Version 1.1
January 1, 2018
HJF

Fermi's Witty Response: A Blackboard with Two, Not One, 'Mistakes'?

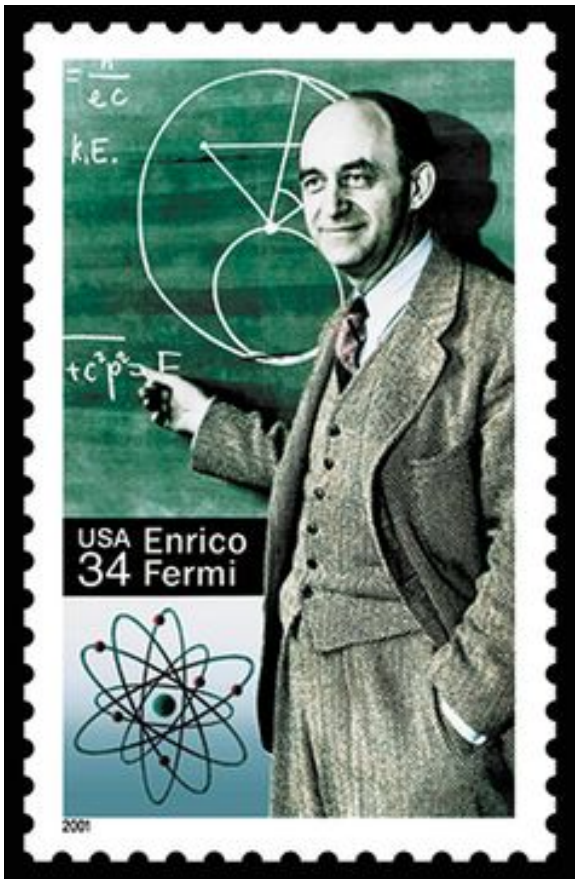


Figure 1: The famous stamp showing Fermi at the blackboard with several formulae and a diagram of circles and triangles.

1 Introduction

I am not the first to doubt that Enrico Fermi would make the much discussed 'mistake' on the blackboard shown in the 1991 US stamp (Figure 1). In a letter to Nature in 1992, Richard Garwin wrote "...it is difficult to believe that Fermi could have written it...", and then goes on to write "The most probably explanation is that Enrico Fermi, a great physicist, both in theory and experiment, and a man full of fun and humour, was having a little fun with the photographer."[2]. In a Symposium on Fermi in 2001, Jim Cronin suggested that '"He might have been pulling our leg"[1]. Garwin was Fermi's student, and Cronin had classes from Fermi; they knew him, in Garwin's case exceptionally well. However the idea that Fermi made a mistake has widely taken hold in the popular mind [3].

2 The Hypothesis: Fermi's Witty Response To An Unwanted Request

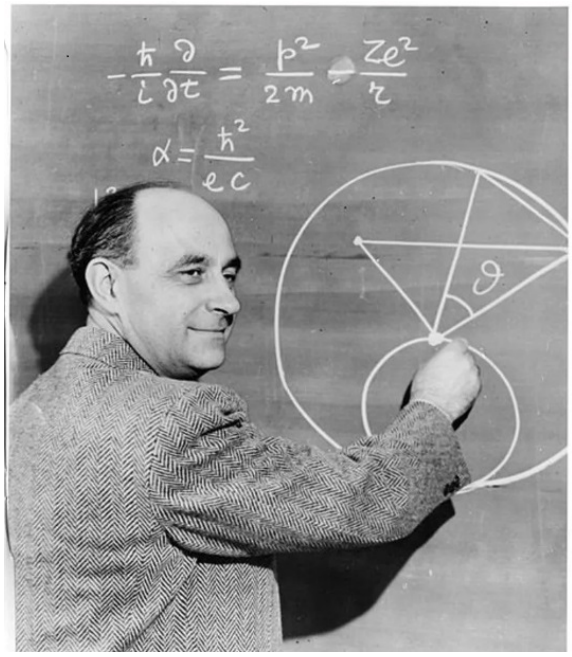


Figure 2: A photograph very similar – presumably from the same Public Relations session– to the photograph from which the stamp was derived. Note both the incorrect formula for alpha and the unusual diagram, which Fermi gives the impression to have just finished drawing.

