The Kinetic Particle Theory of the Fine Structure Constant

The fine structure constant α is the dimensionless quantity $e^2/(\hbar c)$. The units of the electric charge *e* are such that e^2/r^2 is a force. The simplest MKS units of "*e*" are $kg^{1/2}m^{3/2}/s$ so that $\left[e^2/r^2\right]=\left[kg^{1/2}m^{3/2}/s\right]^2\ \left[1/m^2\right]=\left[kg\ m/s^2\right]$. Planck's constant $\hbar$ is an amount of angular momentum so that $\left[\hbar\right]=\left[kg\ m\ m/s\right]=\left[kg\ m^2/s\right]$. The units of the speed of light *c* are $\left[c\right]=\left[m/s\right]$. Thus

$$\begin{aligned}\left[e^2/(\hbar c)\right]&=\left[kg^{1/2}m^{3/2}/s\right]^2/\left[\left(kg\ m^2/s\right)\left(m/s\right)\right]\\&=\left[kg\ m/s^2\right]/\left[kg\ m/s^2\right]\end{aligned}$$

which, of course, is unitless.

The fine structure constant $\left(\alpha=e^2/(\hbar c)\right)$ plays a significant role in quantum electrodynamics. To emphasize the significance of α we quote the following authors.

Halliday [1] page 647. "The basic importance of this constant (e) lies in the fact that it can be combined with two other constants to form a dimensionless number, called the <u>fine structure</u> constant , $*\alpha$. Thus[1]

$$\alpha=\frac{e^2}{2\varepsilon_0\hbar c}\approx\frac{1}{137} \qquad (23\text{-}15)$$

The dimensionless constant is central to the theory of quantum electrodynamics, or QED as it is called. † This theory which combines quantum physics with the special theory of relativity is perhaps the most successful theory in physics in terms of predicting results that agree with experiments. The number 137 has fascinated physicists for decades as they sought-and seek-to explore the significance of the fine structure constant. It is an unusual physicist who, coming upon page 137 of any book, does not have a fleeting thought of this constant."

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[1] The quantity $e/\sqrt{2\varepsilon_0}$ in (23-15) is the same as "*e*" used above in $\alpha=e^2/(\hbar c)$.

Lévy – Leblond [2] page 20. “Since the combination $e^2/\hbar$ is a velocity, its ratio with respect to the velocity of light is a dimensionless number. Its importance greatly transcends the significance that we have just discovered for it. The number is denoted by[1]

$$\alpha \triangleq e^2/\hbar c \qquad (1.4.8)$$

and conventionally, its value is given in terms of its inverse,

$$1/\alpha = 137.037\ldots . \qquad (1.4.9)$$

(independently of any system of units!) It carries the unfortunate name, ‘the fine structure constant’, since (historically)[2] it first appeared in connection with the fine structure of atomic spectra. Actually, it ought to be considered as the square of the elementary charge, evaluated in terms of the universal standards $\hbar$ and c, or, better still, as an absolute measure of the strength of the electromagnetic interaction. It characterizes, in an intrinsic way, the force of coupling between the elementary electric charge and the electromagnetic field; thus, in modern terminology, one calls it ‘the electromagnetic coupling constant’!”

Feynman [3], page 129. “There is a most profound and beautiful question associated with the observed coupling constant, *e* – the amplitude for a real electron to emit or absorb a real photon. It is a simple number that has been experimentally determined to be close to – 0.08542455. (My physicist friends won’t recognize this number because they like to remember it as the inverse of its square: about 137.03597 with an uncertainty of about 2 in the last decimal place. It has been a mystery ever since it was discovered more than fifty years ago, and all good theoretical physicists put this number on their wall and worry about it.)”

The quote from Halliday [1] indicates the mystery of α and also that the mystery was worthy of noting to a large portion of the scientific students in the United States – since the Halliday book has such widespread usage. The quote from Lévy-Leblond [2] is from a scholarly book on the foundations of quantum physics. Finally, the quote from Feynman [3] is from one of the pioneering developers of quantum electrodynamics. All three references indicate the significance of α .

