Electromagnetic interaction

정 혁

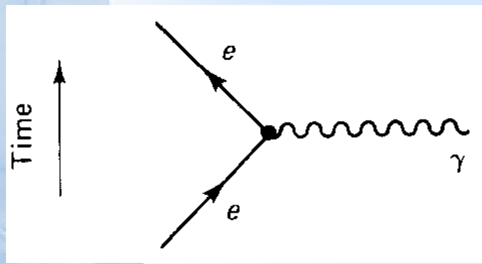
Introduction to elementary particle – D. Griffiths

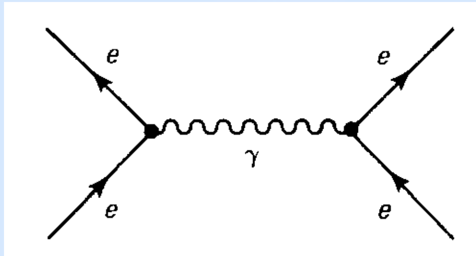
4 Force

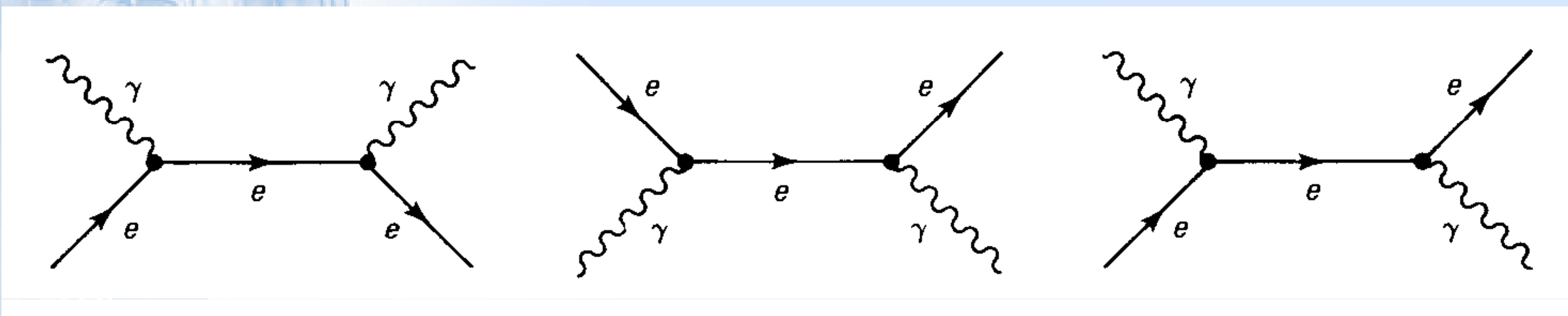
Force	Strength	Theory	Mediator
Strong	10	Chromodynamics	Gluon
Electromagnetic	10^{-2}	Electrodynamics	Photon
Weak	10^{-13}	Flavordynamics	W and Z
Gravitational	10^{-42}	Geometrodynamics	Graviton

QED(Quantum Electromagnetic Dynamics)

→ All electromagnetic phenomena are ultimately reducible to the following elementary process:

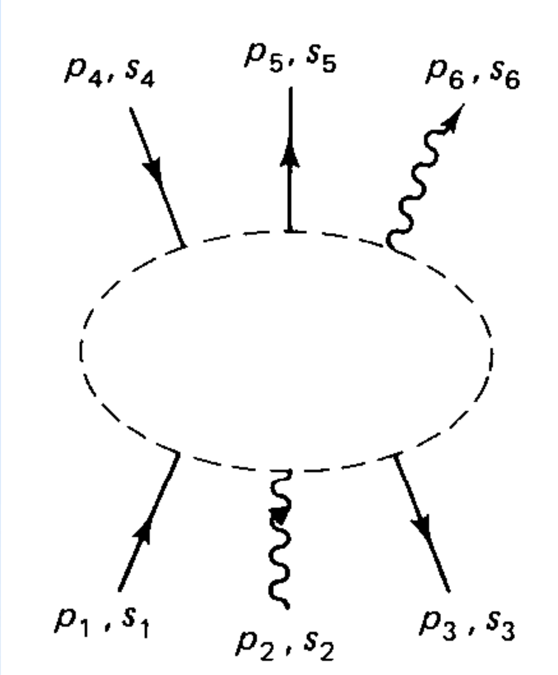






The Feynman rule for QED

1. Notation
   → momentum : $p_1,p_2,\ldots.p_n$
   → corresponding spin : $s_1,s_2,\ldots,s_n$
   → internal momentum : $q_1,q_2,\ldots,q_n$



The Feynman rule for QED

2. External line
   → External lines contribute factors as follows

Electrons:	Incoming ( ): u	
	Outgoing ( ): $\bar{u}$	
Positrons:	Incoming ( ): $\bar{v}$	
	Outgoing ( ): v	
Photons:	Incoming ( ): ϵ^{μ}	
	Outgoing ( ): $\epsilon^{\mu *}$	

The Feynman rule for QED

3. Vertex factor : $ig_e\gamma^\mu$

4. Propagators : Each internal line contribute a factor as follow

Electrons and positrons: $\dfrac{i(\gamma^\mu q_\mu + mc)}{q^2 - m^2c^2}$

Photons: $\dfrac{-ig_{\mu\nu}}{q^2}$

5. Conservation of energy and momentum

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

6. Integrate over internal momenta

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

The Feynman rule for QED

7. Cancel the delta function

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

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).

The Feynman rule for QED

Example

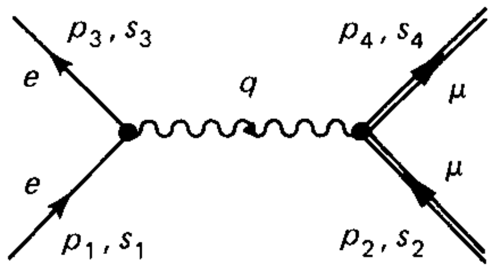


Figure 7.2 Electron-muon scattering.

Electron–muon scattering ($e + \mu \to e + \mu$)

(Mott scattering ($M \gg m$) ⇒ Rutherford scattering ($v \ll c$))

$$(2\pi)^4 \int [\bar{u}^{(s_3)}(p_3)(ig_e\gamma^\mu)u^{(s_1)}(p_1)] \frac{-ig_{\mu\nu}}{q^2} [\bar{u}^{(s_4)}(p_4)(ig_e\gamma^\nu)u^{(s_2)}(p_2)] \times \delta^4(p_1 - p_3 - q)\delta^4(p_2 + q - p_4)d^4q$$

$$\mathcal{M} = -\frac{g_e^2}{(p_1 - p_3)^2} [\bar{u}^{(s_3)}(p_3)\gamma^\mu u^{(s_1)}(p_1)][\bar{u}^{(s_4)}(p_4)\gamma_\mu u^{(s_2)}(p_2)]$$