Why is *c* the symbol for the speed of light?

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Abstract: It has been said that the letter c is used for the speed of light because it stands for the Latin word celeritas. A more careful examination of the historical literature suggests that the real reason is more complex.

"As for *c*, that is the speed of light in vacuum, and if you ask why *c*, the answer is that it is the initial letter of *celeritas*, the Latin word meaning speed." - Isaac Asimov in "C for *Celeritas* (1959)" [1]

A Short Answer

Although *c* is now the universal symbol for the speed of light, the most commonly used symbol in the nineteenth century was an upper-case *V* which Maxwell had introduced in 1865. That was the notation adopted by Einstein for his first few papers on relativity from 1905. The origins of the letter *c* being used for the speed of light can be traced back to a paper of 1856 by Weber and Kohlrausch [2]. They defined and measured a quantity denoted by *c* that they used in an electrodynamics force law equation. It became known as Weber's constant and was later shown to have a theoretical value equal to the speed of light times the square root of two. In 1894 Paul Drude modified the usage of Weber's constant so that the letter *c* became the symbol for the speed of electrodynamic waves [3]. In optics Drude continued to follow Maxwell in using an upper-case *V* for the speed of light. Progressively the *c* notation was used for the speed of light in all contexts as it was picked up by Max Planck, Hendrik Lorentz and other influential physicists. By 1907 when Einstein switched from *V* to *c* in his papers, it had become the standard symbol for the speed of light in vacuum for electrodynamics, optics, thermodynamics and relativity.

Weber apparently meant *c* to stand for "constant" in his force law, but there is evidence that physicists such as Lorentz and Einstein were accustomed to a common convention that *c* could be used as a variable for velocity. This usage can be traced back to the classic Latin texts in which *c* stood for "celeritas" meaning "speed". The uncommon English word "celerity" is still used when referring to the speed of wave propagation in fluids. The same Latin root is found in more familiar words such as acceleration and even celebrity, a word used when fame comes quickly.

Although the *c* symbol was adapted from Weber's constant, it was probably thought appropriate for it to represent the velocity of light later on because of this Latin interpretation.

There is one further thread in the development of this usage. The letter *c* was used for the speed constant in the wave equation since the much earlier work of Euler. This was transferred to the symbol for the speed of sound in the 19th century independently of the origins of its use for the speed of light. It is not clear why Euler chosen this letter but it appeared in work written in French rather than Latin, so it may have been little more than a random choice of letter for a variable. This could have also influenced Drude when he used *c* for the speed of electromagnetic waves.

So history provides an ambiguous answer to the question "Why is *c* the symbol for the speed of light?", and it is reasonable to think of *c* as standing for either "constant" or "celeritas" or simply a variable introduced into the wave equation by Euler.

The Long Answer

In 1992 Scott Chase wrote on sci.physics that "anyone who read hundreds of books by Isaac Asimov knows that the Latin word for `speed' is `celeritas', hence the symbol `c' for the speed of light". Asimov had written an article entitled "C for Celeritas" in a sci-fi magazine in 1959 and had reprinted it in some of his later books [1]. Scott was the first editor of the Physics FAQ on Usenet and Asimov's explanation was later included in the relativity section as the "probable" answer to the question "Why is *c* the symbol for the speed of light?". Since then, Asimov's answer has become a factoid repeated in many articles and books. But if you go back and read his essay you find that Asimov merely stated his case in one sentence, and made no further attempt to justify his theory for the origin of the "c" notation. So is his claim really born out by history, or was *c* originally introduced as a variable standing for something else? The special theory of relativity is based on the principle that the speed of light is constant; so did *c* stand for "constant", or did it simply appear by accident in some text where all the other likely variables for speed had already been used up? These questions have been asked repeatedly on usenet, and now after much searching through old papers and books the answers can be revealed.

