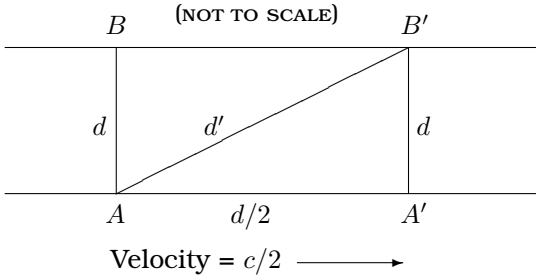
Frames of Reference

Darrin Yeager

2004

About AD 1900 scientists believed everything had been figured out; little remained to discover. Sure, some details required further study, but for the most part we understood the world around us. Then along comes this Einstein guy and messes up the whole thing! Einstein is famous for two things — Relativity and Quantum Physics — plunging scientists into a world of doubt and uncertainty. Let's look at *one* of these two (Relativity) and see why it troubles people so. The other (Quantum Physics) is extremely interesting in its own right, but is a subject for another time (no pun intended).

First, consider the following diagram, and remember, *there will only be one line of Physics in the following discussion*, so if you are of the type thinking "I can't understand Physics stuff," hang on.



You and a friend ride motorcycles, represented by A and B. You travel from point A to point A' at $1/2$ the speed of light, or $c/2$. At point A you shine a flashlight toward your friend, at point B (notice the picture is not to scale).

From your point of view, *neither of you is moving since your speed matches*. This is familiar to anyone who has ridden in a car. If someone pulls up alongside you as you travel down the road, if they match your speed it appears to both of you as if you sit motionless in a parking lot. In either case, both you and your friend see the light travel along the path noted by d. For you both, *your forward motion is irrelevant to your perception of the event as you both exist in the same reference frame.*

Now consider someone standing along side the road, watching you go by. Since you and your friend move, they see you travel from A to A'. What path would the light take to them? Looking at the picture above, the answer is d'. This should also be familiar to anyone who has ridden in a car. Imagine throwing a ball out the window of a moving car. Since the car is moving, as you throw the ball, it still travels forward as it falls, doesn't it?

Before we continue, be sure you understand the diagram and the previous two paragraphs. Neither assume any understanding of Relativity or Physics, just recalling your experiences, however, they are critical to understand before continuing.

OK, now the fun begins! Once again, we must recall some of our experiences. Suppose you travel in a car at 60mph for 1/2 hour. How far have you traveled? How do you know? The answer is the following equation: $d = v*t$ (distance equals speed multiplied by time). Thus 60mph * 1/2 hour = 30 miles. But you already knew this (see, you know much more about Physics than you thought).

Lets apply the previous equation to our paths d and d' above. We thus have $d = v * t$ and $d' = v' * t'$. Fair enough? (Remember, d, v, t are for you and your friend riding the motorcycles, and d', v', t' are for your friend watching you go by). Notice by looking at the picture, that $d' > d$. In the interest of completeness, I shall now prove $d' > d$.

Using some geometric properties of a right triangle (the famous Pythagorean theorem where $a^2 + b^2 = c^2$) yields the following:

$$(d')^2 = \left(\frac{d}{2}\right)^2 + d^2$$

Lets perform the squares to get:

$$(d')^2 = \frac{5d^2}{4}$$

Taking the square root of both sides yields:

$$d' = \frac{\sqrt{5}d}{2}$$

The square root of 5 is about 2.2. Thus $d' > d$, which is what I asked you to believe. We don't really care about the *exact* ratio (it will vary depending on the velocity of the motorcycles), all we are interested in is for the moving motorcycles, $d' > d$.

Consider all we know:

$$d = v * t \tag{1}$$

$$d' = v' * t' \tag{2}$$

$$d' > d \tag{3}$$

Combining inequality 3 with equations 1 and 2 yields the following inequality:

$$v' * t' > v * t \tag{4}$$

OK, I promised only one line of real Physics, and here it is:

> *Every observer measures the same value c for the speed of light*[*]

This was Einstein's proposal. Simply put, it means everyone measures the speed of light as equal. What does that mean for our little example? That $v' = v = c$. Thus, inequality 4 becomes:

$$c * t' > c * t$$

Which simplifies to the following shocking result:

$$t' > t \tag{5}$$

Remember what t represents, *time*. This means for our observer watching us go by, their time appears *longer*. Does this mean for our friends on motorcycles they experience a "slowdown" of time? It does not. If two atomic clocks are placed one on a motorcycle and the other with the person standing along the road, synchronized, and allow the motorcycles to ride by, when they come back we notice the clocks are no longer synchronized! *It is the very nature of time itself that has changed, not the accuracy of the clocks.*

Time is not an absolute property — it varies.

> *But, beloved, be not ignorant of this one thing, that one day is with the Lord as a thousand years, and a thousand years as one day.* 2 Peter 3:8

.

Relativity is a recent discovery (1900's), so how would Peter have known about it thousands of years ago? Only by inspiration of the Holy Spirit. Yet another reason to take your Bible seriously.

[*] Tipler, *Physics, Third Edition Volume 2*, page 1107