Lecture 34.
Serial Compton scattering and accelerating frames I.
(Ch. 7-8 of Unit 2  4.23.12)

Review of fundamental 1-and 2-photon processes and their Feynman diagrams
Space-time view of light scattering

Serial Compton scattering and acceleration plot
Geometric construction
Compton wavelength and formulae
Some numerology: Which is bigger...H-atom or an electron?
Bouncing pulse wave (PW) vs (CW) shrinking laser

Lecture 34 ended here
Elementary Compton process:

IN: Photon absorption

Particle encounters photon

Particle excited and boosted

Particle emits photon

Particle de-excited and boosted again

OUT: Photo-emission

and $\mu_0$-particle of rapidity $\rho_2$
Elementary Compton process:

\[ \omega_1 : \text{Photon in} \rightarrow \text{Particle out} \]

\[ \rho_0 = 0 \]

\[ K_{(\omega_1)} \text{initial} \]

\[ \mu_0 - \text{hyperbola} \]

IN: Photo-absorption

OUT: Photo-emission

\[ \rho_1 \]

\[ \rho_2 \]

\[ \omega_2 \]

\[ \rho_0' = 0 \]

\[ \mu_0' \]

\[ \mu_2 \]

\[ \omega_1' \]

\[ \omega_2' \]

\[ \rho_1' \]

\[ \rho_2' \]
Elementary Compton process:

Initial rapidity $\rho_0 = 0$

$\mu_0$-hyperbola

$K_{\leftarrow(\mu_0)}_{\text{initial}}$

$K_{\rightarrow(\mu_0)}_{\text{initial}}$

$\omega_1$

$\rho_0 = 0$

$\rho_1$

$\rho_2$

IN: Photon-absorption

OUT: Photo-emission

IN: Photons

OUT: Compton photons

$\omega_2$

$\mu_0$

$\mu_1$

$\mu_2$
Elementary Compton process:

\[ \begin{align*}
\text{IN:} & \quad \text{Photon absorption} \\
\text{OUT:} & \quad \text{Photo-emission}
\end{align*} \]

\[ \mu_0 \rightarrow K_{(\omega_1)_{\text{initial}}} \]

\[ \mu_0 \rightarrow \mu_0 \cdot \text{hyperbola} \]

\[ \mu_0 = \mu_0 \cdot \text{inhp} \]

\[ \rho_0 = 0 \]

\[ \omega_1 \]

\[ \omega_2 \]

\[ \rho_1 \]

\[ \rho_2 \]

Tuesday, April 24, 2012
Two consecutive Compton processes

\[ e^{3\rho_1} \mu_0 = \mu_3 = e^{\rho_3} \mu_0 \]

\[ e^{2\rho_1} \mu_0 = \mu_2 = e^{\rho_2} \mu_0 \]

\[ e^{\rho_1} \mu_0 = \mu_1 \]
Serial Compton scattering and acceleration plot

- Geometric construction
- Compton wavelength and formulae
- Some numerology: Which is bigger...H-atom or an electron?
- Bouncing pulse wave (PW) vs (CW) shrinking laser
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\[ \omega_4 \sinh \rho_2 = e^{\rho_2} \omega_2 \sinh \rho_2 = 3/2 \]

**Compton IN**

\[ \omega_2 = \sqrt{2} \]

\[ \sinh \rho_2 = 3/4 \]

\[ e^{\rho_2} = 2 \]

\[ \tanh \rho_2 = 3/5 \]

\[ \omega_4 \sinh \rho_2 = 3 \]

\[ e^{\rho_2} = \sqrt{2} \]

\[ \tanh \rho_2 = 1/3 \]

\[ \rho_2 = 7/9 \]

\[ \rho_2 = 15/17 \]

**Compton FIN**

\[ \omega_2 = 2 \]

\[ \omega_2 = e^{\rho_2} \omega_2 \sinh \rho_2 = 3/8 \]

\[ \omega_2 = 1 \]

\[ \omega_4 = \sqrt{2} \]

\[ \tanh \rho_1 = 2 \]

\[ e^{\rho_1} = 1/2 \]

\[ \omega_4 \sinh \rho_1 = 3 \]

\[ e^{\rho_1} = 4 \]

\[ \delta = 0 \]