A lower-case *c* has been consistently used to denote the speed of light in textbooks on relativity almost without exception since such books started to be written. For example, the notation was used in the earliest books on relativity by Lorentz (1909) [4], Carmichael (1913) [5], Silberstein (1914) [6], Cunningham (1915) [7], and Tolman (1917) [8]. That was not the case just a few years before. In his earliest papers on relativity from 1905 to 1907, Einstein began by using an upper-case V for the speed of light [9]. At that time he was also writing papers about the thermodynamics of radiation, and in those he used up upper-case L [10]. All of these papers appeared in volumes of the German periodical *Annalen Der Physik*. Einstein's notation changed suddenly in 1907 in a paper for the Journal *Jahrbuch der Radioaktivität und Elektronik* [11]. There he used the lower case c, and his most famous equation $E = mc^2$ came into being in its modern form.

It is not difficult to find where Einstein's upper case V had come from. Maxwell used it extensively in his publications on electrodynamics from as early as 1865 [12]. It was the principal symbol for the speed of light in his 1873 treatise on electrodynamics [13]. By the 1890s Maxwell's book was in wide circulation around the world and there were translations available in French and German. It is no surprise then that the upper-case V is found in use in such papers as the 1887 report of Michelson and Morley on their attempt to find seasonal variations in the speed of light [14]. That was written in the United States, but the same notation was also found across Europe, from papers by Oliver Lodge [15] and Joseph Lamor [16] in England, to the lecture notes of Poincaré in France [17], and the textbooks of Paul Drude in Germany [18] and Lorentz in the Netherlands [19]. Einstein's education at the Polytechnik in Zurich had not covered Maxwell's theory of Electrodynamics in the detail he would have liked. But he had read a number of extra textbooks on the new Electrodynamics as self-study, so he would have been familiar with the standard notations. From 1905 he wrote his first papers on relativity, and there is nothing extraordinary in his choice of the symbol V for the speed of light [9].

Why then, did he change it to c in 1907? At that time he still worked as a clerk in the Bern patent office, but for the previous two years he had been in regular correspondence with eminent physicists such as Max Laue, Max Planck, Wilhelm Wien and Johannes Stark. Stark was the editor of the *Jahrbuch*, and had asked Einstein to write the article in which he was to first use the letter c. Einstein mentioned to Stark that it was hard for him to find the time to read published scientific articles in order to acquaint himself with all the work others have done in the field, but he *had* seen papers by Lorentz, Kohn, Monsegeil and Planck [20]. Lorentz and Planck in particular had been using c for the speed of light in their work. Lorentz had won the 1902 Nobel prize for physics, and it is not surprising that physicists in Germany had now taken up the same notation. It is also not surprising that Einstein, who was looking for an academic position, aligned himself to the same conventions at that time. Another reason for him to make the switch was that the letter c is simply more practical. The upper-case V would have been easily confused with the lower case v appearing in the equations of relativity for the velocity of moving bodies or frames of reference. Einstein must have found this confusion inconvenient, especially in his hand written notes.

Looking back at papers of the late 1890s, we find that Max Planck and Paul Drude in particular were using the symbol *c* at that time. The name of Drude is less well known to us today. He worked on relations between the physical constants and high precision measurements of their value. These were considered to be highly worthy pursuits of the time. Drude had been a student of Voigt, who himself had used a Greek ω for the speed of light when he wrote down an almost complete form of the Lorentz transformations in 1887 [43]. Voigt's ω was later used by a few other physicists [44, 45], but Drude did not use his teacher's notation. Drude first used the symbol *c* in 1894, and in doing so he referenced a paper by Kirchhoff [3]. As already mentioned, Paul Drude also used *V*. In fact he made a distinction of using *V* in the theory of optics for the directly-measured speed of light in vacuum, whereas he used *c* for the electromagnetic constant that was the theoretical speed of electromagnetic waves. This is seen especially clearly in his book "Theory of Optics" of 1900 [21], which is divided into two parts with *V* used in the first and *c* in the second part. Although Maxwell's theory of light predicted that they had the same value, it was only with the theory of relativity that these two things were established as fundamentally the same constant. Other notations vied against Drude's and Maxwell's for acceptance. Herglotz [46] opted for an elaborate script *B*, while Himstedt [47], Helmholtz [48] and Hertz [49] wrote the equations of electrodynamics with the letter *A* for the reciprocal of the speed of light. In 1899 Planck backed Drude by using *c*, when he wrote a paper introducing what we now call the Planck scale of units based on the constants of electrodynamics, quantum theory and gravity [22]. Drude and Planck were both editors of the prestigious journal *Annalen Der Physik*, so they would have had regular contact with most of the physicists of central Europe.

