\cos(\varphi))$ assuming rotational symmetry around the x_3 axis with (azimuthal) independence of θ, we have with $Q = \mathbb{R}_+ \times [0, \pi]$

$$E(\psi_1, \psi_2) = \pi\sum_j\int_Q|\psi_{j,r}|^2r^2\sin(\varphi)drd\varphi + \pi\sum_j\int_Q|\psi_{j,\varphi}|^2\sin(\varphi)drd\varphi$$
$$- 2\pi\sum_j\int_Q|\psi_j|^2r\sin(\varphi)drd\varphi + 4\pi^2\int_0^\infty\int_0^\pi\int_0^\infty\int_0^\pi$$
$$\frac{|\psi_1(r_1,\varphi_1)|^2|\psi_2(r_2,\varphi_2)|^2r_1^2\sin(\varphi_1)r_2^2\sin(\varphi_2)}{\sqrt{r_1^2 + r_2^2 - 2r_1r_2\cos(\varphi_1 - \varphi_2)}}dr_1d\varphi_1dr_2d\varphi_2,$$

where $\psi_{j,r} = \frac{\partial\psi_j}{\partial r}$ and $\psi_{j,\varphi} = \frac{\partial\psi_j}{\partial\varphi}$.

For minimizing wave functions (ψ_1, ψ_2), we may assume symmetry across the plane $x_3 = 0$, so that

$$\psi_1(r, \varphi) = \psi_2(r, \pi - \varphi).$$

21.14 MMQM for Lithium

We compute the ground state for Lithium with energy $E =???$ to be compared with the best possible energy reported $E = 7.4780603236$.

21.15 MMQM for the Hydrogen Molecule H_2

A Hydrogen molecule consists of two protons held together by two electrons in a so-called *covalent binding*. An MMQM approach indicates that one of the electrons will take a central position between the two proton kernels, and the other electron will take an outer position around the kernels. The central electron will act like a spring force pulling the protons together, a force which will be balanced by the repulsion between the protons. The outer electron will act like a shield repelling other hydrogen molecules.

We show the MMQM electron densities in Fig ...

21.16 MMQM for Many-Electron Systems

MMQM directly generalizes to an arbitrary number of electrons and kernels, and takes the following form in the case of one positive kernel (fixed at the origin) with charge N and N electrons: Find $\psi_j(t, x)$ for $j = 1, .., N$, such that for $j = 1, ..., N$,

$$i\dot{\psi}_j + (\frac{1}{2}\Delta + V - W_j)\psi_j = 0, \quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3, \tag{21.10}$$

$$W_j(t, x) = \sum_{k \neq j} \int_{\mathbb{R}^3} \frac{|\psi_k(t, y)|^2}{|x - y|}\, dy, \quad x \in \mathbb{R}^3,\ t > 0 \tag{21.11}$$

where $V(x) = \frac{N}{|x|}$. We note that W_j is the potential of the charge distribution $\sum_{k\neq j} |\psi_k|^2$ of all the electrons except electron j. We see that (21.10) is a one-electron Schrödinger equation for electron j with the potential W_j resulting from the sum of the charge distributions for electrons $k \neq j$.

To find the ground state we time step the following system for real valued one-electron wave functions $\psi_j(t, x)$:

$$\begin{aligned}
\dot{\psi}_j - (\frac{1}{2}\Delta + V - W_j)\psi_j = 0, &\quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3, \\
-\Delta w_j(t, \cdot) = 4\pi|\psi_j(t, \cdot)|^2, &\quad \text{in } \mathbb{R} \times \mathbb{R}^3, \\
W_j = \sum_{k \neq j} w_k &
\end{aligned} \tag{21.12}$$

for $j = 1, ..., N$.

The computational complexity of MMQM is Nn^3 with n cells in each space dimension, while that of the full Schrödinger equation is n^{3N}, and the difference is enormous: The full Schrödinger equation for n and N of size $10^2 - 10^3$, which covers a large range of applications, is completely intractable, while MMQM appears completely tractable.