**Compton Wavelength formula**

\[ \lambda_{\text{IN}} - \lambda_{\text{FIN}} = \lambda_{2, e^{-\ell}} - \lambda_{4, e^{-\ell}} = 2\pi c \left( \frac{1}{\omega_{2, e^{-\ell}}} - \frac{1}{\omega_{4, e^{-\ell}}} \right) \]

\[ = 2\pi c \left( \frac{1}{e^{\rho_2} \omega_2 \sinh \rho_2} - \frac{1}{e^{\rho_2} \omega_4 \sinh \rho_2} \right) \]

\[ = 2\pi c \left( \frac{1}{e^{\rho_2} - 1} \right) \frac{1}{\omega_2 \sinh \rho_2} \]

\[ = \frac{2\pi c}{\omega_2} \frac{1}{\frac{1}{\omega_2} \left( \frac{e^{\rho_2} - 1}{\omega_2} \right) \frac{1}{\sinh \rho_2}} \]

\[ = \frac{2\pi c}{\omega_2} \frac{1}{\frac{e^{\rho_2} - 1}{\omega_2} \frac{1}{\sinh \rho_2}} \]

\[ = \frac{2\pi c}{\omega_2} \frac{1}{\frac{e^{\rho_2} - 1}{M_\omega c} \frac{1}{\sinh \rho_2}} \]

\[ = \frac{2\pi c}{\omega_2} \frac{1}{\frac{2\pi e h}{M_\omega c} \frac{1}{\sinh \rho_2}} \]

\[ = \frac{2\pi c}{\omega_2} \frac{1}{\frac{2\pi h}{M_\omega c} \frac{1}{\sinh \rho_2}} \]

\[ = \frac{h}{M_\omega c} \]

\[ = 2\text{-Compton wavelength} = \frac{h}{M_\omega c} \]
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Bouncing pulse wave (PW) vs (CW) shrinking laser
Bohr model has electron orbiting at radius \( r \) so centrifugal force balances Coulomb attraction to the opposite charged proton.

\[
\frac{mv^2}{r} = \frac{e^2}{4\pi \varepsilon_0 r^2}
\]

Bohr hypothesis: orbital momentum \( \ell \) is a multiple \( N \) of \( \hbar \) or

\[
\ell = m \nu r = N \hbar \quad (N = 1, 2, \ldots).
\]

This gives the atomic Bohr radius \( a_0 \)

\[
r = \frac{4\pi \varepsilon_0 \hbar^2}{me^2} N^2 \left(= r_{\text{Bohr}} = 5.28 E - 11 \text{ m}. = 0.528 \text{ Å} \text{ for } N=1\right)
\]

It also implies rear-relativistic electron speed \( \nu \) given as follows.

\[
\frac{\nu}{c} = \frac{\ell}{mrc} = \frac{1}{N} \frac{e^2}{4\pi \varepsilon_0 \hbar c} \quad \left(= 7.31 \text{E-3} = \frac{1}{137}. \text{ for } N=1\right)
\]

The ratio \( \alpha = \frac{e^2}{(4\pi \varepsilon_0 \hbar c)} = 1/137.036 \) is called the fine-structure constant \( \alpha \).

Now, do some numerology and so-called Dirac’s radius involving \( \omega_{\text{zwitterbegung}} \) where \( \omega_{\text{zwitterbegung}} = \frac{2mc^2}{\hbar} = 1.56E21 \text{ (radian)}Hz \)

\[
\omega_{\text{zwitterbegung}} r = c \quad \text{or} \quad r_{\text{Dirac}} = c / \omega_{\text{zwitterbegung}} = \hbar / 2mc = 1.93 \text{E-13 m} \text{ relates to the Compton wavelength}
\]
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Fig. 7.8 Space-time nets (a) PW zigzag paths bounce. (b) CW nodes squeeze like an accordion.