Massachusetts Institute of Technology

Department of Physics

Course: 8.701 — Introduction to Nuclear and Particle Physics
Term: Fall 2020
Instructor: Markus Klute

Problem Set 2

handed out September 23rd, 2020

Problem 1: Complex scalar field [20 points]

The Lagrangian for a complex scalar field $\mathcal{L}_s = \frac{1}{2}(\partial_\mu\phi)^*(\partial^\mu\phi) - \frac{1}{2}m^2\phi^*\phi$ possesses a global $U(1)$ symmetry. Use Noether's theorem to identify the conserved current.

Problem 2: $A \to B + C$ [20 points]

Show that $|\vec{p}_{CM}| = \frac{1}{2m_A}\sqrt{(m_A^2 - (m_B + m_C)^2)(m_A^2 - (m_B - m_C)^2)}$ for $A \to B + C$.

Problem 3: $A + A \to A + A$ [20 points]

Draw all possible lowest-order diagrams for $A + A \to A + A$ in our toy theory and find the amplitude for this process assuming $m_B = m_C = 0$. Leave your answer in the form of an integral over the remaining four-momentum q.

Problem 4: $A + A \to B + B$ [20 points]

Calculate $\frac{d\sigma}{d\Omega}$ for $A+A \to B+B$ a) in the center-of-mass frame and b) in the lab frame at lowest order. Assume $m_B = m_C = 0$ in a toy theory without spin. For a), calculate the total cross section σ. For b), determine the non-relativistic and ultra-relativiistic limits.

Problem 5: QED Feynman diagrams [20 points]

Draw the leading-order Feynman diagrams(s) for the following processes:

- Compton scattering - $\gamma e^- \to \gamma e^-$
- Pair annihilation - $e^+ e^- \to \gamma\gamma$
- Light-by-light scattering - $\gamma\gamma \to \gamma\gamma$
- Moller scattering - $e^- e^- \to e^- e^-$
- Bhabha scattering - $e^+ e^- \to e^+ e^-$

8.701 Introduction to Nuclear and Particle Physics
Fall 2020