21.17 Violation of Pauli's Exclusion Principle

An MMQM set of wave functions $(\psi_1, ..., \psi_N)$ for an N-electron system cannot be expected to satisfy *Pauli's Exclusion Principle (PEP)* demanding that the product wave function $\psi = \psi_1(x_1)....\psi_N(x_N)$ is symmetric or antisymmetric, that is, any interchange of two coordinates x_j and x_k would correspond to multiplying ψ by ± 1. Thus, we see no reason to believe that N-electron systems obey PEP, just as there is no reason to believe that the interaction between a set of (equal) human beings must be either symmetric or anti-symmetric.

21.18 MMQM: Radiating Many-Electron Systems

Combining the above models we obtain the following MMQM model for a radiating multi-electron system: Find ψ_j for $j = 1, .., N$, such that

$$i\dot{\psi}_j + (\frac{1}{2}\Delta\psi_j + V\psi_j - W_j)\psi_j - \gamma\dddot{\psi}_j - \delta^2\Delta\dot{\psi}_j = f, \quad \text{in } \mathbb{R}_+ \times \mathbb{R}^3, \quad j = 1, ..., N, \tag{21.13}$$

where

$$W_j(t,x) = \int \frac{\sum_k |\psi_k(t,y)|^2}{2|x-y|}dy.$$

The total dissipation from radiation and computation is now

$$\sum_j \int_{\mathbb{R}^3} (\gamma|\ddot{\psi}_j|^2 + \delta^2|\nabla\dot{\psi}_j|^2 dx.$$

21.19 Radiating Many-Atom Systems

We can naturally generalize to a multi-atom system allowing also the kernels to move in order to account for temperature effects, e.g. instance by using a classical Newtonian model for the kernels and a quantum model for the electrons. Such a model should have a considerable range of applicability.

21.20 A Model Problem in One Space Dimension

We consider the following model problem in one space dimension: Find $\psi(t,x_1) = (\psi_1(t,x_1),...,\psi_N(t,x_N))$ such that

$$i\dot{\psi}_j + \frac{1}{2}\psi_j'' + V\psi_j - W_j\psi_j = 0, \quad \text{in } \mathbb{R}_+ \times (-1,1), \quad j = 1,...,N, \tag{21.14}$$

where

$$\begin{aligned} W_j(t,x) &= \infty \quad \text{if } \psi_k(t,x) \neq 0 \quad \text{for some } k \neq j,\\ W_j(t,x) &= 0 \quad \text{else},\\ V(x) &= \delta_0 \quad \text{for } |x| \le \epsilon,\\ V(x) &= -\infty \quad \text{for } |x| > 1, \end{aligned}$$

where δ_0 is the delta-function at $x = 0$, and $\psi_j' = \frac{d\psi_j}{dx}$. This corresponds to an extreme form of repulsion between electrons and attraction from the kernel at the origin. The ground state ψ is defined as a solution to the time-independent minimization problem

$$\min_{\psi_1,...,\psi_N} \sum_j (\int_{-1}^{1} \frac{1}{4}|\psi_j'|^2 dx - \frac{1}{2}|\psi_j(0)|^2),$$

where the functions $\psi_j(x)$ have disjoint supports, satisfy the boundary conditions $\psi_j(-1) = \psi_j(1) = 0$, and the normalization condition $\int |\psi_j(x)|^2 dx = 1$.

If $N = 1$, then the wave function $\psi = \psi_1$ is symmetric around $x = 0$ and has the form $\alpha \sin(\beta x)$ for $x > 0$ for certain constants α and β, with a "kink" (discontinuity of ψ') at $x = 0$.

If $N = 2$, then both wave functions ψ_1 and ψ_2 are of the form $\alpha \sin(\beta x)$ with the support of ψ_1 equal to $[-1, 0]$ and the support of ψ_2 equal to $[0, 1]$. The corresponding product wave function $\psi(x_1, x_2) = \psi_1(x_1)\psi_2(x_2)$ is neither symmetric nor anti-symmetric, and thus violate the PEP.

If $N > 3$, then ψ_1 is symmetric around $x = 0$ and ψ_2 and ψ_3) are restricted to $x > 0$ and $x < 0$, respectively. Again PEP is violated.