Following Garwin's and Cronin's suggestions, one can guess what was the context for the 'mistake' in the equation for α. From the number of similar images it is clear that these are staged pictures in a photography session, probably for some article or public announcement. Fermi was most likely told by someone from the UofC Public Relations department to go to the blackboard and write several equations and make a diagram. As described below, in an interaction with Oppenheimer at Los Alamos, Fermi could not be talked into doing something he felt was false. My guess is that, much as in the story with Oppenheimer, after refusing several times, in this case to pretend to be teaching, Fermi decided it was easier to acquiesce than to resist, but would write something on the board that was a clear signal that this was not an authentic picture of him at work. What could be more concise and telling than for Fermi, the master of coupling constants (see Section 4), to write the electromagnetic coupling constant not proportional to the electron charge squared, but to the square of the fundamental unit of quantum mechanics, as far as we know a completely unrelated universal constant? It is so wrong in so many deep but obvious ways that any physicist would immediately pick up on it as a protest[1].

I should add that I was put in the same situation by a team of University of Chicago Public Relations staff, and was saved only by the fact that my young daughter had painted my fingernails white. When I pointed to the blackboard in a staged re-enactment of teaching, the team making the film turned white as well (my own unintended but effective protest).

[1] In 'natural units', both Planck's constant $\hbar$ and the velocity of light c are set $= 1$, so the formula as Fermi wrote it would be $\alpha = \frac{1}{e}$; painful even to contemplate.

3 A Family Story

My parents, David and Rose, came to Los Alamos at age 25 in early 1943 from Wisconsin, where they were in graduate school and Dave was studying cross-sections in Ray Herbst's Van De Graaff group. My dad told me the following story.[2]

Dave said Oppenheimer called what is now called an 'all-hands meeting'. The front row consisted of Bohr, Bethe, Weisskopf, Feynman, Rabi, Teller, and other luminaries. Oppie tells the assembly "Enrico has some wonderful news for us. Enrico, would you tell the group the news on the multiplication factor?". Whereupon Fermi stands up, faces the crowd, says "The number is 2.3", and sits down.

Oppenheimer says "This is wonderful news; this means the Gadget will work", and asks for a round of applause. "However, Enrico, there must be an uncertainty on the number– could you tell us the uncertainty?" Fermi stands up, and says "I don't know the uncertainty. But don't worry, it will work". And sits down again. My dad said that at this point Oppenheimer becomes very formal, and says words to the effect that he had been charged by the President of the United States with the success of the Project and that the future of the Free World hung on this number, and he had to have the uncertainty. Whereupon Fermi stands up again, and says "I don't know the uncertainty", and sits down. Oppenheimer, challenged in front of a large audience, says "Enrico, if you cannot quote a number, could you at least put a limit on the uncertainty." Whereupon Fermi stands up, faces the audience, grins, and says 'The uncertainty is not less than 0.1", and sits down.

The point is that "not less than" is the wrong limit. To be useful, it needs to be an upper limit and not a lower limit, as a lower limit allows uncertainties so large that the number itself is meaningless. Note also that Fermi, rather than argue, did literally what was demanded, in a way that seemed to satisfy the request but on further thought was in fact a dramatic protest. Note also the reference to the grin (See his grin in Figures 1 and 2).

