Chapter 8 Version Date: July 26, 2011

QED: Interaction Theory Applied to Electromagnetism

"At the Pocono Manor Inn that spring day in 1948, Feynman introduced his diagrams … By all indications, [it] was *a flop."*

David Kaiser, Kenji Ito, and Karl Hall
Spreading the Tools of Theory
Soc. Stud. Sci. 34/6, 879–922

And so he felt that his lecture was a complete failure, "a hopeless presentation".

S. S. Schweber recalling taped interview
with Richard Feynman on Nov 13, 1980

8.0 Preliminaries

The Pocono Manor conference, a gathering of luminaries including Oppenheimer, Bohr, Dirac, Wigner, Schwinger and others, was focused on the major problem of the day – how to handle those notorious infinities that crept into the exact (not approximate, as in the present chapter) calculations of transition amplitudes. (See Chaps. 9 and 11 herein.) As part of the demonstration of his solution to the issue, Feynman introduced his now famous Feynman diagrams, a simple, symbolic, short-hand way to organize the complicated mathematical expressions involved, and also his Feynman rules, which associated certain mathematical quantities with each aspect of a given diagram.

No one understood what he was doing, and several were skeptical. Some even wondered whether Feynman, himself, knew what he was doing. Yet, before too long after that conference, the utility of the diagrams became apparent, and their usage spread far and wide.

The lecture Feynman gave that day used Feynman diagrams as a tool for a greater end, elimination of the infinities that plagued the theory. And what he did that day worked. It worked so well that it earned him a share (along with Schwinger and Tomonaga, who did the same thing in a different way) of the Nobel Prize in 1965. On that, he had this to say.

> *"The work I have done has, already, been adequately rewarded and recognized. Imagination reaches out repeatedly trying to achieve some higher level of understanding, until suddenly I find myself momentarily alone before one new corner of nature's pattern of beauty and true majesty revealed. That was my reward."*

Richard P. Feynman
Nobel banquet speech

8.0.1 Background

In the last chapter, we showed how the S operator transforms an initial state into a final state, and how the transition amplitude S_{fi} can be found from the S operator. We also solved for the form of the S operator and then expanded that (via the Dyson expansion) into an infinite series of terms involving time ordering of operators and integration over all of space and time. Finally, we saw how Wick's theorem could convert the time ordering into more manageable normal ordered form.

8.0.2 Chapter Overview

In this chapter, we will take the result of Wick's theorem and apply it to electromagnetism to develop quantum electrodynamics (QED). Note that for this chapter, we will only find approximate values for S_{fi}. We will do this by noting that the higher order terms in the expansion of the S operator for QED should be small, and so restrict our analysis here to second and lower order terms.

Steps in applying QFT interaction theory to e/m to second order approximation

We will

- Use $\mathcal{H}_I^I$ for QED in the Dyson-Wick's expansion of the S operator
- Examine only lower order terms $S^{(0)}$, $S^{(1)}$, $S^{(2)}$ in the expansion
- Show how $S^{(0)}$ implies no transition, and $S^{(1)}$ is not a real physical process and irrelevant
- Analyze all possible terms in $S^{(2)}$, the second order portion of the S operator
- Use Feynman diagrams to represent individual interactions
- Calculate transition amplitudes for typical QED (e.g., Bhabha) scattering processes
- Discuss how to add amplitudes
- Detail the short cut method to find transition amplitudes, i.e., Feynman rules
- Examine mixed lepton (μ and τ particles in addition to electrons/positrons) interactions
- Define inelastic vs. elastic scattering (interactions)

No more RQM

From now on, no RQM, just QFT

Note that from now on we will be dealing exclusively with QFT, and not RQM, because the latter cannot handle the general case of mutation of particles from one type to another.

8.0.3 Summary Chart

Be sure to use the summary wholeness chart, as you study this chapter

All that we will do in this chapter is summarized in Wholeness Chart 8-XX at the end of the chapter. This can also be found at www.quantumfieldtheory.info by clicking the Interacting Fields Wholeness Chart. As in prior chapters, I highly recommend following along, step by step, in that chart as we progress through this chapter.

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THANK YOU FOR UNDERSTANDING.

Robert D. Klauber

8.1 Problems

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