APPENDIX I I

. . . AND AT NO TIME WILL MY HANDS LEAVE MY BODY

(Einstein's Physics and Illusion)

My suspicion is that the universe is not only queerer than we suppose, it is queerer than we can suppose.

J.B.S. HALDANE from his book
Impossible Worlds

If you look closely, you will find that *reality in nature* does not generally present itself in superficially obvious ways. What *appears to be* rarely *is*.

As such, wishing to delve into the unknown in a sane, controlled way is *not* a sign of diminished reason. It is the sign of an intellectually curious, questioning human being. It is, in fact, at the heart of pure science.

The problem comes when we become inflexibly tied to our common-sense notions about the way the world works. Why? Because when ideas don't fit into our narrowly defined perspective, we feel threaten. Feeling threatened, we defend. And in defending, we become even more engulfed in our dogmatism, all the while claiming it is the other guy who is being unreasonable.

For those wishing to unleash the mind to explore new ideas and dimensions, there is a need to consider life and the nature-of-things in new ways. For thousands of years, for instance, mystics from both the east and the west have maintained that our physical and mental worlds are largely made up of illusion. Understanding and coming to grips with that possibility is extremely important for anyone interested in considering the exotic philosophic ideas that have become popular in the western world in the last hundred years.

Interestingly enough, the contention that our world is steeped in illusion has been unwittingly supported by, of all disciplines, modern science. Unfortunately, most people are unfamiliar with the more provocative areas of physics from which that support comes. In an effort to better understand, we are about to take a quick and easy excursion into those required realms, seasoned with a fair portion of lively, de-mustified (sic) history. So bon appetit, and as a magician friend of mine used to say, "Please note that at no time will my hands leave my body."

As far as the scientific community was concerned at the time, everything about the 1880's was pleasantly comfortable. With the exception of a few pesky loose ends, all observable phenomena in nature had been explained within the framework of physics. In fact, scientists were so sure of themselves that physics was considered nearly a dead subject. Some professors even went so far as to tell their most promising students to get out of physics and go into mathematics, "a field where there is still new and exotic ground to be covered."

Such was the scientific mood of the time. Then came the infamous Michelson-Morley experiment (gasp) and that nice, neat, comfortably complacent scientific world completely crumbled into controversy.

To understand why, we need to look at how scientists of the time viewed the phenomenon we call *light*.

Back in 1801, a gentleman by the name of Young did an experiment in which he showed that light, after passing through a pair of thin slits, behaved in a wave-like manner. Due to Young's experiment, the scientific community of the 1880's believed that light was a wave phenomenon.

There was a problem, though. A wave is really nothing more than a disturbance that moves through a medium. As an example, if you drop a pebble into a calm pool, the disturbance produced by the pebble entering the water moves outward in the form of a water wave. In this case, the wave's medium is the *water*--you can't have water waves without it.

Scientists of the time knew that space was a vacuum. And they knew that light traveled 93,000,000 miles to get from the sun to the earth.

But if light was a wave and space emptiness . . . ahhh, you begin to see the problem. There did not appear to be a medium that light waves could use as they passed through the void.

Fortunately, scientists in the 1880's had an ingenious solution to the problem. They assumed that there was an underlying stuff--a kind of fixed understructure--upon which space was built. This under structure was called "ether," and literally everyone believed that it existed. They really had no choice. Without ether, there would be no medium for light waves to travel through.

Enter the Michelson-Morley experiment.

The Michelson-Morley experiment was designed to prove the obvious, to show that ether did, indeed, exist.

I'm not going to explain the ins-and-outs of the entire experiment, but there is one important factor that I do need to mention. The experiment was centered on the idea that if ether did exist, the speed of light should vary depending upon how the light source was moving relative to the fixed ether. All the experiment had to do was to show this variability and, voila, the ether theory would be secure.

Remembering that everybody and his mother believed that ether existed, you can imagine the brouhaha that arose when Michelson and Morley's results showed just the opposite. According to their findings, the speed of light did not change no matter what the light source was doing. And that meant "no ether."

