**U3a Physics: Cosmology/Astrophysics**

**Special Relativity**

Einstein’s theories of relativity have had a n enormous impact on astronomy and cosmology. He published his Special Theory of Relativity in 1905 and the theory showed that the ideas of absolute space and time, at the foundation of Newtonian physics, were mistaken. It also said that mass and energy can be converted from one to the other. (E=mc2).

Einstein wanted to resolve a problem about light (and other forms of electromagnetic radiation). In 1865, James Clerk Maxwell had shown that these radiations are wave-like disturbances in an electromagnetic field, and that they always travel at the same speed in a vacuum.

We are familiar with measuring speed relative to a particular frame of reference, When we drive a car, for example, the speed at which we are travelling is relative to our surroundings (the road, nearby buildings and so on). Waves like water waves and sound waves need a medium through which to travel, so scientists at the time proposed that electromagnetic radiation travelled through a medium called the ether, undetectable but pervading the whole of space). The speed at which the waves travelled would be relative to this ether, regarded as being stationary.

As the Earth moves in its orbit, it must travel through the ether, so the speed of light should be different when measured along the direction of the earth’s movement through the ether and when measured at right angles to this direction. Michelson and Morley decided to try and measure this difference but were unable to do so. Their experiment brought into doubt the whole idea of the ether.

**Inertial Frame**: Newton’s first law of motion says that any body continues in its state of uniform motion unless acted on by an external force. Consider a spaceship in interstellar space, far from any gravitational influences. This would provide a frame of reference inside which objects would obey Newton’s first law. A frame of reference in which this law is obeyed is called an *inertial frame*. This inertial frame cannot have acceleration but can have velocity.

The idea of an inertial frame and Maxwell’s discovery that all types of em radiation travel at the same speed through space were the key factors underlying the Special Theory of Relativity.

1st postulate of special relativity: All laws of physics apply equally in all inertial frames

2nd postulate of special relativity: The speed of em radiation was treated by Einstein as a fundamental law of physics, which must, therefore, apply in all inertial frames of reference. The 2nd postulate is that, from whatever inertial frame the speed of light is measured, it will always be the same.

These postulates led to the surprising conclusion that, since speed = distance ÷ time, and the speed of light is the same when measured by observers moving relative to one another, then the measurements of time and distance made by these observers must be different.

**Time Dilation**: Two observers moving relative to one another will each think that the other’s clock is running slow. Einstein used a thought experiment to convince himself of this.

**Length contraction**: The length of an object as measured by an observer relative to whom the object is moving is smaller than its length as measured by someone in the same inertial frame as the object. (another thought experiment)

**Mass**: The special theory also predicts that the observed mass of an object should increase as its velocity relative to an observer increases. This effect is negligible at everyday speeds but becomes significant at speeds close to the speed of light.

The mass of a body tends towards infinity as its velocity approaches the speed of light. Therefore it is impossible for the velocity of the body to reach the speed of light.

These notes are very brief and I have not, for example, included details of Einstein’s thought experiments. You can find more information in “Cosmology” by Bryan Milner, published by Cambridge University Press.

There are several websites dealing with the topic here are two. The BBC link is short and contains a bit of maths.

[**https://kids.britannica.com/students/article/relativity/276687#:~:text=Einstein%20came%20up%20with%20his,speed%20limit%E2%80%9D%20of%20the%20universe**](https://kids.britannica.com/students/article/relativity/276687#:~:text=Einstein%20came%20up%20with%20his,speed%20limit%E2%80%9D%20of%20the%20universe)**.**

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