Lorentz was next to change notation. When he started writing about light speed in 1887 he used an upper case *A* [23], but then switched to Maxwell's upper case *V* [24]. He wrote a book in 1895 [25] that contained the equations for length contraction, and which was cited by Einstein in his 1907 paper. While Drude had started to use *c*, Lorentz was still using *V* in this book. He continued to use *V* until 1899 [26], but by 1903 when he wrote an encyclopedia article on electrodynamics [27] he too used *c*. Max Abraham was another early user of the symbol *c* in 1902, in a paper that was seen by Einstein [28]. From Drude's original influence, followed by Planck and Lorentz, by 1907 the *c* symbol had become the prevailing notation in Germanic science and it made perfect sense for Einstein to adopt it too.

In France and England the electromagnetic constant was symbolised by a lower case *v* rather than Drude's *c*. This was directly due to Maxwell, who wrote up a table of experimental results for direct measurements of the speed of light on the one hand and electromagnetic experiments on the other. He used *V* for the former and *v* for the latter. Maxwell described a whole suite of possible experiments in electromagnetism to determine v. Those that had not already been done were performed one after the other in England and France over the three decades that followed [29]. In this context, lower case v was always used for the quantity measured. But using v was doomed to pass away once authors had to write relativistic equations involving moving bodies, because v was just too common a symbol for velocity. The equations were much clearer when something more distinct was used for the velocity of light to differentiate it from the velocity of moving bodies.

While Maxwell always used v in this way, he also had a minor use for the symbol c in his widely read treatise of 1873. Near the end he included a section about the German electromagnetic theory that had been an incomplete precursor to his own formulation [30]. This theory, expounded by Gauss, Neumann, Weber, and Kirchhoff, attempted to combine the laws of Coulomb and Ampère into a single action-at-a-distance force law. The first versions appeared in Gauss's notes in 1835 [31], and the complete form was published by Weber in 1846 [32]. Many physicists of the time were heavily involved in the process of defining the units of electricity. Coulomb's law of electrostatic force could be used to give one definition of the unit of charge while Ampère 's force law for currents in wires gave another. The ratio between these units had the dimension of a velocity, so it became of great practical importance to measure its value. In 1856 Weber and Kohlrausch published the first accurate measurement [2]. To give a theoretical backing they rewrote Weber's force law in terms of the measured constant and used the symbol c. This c appeared in numerous subsequent papers by German physicists such as Kirchhoff, Clausius, Himstedt, and Helmholtz, who referred to it as "Weber's constant". That continued until the 1870s, when Helmholtz discredited Weber's force law on the grounds of energy conservation, and Maxwell's more complete theory of propagating waves prevailed.

Two papers using Weber's force law are of particular note. One by Kirchhoff [33] and another by Riemann [34] related Weber's constant to the velocity at which electricity propagated. They found this speed to be Weber's constant divided by the square root of two and it was very close to the measured speed of light. It was already known from experiments by Faraday that light was affected by magnetic fields, so there was already much speculation that light could be an electrodynamic phenomenon. This was the inspiration for Maxwell's work on electrodynamics, so it is natural that he finally included a discussion of the force law in his treatise [30]. The odd thing is that when Maxwell wrote down the force law, he changed the variable c so that it was smaller than Weber's constant by a factor of the square root of two. Maxwell was probably the first to use c for a value equal to the speed of light, although he defined it as the speed of electricity through wires instead.

So c was used as Weber's constant having a value of the speed of light times the square root of 2, and this can be related to the later use of c for the speed of light itself. Firstly, when Maxwell wrote Weber's force law in his treatise in 1873, he modified the scale of *c* in the equation so that it reduced by a factor of the square root of two. Secondly, when Drude first used *c* in 1894 for the speed of light [3], the paper by Kirchhoff that he cited [35] was using *c* for Weber's constant, so Drude had made the same adjustment as Maxwell. It is impossible to say if Drude copied the notation from Maxwell, but he did go one step further in explicitly naming his *c* as the velocity of electrodynamic waves which by Maxwell's theory was also the speed of light. He seems to have been the first to do so, with Lorentz, Planck, and others following suit a few years later.