If you hate science, you would have loved watching all the commotion. The nasty little revelation hit unsuspecting physicists like a ton of bricks. Even Michelson and Morley were appalled. It meant that the accepted theories of light were badly flawed and, to add insult to injury, it meant that the theoretical underpinnings of Newtonian physics had been undermined, too (Newtonian physics is based upon the idea that there exists, somewhere, a fixed frame of reference; in the 1880's, ether was believed to be that fixed, *inertial* frame of reference). It was not until a man named Einstein published his thoughts on the subject that physicists began to sleep better at night.[1]

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[1] (Note from 2019) When I first started talking about this in the early 1980s, there was no Internet and certainly no Google search. That meant that fact-checking was considerably more difficult then than it is today. My undergraduate degree was in electrical engineering, and although my Masters degree was in physics, I never took a class in Special Relativity. The point is that my early understanding of why Einstein developed Special Relativity was flawed—I thought he did it in response to the Michelson Morley Experiment (hence the reference above). In fact, what actually motivated was in response to another

The Special Theory of Relativity was predicated on two very basic assumptions.

The first assumption was that the laws of physics work the same in all stationary or constant-velocity frames of reference. As an example, if you were sitting in an airplane on the ground and you decided you wanted tea, you would pick up your tea pot, position it over the cup, and pour. According to Einstein (Newton too, for that matter), if you decided to have a second cup while the plane was at 35,000 feet moving at 600 miles per hour, the *same* laws of physics would apply, just as before. You would not need to catch the liquid by positioning the cup some number of feet behind the pot, even though your frame of reference, the plane, was moving at 600 miles per hour. All you would need to do is to pour as usual and, if you were a poet at heart, "watch the freely falling liquid extend gracefully, following a typically parabolic arc from the pot to the cup."

Nothing could be more natural.

Einstein's second and considerably more exotic assumption was that "the measure of the speed of light will always be the same in all stationary and constant-velocity frames of reference." This assumption came as a direct consequence of the Michelson-Morley experiment (note from 2019—as I pointed out in the footnote above, this is an inaccurate statement . . . though the assumption was *supported* by the Michelson-Morley experiment), and although it looks innocuous enough, let me assure you that its presence within Einstein's theory produces some very peculiar conclusions.

Follow along and you will see what I mean.

For the moment, assume you are traveling in an automobile moving at *50 miles per hour* when you are overtaken by a second auto traveling *60 miles per hour*. How fast will the second car seem to be going, relative to you, as it passes you by? This is the same as asking, "Relative to your car--your *frame of reference*--how fast is the other car moving?"

Clearly, the other car will creep by you . . . and the answer to the question is *10 miles per hour*.

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problem in physics—the fact that Newtonian mechanics predicted that the speed of light had to be frame-of-reference dependent while Maxwell's equations (those that governed electricity and magnetism) predicted that it was *not* frame dependent. The Michelson-Morley finding, turns out, was just another nail in the Newtonian coffin.

Now, if you pass a third car moving *60 miles per hour* in the *opposite* direction, how fast will that car appear to be traveling, *relative to you?*

That car would pass you like a shot . . . and the answer to the question would be *110 miles per hour*.

So far, so good. Nothing dazzling, and in each case the apparent velocity of the other cars, relative to your frame of reference, has depended upon your motion and their motion. But what happens when we look at a comparable scenario involving light?

Imagine you are sitting in a stationary space ship out in space, just dying to do something exciting. Nothing much is happening, so you are just about to give up and go home when a beam of light passes by your ship.

Naturally your ship is equipped to the teeth, so for lack of anything better to do you extend your Tom Swift "velocity-measuring device" into the beam and measure the speed of the light as it passes your motionless ship. The device registers a speed of approximately 186,000 miles per second . . . the accepted speed of light.

Not being content with so ho-hum an exercise, you fire up the old warp-drive and accelerate your ship to a speed of 150,000 miles per second (I should probably mention how absurdly fast this is--our fastest military jets only go around three-quarters of a mile per second, and the space shuttle top end is only around seventeen miles per second when in space).

You are traveling in the same direction as the light beam. It catches up to you, you again extend your velocity-measuring device and the device measures the speed of the light, relative to your moving ship. What would you expect the device to register?

