

8.701

Introduction to Nuclear
and Particle Physics

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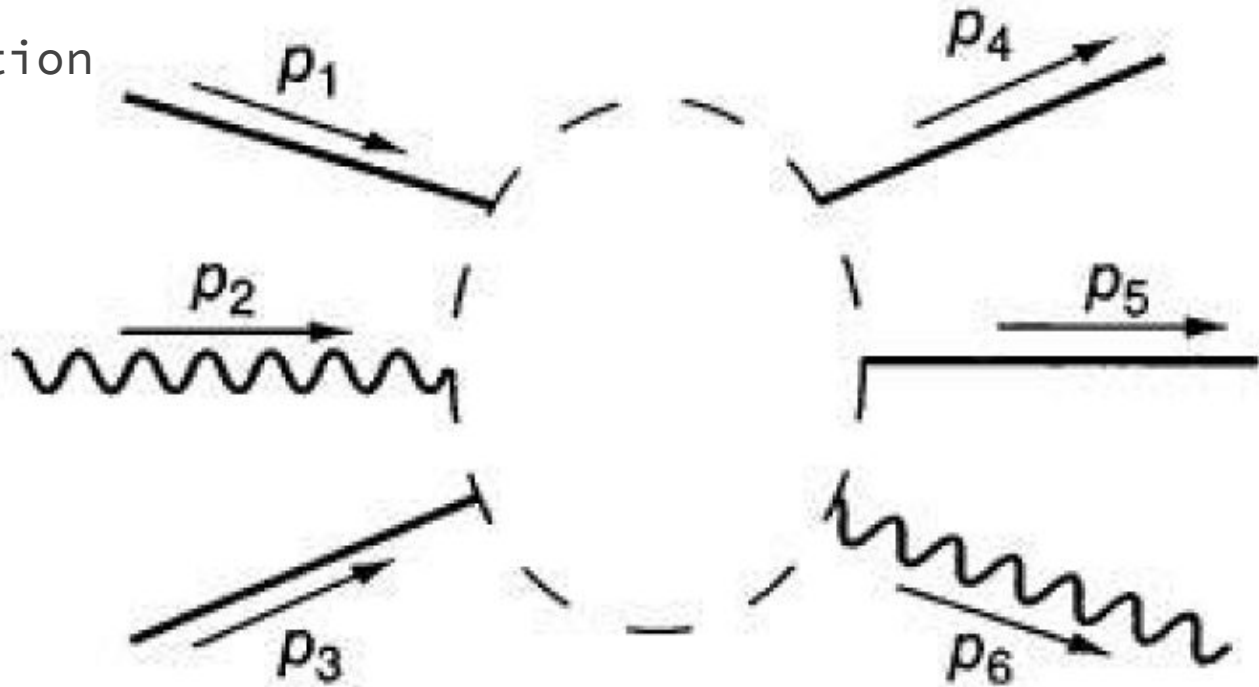
4. QED

4.5 Feynman Rules for QED



Feynman Rules for QED

1. Notation



Feynman Rules for QED

2. External lines

$$\begin{array}{l} \text{Electrons :} \\ \text{Positrons :} \\ \text{Photons :} \end{array} \left\{ \begin{array}{l} \text{Incoming}(\text{---}\bullet) : u \\ \text{Outgoing}(\bullet\text{---}) : \bar{u} \\ \text{Incoming}(\text{---}\bullet) : \bar{v} \\ \text{Outgoing}(\bullet\text{---}) : v \\ \text{Incoming}(\text{wavy}) : \epsilon_\mu \\ \text{Outgoing}(\text{wavy}) : \epsilon_{\mu}^* \end{array} \right. \quad \begin{array}{l} \bar{u} = u^\dagger \gamma^0 \\ \bar{v} = v^\dagger \gamma^0 \end{array}$$

Feynman Rules for QED

3. Vertex factor

$$ig_e \gamma^\mu$$

4. Propagator

Electrons and positrons:

$$\frac{i(\gamma^\mu q_\mu + mc)}{q^2 - m^2 c^2}$$

Photons:

$$\frac{-ig_{\mu\nu}}{q^2}$$

Feynman Rules for QED

5. Energy and momentum conservation

$$(2\pi)^4 \delta^4(k_1 + k_2 + k_3)$$

6. Integrate over internal momenta

$$\frac{d^4 q}{(2\pi)^4}$$

7. Cancel delta function

$$(2\pi)^4 \delta^4(p_1 + p_2 + \cdots - p_n)$$

Feynman Rules for QED

The order is important. Each fermion line is of the form:

$$\text{adjoint spinor} * 4 \times 4 \text{ matrix} * \text{spinor} = \text{number}$$

8. Antisymmetrization

Include a minus sign between diagrams that differ only in the interchange of two incoming (or outgoing) electrons (or positrons) or of an incoming electron with an outgoing positron (or vice versa)

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