The literature indicates that the square root of the fine structure constant is a velocity ratio associated with the electromagnetic force. In the context of the kinetic particle theory of physics the ratio apparently is the value of the electromagnetic force velocity to the nuclear (force) velocity. Interpreting these velocities in this manner, within the context of the kinetic particle theory of physics, these velocities are flow velocities of particles, and the square of these velocities are proportional to forces. Thus,

[1] The notation $\triangleq$ denotes a definition of the term appearing on the left.
[2] Parentheses added by translator.

based on the kinetic particle theory of physics we would anticipate that the fine structure constant is closely associated with the ratio of the electromagnetic force to the nuclear force.

Let us now show how the fine structure constant occurs in the analysis of the hydrogen atom. Consider a hydrogen atom with its electron in its lowest energy state. The electrostatic force balances the centrifugal force. Thus

$$F = \frac{e^2}{\left(r_e + r_p\right)^2} = \frac{m_e \mathrm{v}_e^{\ 2}}{\mathrm{v}_e}$$

where r_e and r_p are the electron and proton distances, respectively from the hydrogen center of mass, m_e is the electron mass, e is the electrostatic charge, and v_e is the electron velocity. The angular momentum of the system is $\hbar$ and letting m_p be the mass of the proton. Its value is

$$\begin{aligned}\hbar &= m_e \mathrm{v}_e r_e + m_p \mathrm{v}_p r_p \\ &= m_e \mathrm{v}_e r_e + m_e \frac{r_p}{r_e} \mathrm{v}_e \frac{r_e}{r_p} r_p = m_e \mathrm{v}_e r_e \left(1 + \frac{r_p}{r_e}\right) \\ &= m_e \mathrm{v}_e r_e \left(1 + \frac{m_e}{m_p}\right)\end{aligned}$$

since $m_e r_e = m_p r_p$ from the definition of the center of mass. Substituting $\hbar$ into the force balance equation we have

$$\frac{e^2}{r_e^{\ 2}\left(1 + \frac{r_p}{r_e}\right)^2} = \frac{\hbar}{r_e\left(1 + \frac{m_e}{m_p}\right)} \frac{\mathrm{v}_e}{r_e}$$

and solving for v_e gives

$$\mathrm{v}_e = \frac{e^2}{\hbar\left(1 + \frac{r_p}{r_e}\right)}$$

Dividing both sides of the equation by c (the speed of light) gives dimensionless quantities on both sides of the equation and multiplying both sides by $\left(1 + r_p / r_e\right)$ gives

$$\frac{e^2}{\hbar c} = \left(1 + \frac{r_p}{r_e}\right)\frac{\mathrm{v}_e}{c} = \left(1 + \frac{m_e}{m_p}\right)\frac{\mathrm{v}_e}{c}$$

The term $e^2/(\hbar c)$ is named 'the fine structure constant' and is denoted by α. Its experimentally determined vale is

$$\alpha = 0.007,297,685,866(27)$$

which means it is accurate to 4 parts in 100,000,000. The term v_e/c is the orbital velocity of the electron and is also the ratio of the electromagnetic force to the nuclear (binding) force.

The experimentally determined magnitude of v_e/c thus is

$$\begin{aligned}(\mathrm{v}_e/c)_{\exp} &= \left[e^2/(\hbar c)\right]/\left(1 + m_e/m_p\right) = \alpha/\left(1 + m_e/m_p\right) \\ &= 0.007,297,685,866/\left[1 + 9.109534 \times 10^{-31}/\left(1.6726485 \times 10^{-27}\right)\right] \\ &= 0.007,297,685,866/\left(1 + 0.000544617\right) \\ &= .007,293,713,586\end{aligned}$$