There does not seem to be a lot of difference between this situation and the situation we looked at earlier with the two cars driving in the same direction, so common sense would lead us to believe that the device would register a speed of 36,000 miles per second. But that is not what you would find in this situation. What you would find is that the device would measure the passing light at a speed of 186,000 miles per second . . . again, the accepted speed of light.

Do I hear someone in the back row beginning to hum the theme to the Twilight Zone? Are you beginning to mentally twitch? Don't worry, this *is* very peculiar.

Strange or not, though, physics has substantiated Einstein's assumption. Contrary to all common sense, the measured speed of light will always be 186,000 miles per second whether you are traveling into the light beam, away from the light beam, or just standing still. The speed of light is the same in all frames of reference.

Naturally, Einstein had a perfectly simple, straight-forward explanation for this apparently mysterious behavior of light, but to understand it we will have to spend more time looking back into history.

If you were seven or eight years old, you would probably be secure in the belief that Sir Isaac Newton's main claim to fame had something to do with being hit on the head by an apple. In fact, Newton was a brilliant scientist who lived in the late 1600's. He did extensive work in the field of optics; he literally invented calculus, almost as an afterthought of some of his scientific speculations; and he developed one of physics' first coherent, workable theories centered on the mechanics of the physical universe.

In that theory, Newton presented a mathematical coupling between the ideas of *distance traveled* and *velocity*, *velocity* and *acceleration*, and *acceleration* and *force*. In other words, he was the first in the western world to take the somewhat nebulous concepts of motion and use the language of mathematics to define and relate them.

Newton's physics was brilliant. It was so good that it is still used in "everyday life." Unfortunately, we now know that it completely falls apart when phenomena associated with the limits of the physical world are examined. That is, when we begin to delve into the world of the very small, like inside the atom; or when we look at the effects of very massive objects, like black holes in space; or when we are examining objects moving at very high speeds, speeds close to the speed of light; . . . in all of these cases, Newton's physics does not work.

Why?

Part of the problem lies in assumptions Newton made about time and space. Once again, the assumptions follow from observation and common sense. Unfortunately, science has since found that they are not true reflections of the way nature really is, and that kind of flaw inevitably leads to big-time problems somewhere down the line.

The first of Newton's assumptions had to do with time.

By *time*, we are talking about *a measure of the rate at which the moment passes*. As far as Newton was concerned, time was a universal--something that was constant and independent of all else. He saw it the way you and I would. We do not notice time running faster in the mountains than it does at the seashore. Neither did he. We all see it as a constant thing, the same *here* as *there*.

Newton's second assumption had to do with space. As far as he was concerned, space was nothing more than a homogeneous, three-dimensional void. Again, not a hard assumption to accept when you think about it. A void does seem to be the same in all directions (i.e., homogeneous), and space does seem to be associated with length, width, and height--three dimensions.

As far as everyday observations go, you and I and Newton would all have happily agreed: Newton's second assumption was a safe bet.

With this in mind, let us return to the question at hand: How can the speed of light be the same, no matter what?

Newton defined speed s as the distance d an object travels, divided by the time t required for it to do that traveling. Mathematically, this ratio can be characterized as $s=d/t$.

Looking back at our space ship example, the distance the beam of light had to travel to get through the trap of our velocity-measuring device was a fixed length--it did not vary within the apparatus. On the other hand, the time it took for the beam to get through the device should have depended upon whether the device was traveling into the beam or away from the beam. Summarizing, the *time* part of the speed ratio should have depended upon what the ship--your frame of reference--was doing relative to the beam, and the *spatial* part should have been a constant.

You can see that with the *distance part* fixed and the *time part* varying from situation to situation, there is no way the speed of light could possibly be the same for all possible frames of reference.

But it is! So now what?

One of the things that made Einstein great was his ability to think simply. He took this problem, as did hundreds of other scientists around the world, and he did what none of the rest seemed able to do. He set aside all of his preconceived notions about "the way things are," and just looked at the situation as it stood:

1.) Speed is nothing more than a ratio between two variables, a spatial measurement and a temporal measurement.

2.) The speed of light has been shown to be the same, no matter what.

