

Exercises to “Standard Model of Particle Physics”

Summer 2013

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Sheet 1

22.04.13

Exercise 1: ”Natural Units” [5 Points]

This is to recall the use of $\hbar = 1$, $c = 1$, etc.

- Find the connection of energy (GeV) with time (s), length (cm) and gram (g). Express millibarn in GeV^{-2} (1 barn = 10^{-24} cm²).
- One can also set the Boltzmann constant to one: $k_B = 1$. Find the connection between temperature (K) and energy (MeV) and between temperature (K) and time (s).
- The Planck mass M_{Pl} is given as $G_N = 1/M_{\text{Pl}}^2$, where G_N is Newton’s constant. Evaluate the Planck time and Planck length. Express the fundamental parameters c und \hbar in terms of the Planck units.

Exercise 2: 2-to-2 scattering [15 Points]

Consider a 2-to-2 scattering process $1 + 2 \rightarrow 3 + 4$.

- Calculate in the center-of-mass system the energies and momenta of the individual particles, and give their asymptotic ($s \gg m_i^2$) behavior.
- Show that the scattering angle θ in the center-of-mass system is given by

$$\cos \theta = \frac{s(t - u) + (m_1^2 - m_2^2)(m_3^2 - m_4^2)}{\sqrt{\lambda(s, m_1^2, m_2^2) \lambda(s, m_3^2, m_4^2)}}$$

- Calculate in the lab system the energies and momenta of the individual particles.
- Calculate the scattering angle θ in the lab system.

Bonus Exercise: Kinematics [10 Points]

- Show that the decay $e^- \rightarrow e^- \gamma$ is kinematically forbidden.
- In Grand Unified Theories the proton can decay into e^+ and π^0 . Show that this decay is kinematically allowed.
- Consider the process $pp \rightarrow ppp\bar{p}$, i.e. proton-proton collision with production of 4 protons. Calculate the threshold energy in the center-of-mass system, and the corresponding energy in the lab system.

- d) A photon γ ($k^2 = 0$) with 4-momentum $k^\mu = (E, E, 0, 0)$ scatters with an electron at rest. After the process the photon has 4-momentum $k^\mu = (E', E' \cos \theta, E' \sin \theta, 0)$. Show that

$$E' = \frac{E}{1 + \frac{E}{m_e} (1 - \cos \theta)}$$

Tutors:

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Tutorials homepage: <http://www.mpi-hd.mpg.de/manitop/StandardModel/exercise.html>

Hand-in of sheet:

during lecture on 29.4.

Discussion of sheet:

Thursday, 02.05. 2.15 pm, INF 227 SR 2.402

Friday, 03.05. 2.15 pm, INF 227 SR 1.403 (?)