21.21 Relatitivistic Quantum Mechanics

We can naturally extend MMQM to include interaction by gravitation, simply by adding Coulomb potentials representing gravitational attraction. This gives a form of many-minds relativistic quantum mechanics where each mind is represented by a particle interacting with other minds/particles through Coulomb potentials requiring agreement on mutual distance and a common time. Thus, without the prison of Lorentz invariance it appears the quantum mechanics can naturally be combined with relativity in a many-minds form and thus it should be possible to construct unified many-minds field theories.

21.22 Connection to Leibniz Monads

We cannot refrain from making a connection to Leibniz *Monad Theory*, which may be viewed as an early version of a MMQM. A Leibniz monad is like an elementary particle such as an electron. According to Leibniz, each monad has its own (blurred) perception of the other monads and is acting accordingly. Only God can collect the totality of all perceptions, and he keeps it for himself, letting each monad do its best on its own, in a form of MMQM.

Chapter 22

Conclusion

> Einstein arrived at the special theory of relativity after thinking for ten years about the properties of light, and at the general theory of relativity after thinking for eight years about gravitation. (Pais [89])
>
> At the singularity of Big Bang: Naturally, we were all there–old Qfwfq said–where else could we have been? Nobody knew then that there could be space. Or time either: what use did we have for time, packed in there like sardines? (Calvino [15])
>
> This is the kind of beautiful dream which suddenly transforms into a nightmare. (Calvino)

22.1 Einstein's Summary of His Work

We quote from Einstein's summary of his work in *Out of My Later Years* [37]:

- *Science is the attempt to make the chaotic diversity of our sense-experience correspond to a logically uniform system of thought. In this system single experiences* **must be correlated** *with the theoretic structure in such a way that the resulting coordination is* **unique and convincing**
- *What we call physics comprises that group of natural sciences ...which... lend themselves to mathematical formulation. Its realm is accordingly defined as that part of the sum total of our knowledge which is capable of being expressed in mathematical terms.*
- *From the very beginning there has always been present the attempt to find a unifying theoretical basis consisting of a minimum of concepts and fundamental relationships, from which all the concepts and relationships of the*

single disciplines might be derived **by a logical process**. *This is what we mean by the search for a foundation of the whole of physics.*

- *The so-called special relativity is based on the fact that Maxwell's equations are converted into equations of the same form when they undergo Lorentz transformation. This* **formal** *property is supplemented by our* **fairly** *secure* **empirical** *knowledge that the laws of physics are the same with respect to all inertial systems. This leads to the result that the Lorentz transformation* **must** *govern the transition from one inertial system to another.*
- *Natural laws* **are to be** *formulated in such a way that their form is identical for coordinate systems of any kind of states of motion. To accomplish this is the task of the general theory of relativity.*

We see here Einstein at the end of his career emphasizing the formal mathematical aspect of special relativity with its stipulation of Lorentz invariance, while he vaguely hints at "fairly secure empirical knowledge".

22.2 What Did Einstein Think of His Work?

What did Einstein think of himself and his work as a scientist? Did he understand that he maybe too freely had "borrowed" from others, and that his (analytic) relativity theory maybe represented pseudo-science? We recall the following citations, some from above, where Einstein maybe gives his own answers:

- *There is not a single concept of which I am convinced that it will stand firm, and I feel uncertain whether I am in general on the right track.*
- *What I wanted to say was just this: In the present circumstances, the only profession I would choose would be one where earning a living had nothing to do with the search for knowledge.*
- *Why is it that nobody understands me, and everybody likes me?*
- *It strikes me as unfair, and even bad taste, to select a few individuals for boundless admiration, attributing superhuman powers of mind and character to them. This has been my fate, and the contrast between the popular assessment of my powers and achievements and the reality is grotesque.*
- *Newton, forgive me.*
- *The scientist must appear to the systematic epistemologist as a type of unscrupulous opportunist.*

- *I do not consider the main significance of the general theory of relativity to be the prediction of some tiny observable effects, but rather the simplicity of its foundations and its consistency.*
- *The idea of general relativity is a purely formal point of view and not a definite hypothesis about nature.*
- *In my opinion the general theory of relativity posses little inner probability.*
- *Thus we see Einstein move from the joy of successfully confronting experimental fact to higher abstraction and finally to that discontent with his own achievements which accompanied his search for a unified field theory.* (Pais [89])

These statements seem to indicate that Einstein himself was not sure about the scientific value of his work (in contrast to his many adherents), and that he wanted to be excused for not being able to live up to the (high) expectations...

