Chapter 10, The Wedding of space and Time

Learning Notes, Physics for Poets

There are two ways to resolve a disagreement. One is to learn to *live with it*, as long as all parties thoroughly understand and tolerate each other's point of view. The other is to *find a common ground* on which all parties can agree. The theory of relativity offers both of these ways to resolve the disputes between observers implied by Einstein's postulate.

The *"live with it"* approach was outlined in Einstein's first paper on special relativity, submitted to the journal *Annalen der Physik* in June 1905. It allows any observer to translate the picture of reality in any reference frame to that in any other; we do this by using the famous Lorentz Transformations. The *"common ground"* approach allows us to convert our measurements to a four dimensional space-time representation where we can all agree.

1 Special Relativity, What We See

From our previous chapter on special relativity we found that our observations give us a picture of reality which might differ from that of other observers, mainly:

1. Moving clocks appear to run slow: i.e. time slows down for a moving object as seen from the ground.

2. Moving objects appear shortened along their line of motion. Objects contract along their line of motion as seen from the ground.

3. Events that are simultaneous in one reference frame may not be in another: what we consider simultaneous is really only an illusion; we are not taking into account the time it takes for light to reach our eyes. In fact two events that appear simultaneous in a moving frame will appear to happen at different times (non-simultaneous) as seen from the ground.

Einstein has, in effect, relocated the boundary between what is out there in nature and what is constructed in our minds. Our observations are true only by convention, in an arbitrarily chosen reference frame. Useful as reference frames may be, nature doesn't hand them to us; we make them up for ourselves.

2 Space-Time: The Fourth Dimension

When we convert our measurements to space-time coordinates, we are accounting for the distance lights travels and how it affects our individual measurements in different reference frames. As we move to space time coordinates and compensate for relativistic effects, our measurements are in agreement with each other.

General relativity tells us that time can be appended to the Pythagorean theorem, but in a peculiar way that reminds us that we are not dealing simply with another dimension of space. Instead adding its square to the squares of the space dimensions we must subtract it! If we do this, we get a quantity that remains the same in all reference frames; *an invariant*

$$s^2 = x^2 + y^2 + z^2 - (ct)^2$$

When we move to 4 dimensional space-time all observers can agree on the space-time distance between two observations.

But 4 dimensional space time can not be easily visualized because it is a convenient mathematical representation to account for relativistic effects.

3 Our View of Reality

The eye can look upon objects a few inches away or gaze upon a grand vista covering tens or at most hundreds of miles. But we can scarcely imagine the time it takes light to cover such distances.

Our customary view of reality is like a motion picture - a series of still frames showing events in different places at successive instants in time. The problem is that two different movies are constructed in two different reference frames. Both contain all the same events, but those that are in the same still picture in one reference frame may be in different pictures in another.

Remember the difference in "realities" that comes about from two observers, one moving at a speed close to the speed of light and the other at rest (remember every observer could claim it is the other one that is moving): The observer at rest claims that the moving observer's clock slowed down, while the moving observer claims the rest observer's clock sped up, either observer knows what they saw and both realities are simply made up by our brains.

While we can not deny what the other person saw in the watches, the observers are free to conclude that it was the train (or terrain or fabric) that contracted; by using Lorentz conversions both observers can live with their realities of what they saw but gracefully disagree on those things they did not see.

Summary

Relativity offers two remedies for conflicting pictures in different reference frames. One is to provide rules to translate from one frame to another, the other constructs a new mode of representation on which all can agree.