To understand why *c* became the symbol for the speed of light we now have to find out why Weber used it in his force law. In the paper of 1856 [2] Weber's constant was introduced with these words "and the constant *c* represents that relative speed, that the electrical masses e and e must have and keep, if they are not to affect each other." So it appears that *c* originated as a letter standing for "constant" rather than "celeritas". Nevertheless, it had nothing to do with the constancy of the speed of light until much later. German speakers may find it odd that Weber and Kohlrausch introduced the letter c to stand for “constant” when the usual German translation is “konstant” with an initial k. A check of the original paper shows that the authors did indeed use the spelling “constant” in German.

Despite this, there could still be some substance to Asimov's claim that *c* is the initial letter of "celeritas". It is true, after all, that *c* is also often used for the speed of sound, and it is commonly used as the velocity constant in the wave equation. Furthermore, this usage was around before relativity.

Starting with the Latin manuscripts of the 17th century, such as Galileo's "De Motu Antiquiora" or Newton's "Principia", we find that they often use the word "celeritas" for speed. But their writing style was very geometric and descriptive, and so they did not tend to write down formulae where speed is given a symbol. An example of the letter *c* being used for speed can be found from the eighteenth century. In 1716 Jacob Hermann published a Latin text called Phoronomia, meaning the science of motion [36]. In it he developed Newton's mechanics in a form more familiar to us now, except for the Latin symbols. His version of the basic Newtonian equation $F = ma$ was $\mathrm{d}c = p\ \mathrm{d}t$, where *c* stands for "celeritas" meaning speed, and *p* stands for "potentia", meaning force.

Apart from in relativity, the most pervasive use of *c* to represent a speed today is in the wave equation. In 1747 Jean d'Alembert made a mathematical study of the vibrating string and discovered the one dimensional wave equation, but he wrote it without the velocity constant. Euler generalised d'Alembert's equation to include the velocity, denoting it by the letter *a* [38]. The general solution is $y = \mathrm{f}(x - at) + \mathrm{f}(x + at)$, representing two waves of fixed shape travelling in opposite directions with velocity *a*.

Euler was one of the most prolific mathematicians of all time. He wrote hundreds of manuscripts and most of them were in Latin. If anyone established a convention for using *c* for "celeritas", it has to have been Euler. In 1759 he studied the vibrations of a drum, and moved on to the 2-dimensional wave equation. This he wrote in the form we are looking for with *c* now the velocity constant [39]. Nevertheless it might be too hasty to conclude that Euler was thinking of the word celeritas when he wrote down this work because it appeared in French rather than Latin. Perhaps he had been thinking of the two dimensional wave speed as the hypotenuse of a right triangle with sides of length a, b and c. There is nothing in the final form of his work that tells us how the terminology arose beyond such guesswork.

The wave equation became a subject of much discussion, being investigated by all the great mathematicians of the epoque including Lagrange, Fourier, Laplace, and Bernoulli. Through their works, Euler's form of the wave equation with *c* for the speed of wave propagation was carved in stone for good. To a first approximation, sound waves are also governed by the same wave equation in three dimensions, so it is not surprising that the speed of sound also came to be denoted by the symbol *c*. This predates relativity and can be found, for example, in Lord Rayleigh's classic text "Theory of Sound" [40]. Physicists of the nineteenth century would have read the classic Latin texts on physics, and would have been aware that *c* could stand for "celeritas". As an example, Lorentz used *c* in 1899 for the speed of the Earth through the ether [41]. We even know that Einstein used it for speed outside relativity, because in a letter to a friend about a patent for a flying machine, he used *c* for the speed of air flowing at a mere 4.9 m/s [42].

In conclusion, although we can trace *c* back to Weber's force law where it most likely stood for "constant", it is possible that its use persisted because *c* could stand for "celeritas" and had therefore become a conventional symbol for speed. It can also be traced back to Euler’s work on the wave equation where it may have been simply the next letter to be chosen for a variable. We cannot tell for sure how Drude, Lorentz, Planck or Einstein thought about their notation, so there can be no definitive answer for what it stood for then. If you ask what c stands for now, the only logical answer is that, it stands for whatever possibility you prefer to think of.

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