**Chapter 01: Relativity**

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## 1.1 Special Relativity

### Inertial Frame of Reference

Law of Inertia:

1. There is no universal frame of reference (laws of physics are the same)

2. Speed of light is constant in all inertial frames of reference (in free space)

Inertial frame of reference: One which follows Newton’s 1st law accurately (non-accelerating frame).

All measurements are relative and there is no preferable frame of reference. E.g. the length of a plane as measured by someone on the ground will be different from that measured by someone on the plane.

No motion is absolute. It is all relative.

However, the speed of light will not change in any inertial (non-accelerated) frames of reference. People on different frames of reference will still measure the speed of light to be the same.

### 1st Postulate of the Special Theory of Relativity

The principle of relativity: All inertial frames of reference are the same. The laws of physics are the same in all of them.

### 2nd Postulate of the Special Theory of Relativity

The speed of light in vacuum is constant. This postulate is true due to the effects of time dilation and length contraction. Measuring time and length from a different frame of reference will make time appear to be longer and length shorter in such a way so as to keep the speed of light constant.

### Michaelson Morley’s Experiment

This experiment attempted to measure the movement of the Earth through the ether, a hypothetical medium that was thought to carry light waves through space. Two beams of light, one parallel to the ‘ether current’ and another perpendicular to it were directed to mirrors. Both ended up at the same viewing screen at the same time. If an ether current did exist, this would not be true as it would carry the beam parallel to it further. This proved that an ether did not exist, that no motion was absolute, and that the speed of light was the same for all observers, regardless of the frame of reference, meaning light did not need a medium to propagate.

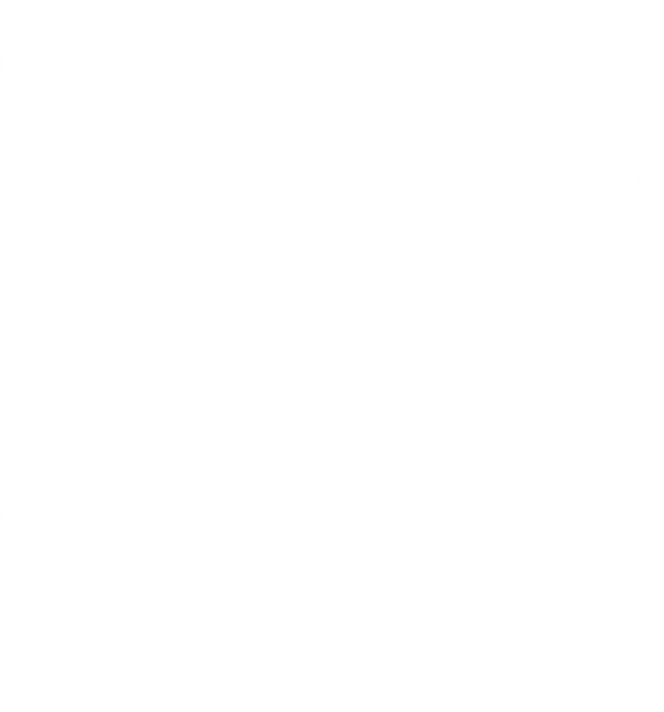
## 1.2 Time Dilation

Time Dilation – Time is lengthened in the moving frame (clock ticks slower) in comparison to proper time.

Proper time is time as measured by someone in the same frame of reference as the event. For frame and frame, proper time,

However, from the laboratory, the event in the frame is viewed like this:

- time dilation



The speed of light in vacuum is the maximum speed that can be obtained by any object. This is proven by a simple argument. If a spacecraft is travelling faster than the speed of light and a flashlight is switched on, the light from the flashlight will appear to move backwards instead of forwards, which would make it seem as though the laws of physics on the spacecraft were different, which cannot be true.

This argument only stands for the speed of light in vacuum. In other media, objects can have speeds greater than the speed of light.

### Reflective Index

- speed of light in vacuum

Speed of conducting electron in this medium can be higher than the speed of light in the medium.

This will cause to radiate a cone of light bough wave called Cerenkov waves.

## 1.3 Doppler Effect

- doppler effect for sound

For sound, the doppler effect varies depending on whether the source, observer, or both are moving. This would appear to violate the principle of relativity, but sound only occurs in a medium which is in itself a frame of reference, so there is no contradiction.

For light however, the doppler effect is different since light is present in vacuum. It makes no difference which body is moving, the effect is the same.

The light emitted by distant stars (called spectral lines) always show a red-shift (frequency observed is lower than source frequency), meaning the stars are moving away. Edward Hubble proved that the speed at which the stars are moving is proportional to their distance, proving that the universe is expanding.

## 1.4 Length Contraction

Length of an object as measured by an observer in a different frame of reference always appears to be shorter than the proper length. This contraction occurs in the direction of the relative motion.

## 1.6 Electricity and Magnetism

Like light, electric charge is also unaffected by relative motion. When the charges move, the spacing between the decreases by a factor of . When two current carrying conductors are placed next to each other, this effect occurs but since the speed of positive and negative charges are the same, their spacing changed by the same amount, meaning the conductors still appear neutral to an observer.

From the frame of reference of one of the charges in one conductor, the equivalent charges in the other conductor are at rest (since they move in the same direction), while the opposite charges are moving at twice the speed. The spacing between the opposite charges appear to change twice the amount, while that between the similar charges do not change at all. The other conductor thus appears to have a net opposite charge. The same thing happens from the other frame of reference as well. So, both conductors appear to be charged to the other, and they attract each other.

For the circuit to be complete however, there must be a conductor carrying charge in the opposite direction as well, meaning the circuit as a whole is definitely neutral.

Mass is also relative. As electrons move at nearly the speed of light, mass varies according to the equation:

where is the speed of the electron and

is the speed of light

============================= SKIPPING 1.7 – 1.10 =============================

## Appendix 1: Lorentz Transformation

### Galilean Transformation

In Galilean transformation it is assumed that,

If only moving in the direction

However, this means , which cannot be true.

1st Postulate of Special Relativity violated since equations of electricity and magnetism become different (laws of physics cannot change).

2nd Postulate violated if speed of light is measured (it cannot change) This proves that Galilean transformation cannot be used.

### Lorentz Transformation Equations

No change in or if not moving in those directions.

Derivation

Length Contraction Derivation:

Inverse Lorentz Transformation:

Time Dilation Derivation:

Velocity Addition:

Velocity equations can be derived from the above equations.

============================= Skipping Appendix 2 =============================