15.30: The Speed of Light

The speed of light is, by definition, exactly 2.997 924 58 x 10^8 ms^{-1}, and is the same relative to all observers.

This seemingly simple sentence invites several comments.

First: Note that I have used the word “speed”. Some writers use the word “velocity” as if it were merely a more impressive and scientific-sounding synonym for “speed”. I trust that all readers of these notes know the difference and will use the word “speed” when they mean “speed”, and the word “velocity” when they mean “velocity – surely not an unreasonable demand. To say that the “velocity” of light is the same for all observers means that the direction of travel of light is the same relative to all observers. This is doubtless not at all what a writer who uses the word “velocity” intends to convey – but it is the literal (and of course quite erroneous) meaning of the assertion.

Second: How can we possibly *define* the speed of light to have a certain *exact* value? Surely the speed of light is what we find it to be, and we are not free to *define* its value. But in fact we *are* allowed to do this, and the explanation, briefly, is as follows.

Over the course of history, the *metre* has been defined in several different ways. At one time it was a specified fraction of the circumference of Earth. Later, it was the distance between two scratches on a bar of platinum-iridium alloy held in Paris. Later still it was a specified number of wavelengths of a particular line in the spectrum of mercury, or cadmium, or argon or krypton. In our present state of technology it is far easier to measure and reproduce precise standards of *frequency* than it is to measure and reproduce standards of length. Because of that, the current SI (Système International) unit of time is the SI second, which is based on the frequency of a particular transition in the spectrum of caesium, and from there, the metre is *defined* as the distance travelled by light in vacuo in a defined fraction of an SI second, the speed of light being assigned the exact value quoted above.

Detailed discussion of the exact definitions of the units of time, distance and speed is part of the subject of *metrology*. That is an important and interesting subject, but it is only marginally relevant to the topic of relativity, and consequently, having quoted the exact value of the speed of light, we leave further discussion of metrology here.

Third: How can the speed of light be the same relative to *all observers*? This assertion is absolutely central to the theory of special relativity, and it may be regarded as its fundamental and most important principle. We shall discuss it further in the remainder of the chapter.