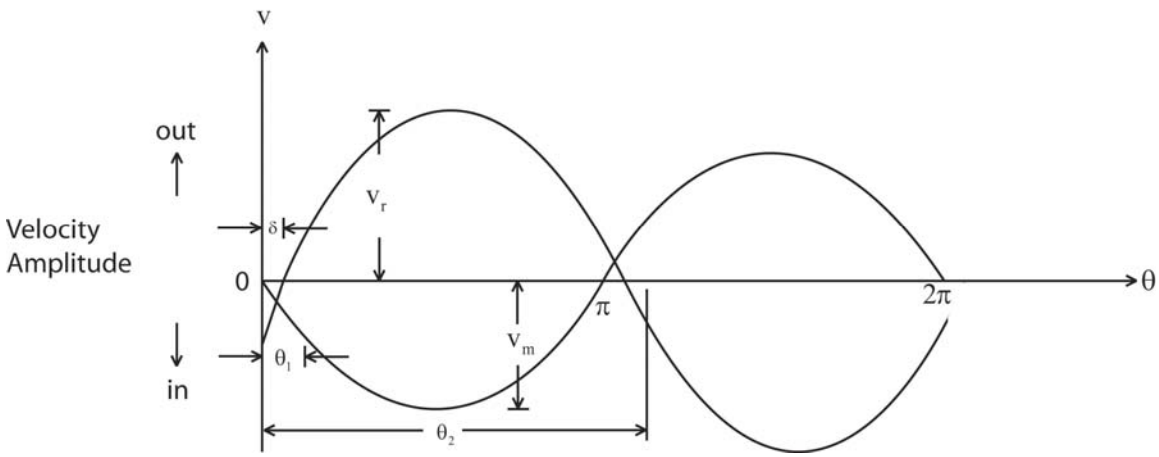
In this expression the rest masses of m_e and m_p are used. Correcting for magnetic and relativistic effects does not change the value of $(\mathrm{v}_e/c)_{\exp}$ within its accuracy of measurement.

In the kinetic particle theory of physics the ratio of the forces is exactly the same as the ratio of the squares of the flow velocities producing the forces.

The nuclear binding flow velocity is v_m, the mean velocity of the ether background gas, see pages 29-31 of Brown [4].

The electromagnetic force flow velocity is slightly greater than the speed of light. This flow velocity is determined from the mechanism producing the electrostatic force, see pages 23-24 of Brown [4].

The electrostatic force of a proton is produced by an inflow into and then and outflow from the neutrino comprising the proton. The inflow is at velocity v_m, the outflow is at a slightly later time, and at velocity v_r, the rms speed of the background ether gas. The following figure shows one cycle of the two waves.



In this figure the small angle δ indicates the lag angle. The time for one cycle is the time for the proton neutrino to make one cycle:

$$\left(\tau_p \approx 2\pi\, \mathrm{v}_p / c \approx 2\pi \times 10^{-10} / \left(3 \times 10^{8}\right) = 2 \times 10^{-24}\ \mathrm{sec}\right)$$

The time for the flow through the neutrino τ_γ is the "effective" neutrino length $"l_\nu"$ divided by the flow speed $\mathrm{v_m}$. Thus $\tau_\nu = l_\nu / \mathrm{v}_m$. Now

$$\delta = 2\pi\, \tau_\nu / \tau_p = \left(2\pi l_\nu / \mathrm{v}_m\right) / \left(2\pi v_p / c\right)$$
$$= \left(c / \mathrm{v}_m\right)\left(l_\nu / r_p\right)$$

where δ is measured in radians.

The value of l_v requires a complete analysis of the neutrino which has not yet been completed. What can be done is to determine the value of δ required to make the theoretical value of the electromagnetic force to nuclear force ratio agree with the experimental value. The value of l_v then can be determined and evaluated with what we think is reasonable (a reasonable value for l_v could be $r_p / 100$).