22.3 Towards a Unified Many-Minds Field Theory?

Is it possible to combine quantum mechanics with gravitation into a unified field theory? Yes, why not? Without the straitjacket of Lorentz (or more general) invariance, a path to progress seems to be passable...We hope this book can stimulate someone to try out...maybe following Leibniz' idea that space is the order of coexistence and time the order of succession...of many minds...[15].

22.4 Maxwell Song of Rigid Body

One of the earliest examples of a song written by a scientist specifically about a scientific principle, I discovered while perusing a collection of comic verse [2]. It was listed as a poem written by James Clarke Maxwell (1831-1879), the eminent physicist, and was entitled "Rigid Body Sings". It deals with the motion of two rigid bodies in air:

Gin a body meet a body
Flyin' through the air,
Gin a body hit a body,
Will it fly? And where?
Ilka impact has its measure,
Ne're a' ane hae I,

Figure 22.1: Unified Field Theory of Many-Minds?

Yet a' the lads they measure me,
Or, at least, they try.
Gin a body meet a body
Altogether free,
How they travel afterwards
We do not always see,
Ilka problem has its method
By analytics high;
For me, I ken na ane o' them,
But what the waur am I?

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[8] Max Born: If God has made the world a perfect mechanism, He has at least conceded so much to our imperfect intellects that in order to predict little parts of it, we need not solve inummerable differential equations, but can use dice with fair success, in *Quantum Physics*.

[9] Max Born: Schrödinger's point of view is the simplest; he thought that by his development of de Broglie's wave mechanics the whole paradoxical problem of the quanta had been settled: there are no particles, no 'quantum jumps'– there are only waves with their well-known vibrations, characterized by integral numbers. The particles are narrow wave-packets. The objection is that one generally needs waves in spaces of many dimensions, which are something entirely different from the waves of classical physics, and impossible to visualize, in *The Born-Einstein Letters*.

[10] Max Born: Schrödinger was, to say the least, as stubborn as Einstein in his conservative attitude towards quantum mechanics; indeed, he not only rejected

the statitical interpretation but insisted that his wave mechanics meant a return to a classical way of thinking. He would not accept any objection to it, not even the most weighty one, which is that a wave in $3n$-dimensional space, such as needed to describe the n, is not a classical concept and cannot be visualized, in *The Born-Einstein Letters.*

[11] Max Born: De Broglie, the creator of wave mechanics, accepted the results of quantum mechanics just as Schrödinger did, but not the statistical interpretation, in *The Born-Einstein Letters.*

[12] Max Born: I cannot understand how you (Einstein) can combine an entirely mechanistic universe with the freedom of the ethical will, in *The Born-Einstein Letters.*

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[30] Albert Einstein: Usually W is put equal to the number of complexions. In order to calculate W, one needs a *complete* (molecular-mechanical) theory of the system under consideration. Therefore it is dubious whether the Boltzmann principle has any meaning without a *complete* molecular-mechanical theory or some other theory which describes the elementary processes (and such a theory is missing).

[31] Albert Einstein: I consider it quite possible that physics cannot be based on the field concept, i.e., on continuous structures. In that case, nothing remains of my entire castle in the air, gravitation theory included, and of the rest of physics, 1954.

[32] Albert Einstein: Since the theory of general relativity implies representations of physical reality by a continuous field, the concept of particles or material points cannot have a fundamental part, nor can the concept of motion.

[33] Albert Einstein: You believe in the God who plays dice, and I in complete law and order in a world which objectively exists, and which I, in a wild speculative way, am tryin to capture. I hope that someone will discover a more realistic way, or rather a more tangible basis than it has been my lot to find. Even the great initial success of Quantum Theory does not make me believe in the fundamental dice-game, although I am well aware that younger collegues interpret this as a consequence of senility. No doubt the day will come when we will see those instictive attitude was the correct one, to Born, 1944.

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