3.) The only way both number 1 and number 2 can be simultaneous satisfied is if there exists a not-so-obvious relationship between spatial measurements and temporal measurements.

If the speed of light is a constant in all frames of reference, Einstein realized that we can no longer assume that space and time are independent of one another. Evidently, time is not the universal constant Newton thought it to be. Evidently, time depends upon *where* the moment passes.

And that, gentle readers, is where Einstein got the idea that real space is not a dull, three-dimensional, homogeneous void, but rather a FOUR DIMENSIONAL entity whose fourth dimension is (gulp) TIME ITSELF.

Put another way, Einstein's Theory of Relativity maintains that TIME IS QUITE LITERALLY A PART OF THE FABRIC OF SPACE. In physics, this *real space* is called *space-time* or *four-space.*

But it gets better. Einstein's theory predicts that four-space does not have to be the same everywhere. Indeed, there are areas in which it is generally homogeneous. This is called *flat space*--"flat" because there is no variation to its make-up from point to point. But there are also areas where there is considerable variation in the space-time structure. This is called *curved* or *warped space*.

(I know how mind bending it is trying to visualize curved space when we all associate space with a void, but you have to remember that we are talking about a physical model that is attempting to reflect what we know about our universe. As hard as it is to swallow, this obscure construct is the best representation we have been able to develop given what we know to be true.)

For those who are wondering, space does not just warp itself for the pleasure of it. According to Einstein, space warps in the presence of matter. Out where there are no planets or stars or other massive structures, space-time is relatively flat. But sidle up to a planet and, if you have the equipment required to measure such things, you will find that the space-time geometry around the planet varies from place to place. The closer you get to the planet's surface, the greater the warping becomes. Massive bodies curve the geometry of space-time.

Even more provocative, the more space-time is warped, *the more time slows down*. This has been observed experimentally by contemporary physicists. For instance, this slowing of time as one gets closer to the surface of the earth (i.e., as one move into more and more curved space) was experimentally observed at Harvard University. The Pound-Rebka experiment at Harvard used a gamma ray source, a Mossbauer detector and the Doppler effect to indirectly show that time on one floor of a Harvard building ran more slowly than time on an upper floor of that same building. The variation between the two readings was exactly the difference predicted using Einstein's theory, and the results have been experimentally verified by scientists all over the world.

The conclusion?

Time--the rate at which the moment passes--is not universal. No matter what common sense tells you, the moment does not pass at the same constant rate everywhere. Time really is a part of the geometry of space, and the more four-space is curved by the presence of matter, the more slowly the passage of the moment proceeds.

Let me re-emphasize, we are not looking at sleight of hand here. Do not expect the Amazing Randi to come hopping out of a hat, debunking this madness with a wave of his magic pinkies. Time will always pass "normally" for you, no matter where you are. But as observed by others outside of your frame of reference, your pulse, the cadence of your speech, even the rate at which the molecules of your body vibrate--the pace of all of these time-related occurrences will be affected by *where you are.* Time on a mountaintop is not the same as time at the seashore.

Does that mean that if you leave the mountains on your way to the beach, you will be liable to arrive at the ocean ahead of their time? Or does it mean that if you work on the first floor of an office building you will live longer than if you work on the tenth floor?

OF COURSE NOT! The time difference in the Harvard experiment was predictably minuscule. The earth is not massive enough to exhibit any really obvious deviations in time over its contour. Before you begin to experience big curvatures of space-time, you have to get close to a densely massive object like a *neutron star*, with a weight density of 7,000,000,000,000 pounds per cubic centimeter, or better yet, a *black hole*. That is where you find truly spectacular effects on the passage of the moment.

Take a black hole, for instance.[1]

The mass density of a black hole is so great and the resultant warping of four-space so radical that not even *light* can escape the "gravitational effects" of the hole. With that in mind, let us pretend that you had the opportunity of a lifetime. Let us say you were about to be sucked into a stationary black hole. How would your demise look, say, to a friend watching from a respectable distance?

To begin with, you have to remember that you, the suckee, are in a space-time geometry that is unbelievably warped in comparison to the space-time geometry of your friend. That means that your time, from her perspective, will proceed much more slowly than her own time. So what will she see?