To evaluate δ we will use the following process. The speed of light is given by $c = \mathrm{v}_r - \mathrm{v}_m$, see pages 6 and 7 of [4]. The maximum electrostatic force which possibly could be generated would be if δ were π radians so that the v_m wave would be in phase with the v_r wave. In that case the electrostatic force would be proportional to $\left(\mathrm{v}_r + \mathrm{v}_m\right)^2$. In the (other impossible) case where δ was zero the electrostatic force would be proportional to $\left(\mathrm{v}_r - \mathrm{v}_m\right)^2$, i.e., proportional to c^2.

What we will do is compute the average of the electrostatic force velocity in terms of the lag angle δ and then divide that by the average flow velocity if there were no lag. This ratio times the constant $\left(\mathrm{v}_r - \mathrm{v}_m\right) / \mathrm{v}_m$ then will give the actual electromagnetic force flow velocity to the nuclear force flow velocity and the squares of both terms (i.e., the ratio in terms of δ and the term $\left(\mathrm{v}_r - \mathrm{v}_m\right)/\mathrm{v}_m$ will be the electromagnetic force to nuclear force ratio.) This value then will be equated to 0.007,293,713,586 so that the lag angle δ can be determined.

Returning to the previous figure we take the minimum value of θ to be θ_1, where the upper curve ordinate is equal (in magnitude) to the lower curve ordinate. As $\theta + \theta_1$ increases by π radians the upper and lower ordinates again are equal. Thus, from θ_1 to θ_2 the velocity amplitude is positive. The net value of the amplitude is

$$\mathrm{v}_r \sin\left(\theta - \delta\right) - \mathrm{v}_m \sin\theta$$

The net amplitude for the next π radians is the same as above but with its sign reversed. The average velocity amplitude for the portion of the cycle where the net velocity is positive is

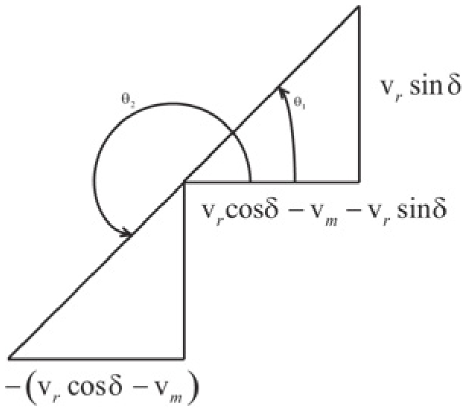
$$\begin{aligned}
\bar{\mathrm{v}} &= \int_{\theta_1}^{\theta_2} \left[\mathrm{v}_r \sin\left(\theta - \delta\right) - \mathrm{v}_m \sin\theta\right] d\theta / \pi \\
&= \frac{1}{\pi}\int_{\theta_1}^{\theta_2} \left[\mathrm{v}_r \left(\sin\theta\cos\delta - \cos\theta\sin\delta\right) - \mathrm{v}_m \sin\theta\right] d\theta \\
&= \frac{1}{\pi}\left[\mathrm{v}_r \left(-\cos\theta\cos\delta - \sin\theta\sin\delta\right) + \mathrm{v}_m \cos\theta\right]_{\theta_1}^{\theta_2}
\end{aligned}$$

The value of θ_1 and θ_2 are given by

$$\begin{aligned}
&\mathrm{v}_r \sin\left(\theta_1 - \delta\right) = \mathrm{v}_m \sin\theta_1 \\
&\mathrm{v}_r \left(\sin\theta_1 \cos\delta - \cos\theta_1 \sin\delta\right) = \mathrm{v}_m \sin\theta_1 \\
&\sin\theta_1 \left(\mathrm{v}_r \cos\delta - \mathrm{v}_m\right) = \cos\theta_1 \mathrm{v}_r \sin\delta
\end{aligned}$$

or

$$\tan\theta_1 = \frac{\mathrm{v}_r \sin\delta}{\mathrm{v}_r \cos\delta - \mathrm{v}_m}$$