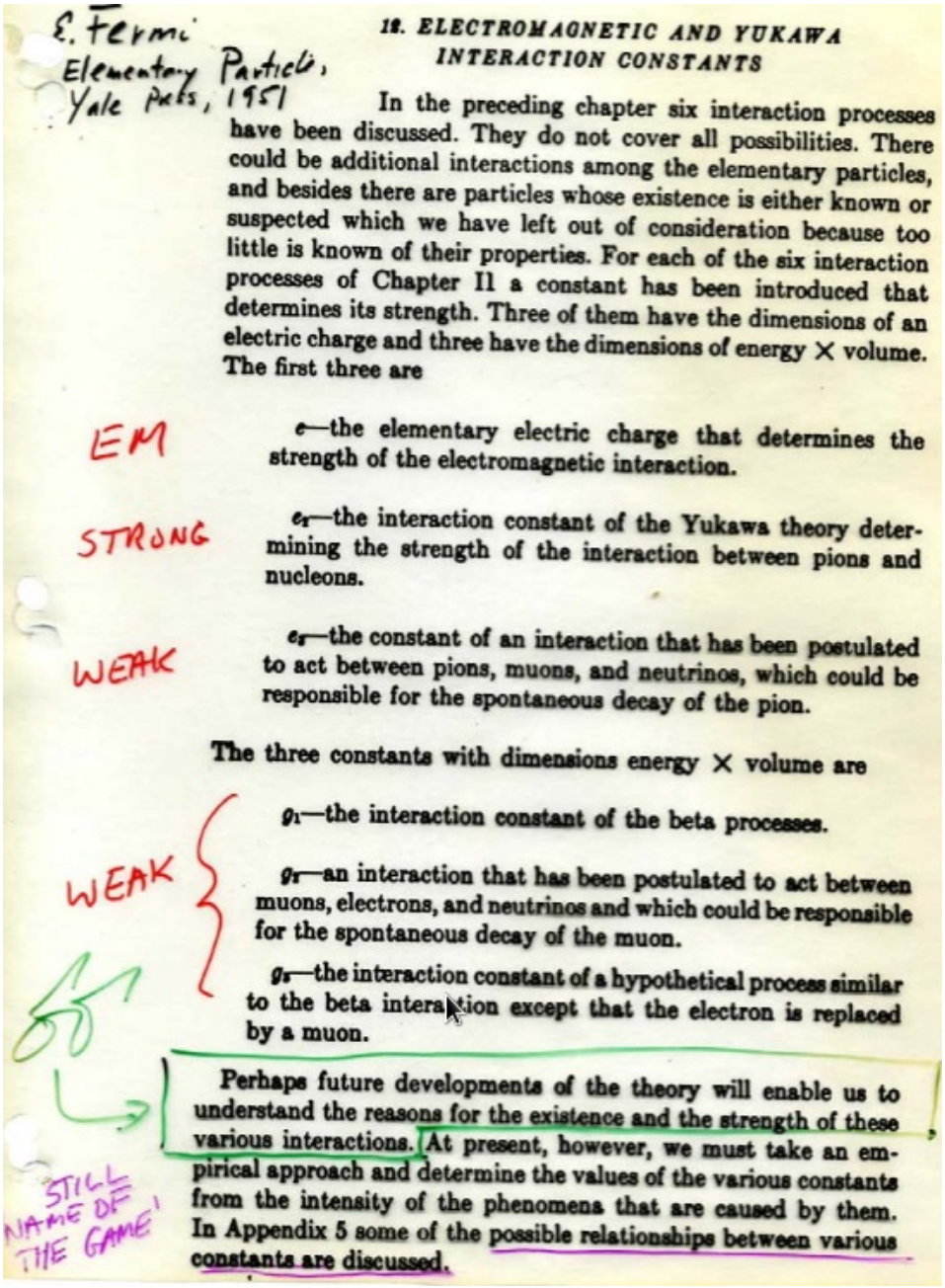
4 Fermi and Coupling Constants

The choice of $\alpha = e^2/\hbar c$ as the response to "Could you write an equation on the board?" is natural– it's a simple relationship, and the formula is physically transparent, being basically a change of units (α is just the square of the electric charge e). In Fermi's Yale lectures in 1950 he discussed the importance of the couplings in the larger picture of the fundamental forces. Figure 3 shows his thoughts on the couplings. To me there is no way that he would write alpha incorrectly, with the coupling inverse to the charge. This was a protest, much as the wrong limit presented to Oppie, and with a grin.

5 The 'Nonsense' Diagram: An Additional Clue?

I believe there is a definitive test of the hypothesis that the 'mistake' is instead a witty protest for sophisticated viewers. I have not seen discussed the diagram Fermi has drawn on the board. Like the equation for alpha, it's very elegant, consisting of two circles and two triangles. It is drawn well, in a clear and bold hand.

[2]This is as I remember it – quite possibly not as told. The number 2.3 is made up- I don't remember what Dave said it was.



E. Fermi
Elementary Particles,
Yale Pubs, 1951

18. ELECTROMAGNETIC AND YUKAWA INTERACTION CONSTANTS

In the preceding chapter six interaction processes have been discussed. They do not cover all possibilities. There could be additional interactions among the elementary particles, and besides there are particles whose existence is either known or suspected which we have left out of consideration because too little is known of their properties. For each of the six interaction processes of Chapter II a constant has been introduced that determines its strength. Three of them have the dimensions of an electric charge and three have the dimensions of energy × volume. The first three are

EM

e—the elementary electric charge that determines the strength of the electromagnetic interaction.

STRONG

e_τ—the interaction constant of the Yukawa theory determining the strength of the interaction between pions and nucleons.

WEAK

e_σ—the constant of an interaction that has been postulated to act between pions, muons, and neutrinos, which could be responsible for the spontaneous decay of the pion.

The three constants with dimensions energy × volume are

WEAK

g_1—the interaction constant of the beta processes.

g_2—an interaction that has been postulated to act between muons, electrons, and neutrinos and which could be responsible for the spontaneous decay of the muon.

g_3—the interaction constant of a hypothetical process similar to the beta interaction except that the electron is replaced by a muon.