As you get closer and closer to the hole, you will appear to physically slow down. If she could observe your watch, its hands would hardly be moving; if she could hear your heart, there would be great spans of silence between thumps. And as she continued to

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[1] Background: A ten-solar mass star (a solar mass is the mass of our star, the sun) will have a diameter of somewhere around 10,000,000 kilometers. Its core will be somewhere around 1.5 solar masses. I can't find an exact diameter for the core of a ten-solar mass start, but the core of the sun is 860,000 miles across (this is approximately 1,400,000 kilometers). The core of a 10-solar mass star will not be ten times that size, but it will be considerably larger. In any case, when the star begins to run out of fusionable nuclear fuel in its core, the core will begin to shrink forcing electrons in the core's atoms into what are called *degenerate energy states.*

When the degeneracies get large enough, the electrons will be pulled out of their orbitals and into the nucleus of their respective atoms where they will combine with protons to make neutrons. This produces a spectacular occurrence at the star's center. Normal atoms consist of tiny electrons in orbitals centered on the bigger but still tiny, proton-and-neutron-filled nucleus. Between the electrons and their nucleus is a vast expanse of nothing (in fact, the volume of an atom is approximately 125,000 times greater than the volume of the protons, neutrons and electrons that constitute the material component of the atom--put succinctly, atoms are almost entirely made up of space).

When electrons are pulled into the nucleus, all that space is lost. What that means for our star is that when the electrons are pulled into their respective nuclei, the core shrinks in seconds from a radius of "a whole lot bigger than the sun's core" (1,400,000 kilometers) to a radius of around *10-kilometers*. The implosion doesn't stop until all the space is removed (i.e., until the core is made up solely of jammed together neutrons). The super-dense core is called a *neutron star*.

The process liberates an enormous amounts of gravitational potential energy which super-heats the gasses around the core blowing that outer envelope of the star—the remaining 8.5-solar masses worth, completely off leaving nothing but the *10-kilometer* neutron star.

This kind of star-death is called a *supernova.*

If the mass of the star's core is greater than 1.8 solar masses, the implosion never stops and we end up with what is called a *black hole*, a structure that is so gravitationally dense that not even light can escape it if it gets too close to it (maybe 3 kilometers).

watch, there would finally come a time when your motion from her vantage point would appear to come to a dead stop.

On the other hand, from your point of view, things would be quite different. Everything would proceed just as you would expect during such an event. The gravitational effect of the hole would be irresistibly strong, and if you were going in feet first it would not take more than a few seconds before the gravitational force at your feet was so much greater than at your head that you would just noodle out into a disassociated aggregate of individual atoms.

BUT, if you could look out into the universe during those last fleeting seconds, you would witness amazing things. You would see the evolution of our universe passing before your eyes at incredible speed. You would witness the birth, life, and death of whole galaxies, and it all would happen in the time it takes to wink.

In short, the incredibly massive character of the black hole would so warp the geometry of space-time around you that, as seen from *out there*, your time would slow almost to a standstill. But *you* would feel normal because you would be a part of that geometry, and what you would see occur *out there* in a few of your seconds would take incredible amounts of *out there* time to actually happen.

Hard to believe?

True.

Amazing?

You bet.

Where are we going?

The space around us is something we deal with every day. Without its void-like nature, something as unremarkable as a water-glass would be quite impossible--without the space within, the glass could hold nothing.

But while apparently empty space is an integral part of our everyday experience, we have found that our perception of space is so far off the mark that it is laughable. It is not the uncomplicated void we think it to be . . . it is something else. And in my country, a situation like that is called *an illusion*.

Bottom line: Reality is not necessarily a straightforward proposition. Everyone surely has beliefs about what it means to be human; about what is-and-is-not possible within the scheme of things; about the nature of reality. Each individual's perceptions may be right on the mark. Then again, they may not be. But in any case, most people so strongly *accept* their beliefs that they never, ever honestly question their validity.

Our foray into the world of physics was aimed at showing how off-target we can be and how unexpectedly deceptive the nature of the physical world really is. That, and to inflame curiosity about the possibility that there might be other aspects of our everyday lives and beliefs that are similarly shrouded in illusion.