Let

$$\sqrt{\ } = \sqrt{v_r{}^2 \sin^2 \delta + (v_r \cos\delta - v_m)^2}$$
$$= \sqrt{v_r{}^2 - 2v_r v_m \cos\delta + v_m{}^2}$$

Substituting for the upper and lower limits gives

$$\bar{v} = \frac{1}{\pi\sqrt{\ }}\left[v_r\left\{(v_r \cos\delta - v_m)\cos\delta + v_r \sin\delta \sin\delta\right\} - v_m(v_r \cos\delta - v_m)\right]$$
$$-\frac{1}{\pi\sqrt{\ }}\left[v_r\left\{(-v_r \cos\delta + v_m)\cos\delta - v_r \sin\delta \sin\delta\right\} + v_m(v_m \cos\delta - v_m)\right]$$
$$= \frac{2}{\pi\sqrt{\ }}\left[v_r\left\{(v_r \cos\delta - v_m)\cos\delta + v_r \sin\delta \sin\delta\right\} - v_m(v_r \cos\delta - v_m)\right]$$

Simplifying this gives

$$\bar{v} = \frac{2}{\pi\sqrt{\ }}\left[v_r{}^2 \cos^2\delta - v_r v_m \cos\delta + v_r{}^2 \sin^2\delta - v_m v_r \cos\delta + v_m{}^2\right]$$
$$= \frac{2}{\pi\sqrt{\ }}\left[v_r{}^2 - 2v_r v_m \cos\delta + v_m{}^2\right]$$
$$= \frac{2}{\pi}\sqrt{v_r{}^2 - 2v_r v_m \cos\delta + v_m{}^2}$$

If there is no delay then the average velocity is

$$\overline{v_0} = \frac{1}{\pi}\int_0^{\pi}(v_r \sin\theta - v_m \sin\theta)\,d\theta = \frac{2}{\pi}(v_r - v_m)$$

Now, the ratio of the average electromagnetic force velocity to the speed of light is

$$\frac{\overline{v}}{\overline{v_0}} = \frac{\sqrt{v_r^{\,2} - 2v_r v_m \cos\delta + v_m^{\,2}}}{v_r - v_m} = \frac{\sqrt{3\pi/8 - 2\sqrt{3\pi/8}\cos\delta + 1}}{\sqrt{3\pi/8} - 1}$$

This ratio must be unity if the delay is zero. Letting δ be zero we have

$$\frac{\overline{v}}{\overline{v_0}} = \frac{\sqrt{v_r^{\,2} - 2v_r v_m + v_m^{\,2}}}{v_r - v_m} = 1.0$$

which is a check on the analysis leading to the equation for $\overline{v}$. We note that if δ is slightly greater than zero then the ratio $\overline{v}/\overline{v}_0$ will be slightly greater than unity, which obviously it should be. In fact, as δ increases from zero to π the ratio increases monotonically from unity to:
$\left(v_r + v_m\right)/\left(v_r - v_m\right) = \left(\sqrt{3\pi/8} + 1\right)/\left(\sqrt{3\pi/8} - 1\right) = 2.085/0.085 = 24.5$

We will now determine the value of $\delta\left(=\delta_o\right)$ which increases the non-delay average velocity to the delay velocity which produces the electromagnetic force. The non-delay force ratio is

$$\left(\frac{v_r - v_m}{v_m}\right)^2 = \left(v_r / v_m - 1\right)^2 = \left(\sqrt{3\pi/8} - 1\right)^2$$
$$= 0.007{,}293{,}481{,}422$$

Multiplying this by the square of $\overline{v}/\overline{v_o}$ then must be the fine structure constant adjusted for the center of mass system. Thus:

$$\left(0.007{,}293{,}481{,}422\right)\frac{\left(3\pi/8 - 2\sqrt{3\pi/8}\cos\delta + 1\right)}{\left(\sqrt{3\pi/8} - 1\right)^2}$$
$$= \left(3\pi/8 - 2\sqrt{3\pi/8}\cos\delta + 1\right) = 0.007{,}293{,}713{,}586$$