Perhaps future developments of the theory will enable us to understand the reasons for the existence and the strength of these various interactions. At present, however, we must take an empirical approach and determine the values of the various constants from the intensity of the phenomena that are caused by them. In Appendix 5 some of the possible relationships between various constants are discussed.

STILL NAME OF THE GAME!

Figure 3: A page from Fermi's 1950 Yale Silliman lectures on the future unification of forces and the relationships of their coupling constants. (The scribblings are my own for a long-gone talk.)

However, I have not been able to think of a physical process or object that the diagram describes[3]. While striking and appealing, I think it too is a subtle but, with some thought obvious, 'mistake'. My hypothesis is that this too is a witty protest– Fermi was told to draw a diagram as well as write some equations on the board, and he drew a picture that has no basis in physics. I personally think it is a brilliant response to a spur-of-the-moment need in its clarity and appeal [5].

[3]I would welcome references for prior discussions of the diagram– it seems odd to me that it hasn't been discussed along with the equation for alpha.

In the spirit of 'a priori' testing of hypotheses, the diagram can serve as a test. If the picture has a well-defined physics context, the situation will remain as it is with alpha being the sole possible protest. However, if physicists across a wide array of fields cannot find a plausible explanation for what I think is a 'nonsense diagram', then the diagram is a second 'mistake', and one that cannot be accidental. In this case Fermi was sent to the board and arm-twisted into writing on it for public relations reasons, and both the 'wrong' equation for alpha and the meaningless diagram constituted a witty message of resistance for the cognoscenti.

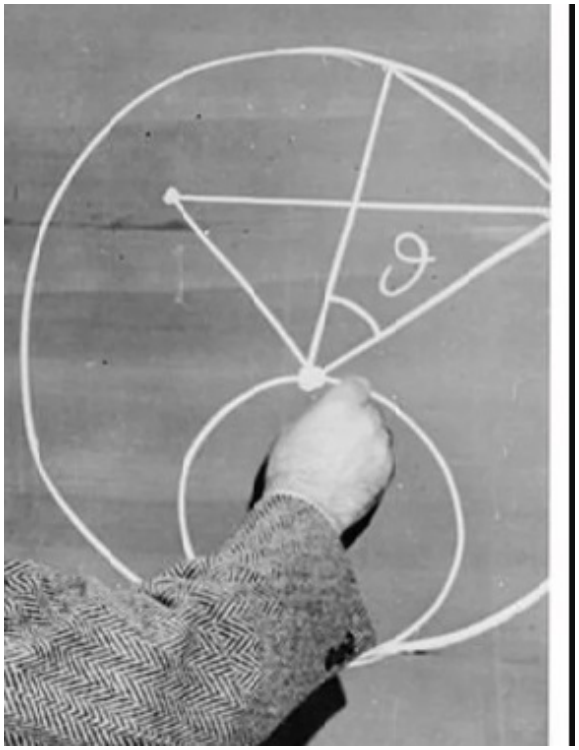


Figure 4: The mysterious diagram on the blackboard. Is there a physical process or object that it represents?

6 Epilogue– Note on Uncertainties in HEP

To be hard-nosed about the Los Alamos story, I believe that it is quite likely that Fermi did not 'know' a number for the uncertainty on the multiplication factor, but had other evidence from the experiments making him confident that the chain reaction would work. Thus he was being precise and responsible, rather than perverse, in not quoting a number to Oppenheimer. In both cases the 'protest' was not subtle when expressed in the language of Physics.

References

[1] J. W. Cronin, as quoted by Richard Mertens, University of Chicago Magazine, Vol. 94, #2. Mertens writes: "Cronin says Fermi may have been asked to put some scientific-

looking stuff on the board as background for the photo session: 'He might have been pulling our leg'."

[2] R. Garwin, Nature Vol 355, 20 Feb. 668 1992;
https://www.nature.com/articles/355668d0.pdf

[3] See, for example, G. Huber, *Postage Stamp Poses a Fermi Problem*. Science Vol 294, Oct 2001.

[4] http://fermi.lib.uchicago.edu/fermicommemoration.htm

[5] I thank Andrey Elagin and Carla Grosso-Pilcher for pointing out that drawing geometric diagrams, often with circles and inscribed triangles, was a basic part of the mathematics curriculum in elementary school when Fermi was young. The drawing mastery thus would be from practice.