Solving for δ gives

$$2.178\,097\,245 - 0.007\,293\,713\,586$$
$$= 2.170\,803\,764\cos\delta$$

or

$$\cos\delta = \frac{2.170\,803\,532}{2.170\,803\,764} = 0.999\,999\,893$$

Using the approximation

$$\cos\delta = 1 - \delta^2 / 2$$

We have

$$\delta = \sqrt{2\left(1 - 0.999\,999\,893\right)} = 0.000462\ \text{radians}$$
$$= 0.0265\ \text{degrees.}$$

Returning now to the relation of δ to the length of path of the flow inside the proton's neutrino we have

$$\delta = \left(c / \mathrm{v}_m\right)\left(l_v / r_p\right)$$

or

$$l_v = \delta r_p / \left(c / \mathrm{v}_m\right) = \delta r_p / \left(\mathrm{v}_r / \mathrm{v}_m - 1\right)$$
$$\approx 0.000462\left(10^{-16}\right) / \left(\sqrt{3\pi / 8} - 1\right)$$
$$= 5.4 \times 10^{-19}\, m$$

This is about $5/1000$ times the proton orbital radius, which seems reasonable. We thus have shown the relationship of the fine structure constant to the constant

$$\left(\frac{\mathrm{v}_r - \mathrm{v}_m}{\mathrm{v}_m}\right)^2 = \left(\sqrt{3\pi / 8} - 1\right)^2 = 0.007,293,481,422$$

Recapitulating, what we have is – the ratio of the electromagnetic force to the nuclear force is

$$\frac{F_e}{F_m} = \frac{\mathrm{v}_m{}^2 - 2\mathrm{v}_r\mathrm{v}_m\cos\delta + \mathrm{v}_m{}^2}{\left(\mathrm{v}_r - \mathrm{v}_m\right)^2}\left(\frac{\mathrm{v}_r - \mathrm{v}_m}{\mathrm{v}_m}\right)^2$$
$$= \frac{\mathrm{v}_r{}^2 - 2\mathrm{v}_r\mathrm{v}_m\cos\delta + \mathrm{v}_m{}^2}{\mathrm{v}_m{}^2}$$
$$= \frac{\mathrm{v}_r{}^2 - 2\mathrm{v}_r\mathrm{v}_m\left(0.999\,999\,983\right) + 1}{\mathrm{v}_m{}^2}$$
$$= \left(\mathrm{v}_r / \mathrm{v}_m\right)^2 - 2\mathrm{v}_r / \mathrm{v}_m\left(0.999\,999\,983\right) + 1$$
$$= 3\pi / 8 - 2\sqrt{3\pi / 8}\left(0.999\,999\,893\right) + 1$$

$$= 1.178\,097\,245 - 2.170\,803\,531 \; + \; 1$$
$$= 0.007\,293\,714$$

and

$$\frac{F_e}{F_m}\left(1+\frac{m_e}{m_p}\right) = \frac{e^2}{\hbar c} = 0.007293714\left(1+0.000544617\right)$$
$$= 0.007\,297\,686 = \alpha$$

References:

1. Halliday, David; Resnick, Robert; and Walker, Jearl; *Fundamentals of Physics 4th Edition with Modern Physics*, John Wiley and Sons, Inc., NY 1993.

2. Lévy-Leblond, Jean-Marc and Balibar, Francoise, *Quantics: Rudiments of Quantum Physics*, ISBN: 0-444-881204, North Holland, NY 1990.

3. Feynman, Richard P., *QED: The Strange Theory of Light and Matter*, ISBN: 0-691-082388-6, Princeton University Press, Princeton, NJ, 1985.

4. Brown, Joseph M., *The Grand Unified Theory of Physics*, ISBN: 0-9712944-6-1, Basic Research Press, Starkville, MS, 2004.