

Advanced quantum mechanics and quantum field theory, FS 2021

Blatt 6

Submission: 22.04.2021, 12:00H, on adam in the appropriate folder.

One file per submission please; the filename HAS TO contain your name, or the submission will not be corrected!

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- (1) **Feynman propagator for the quantum harmonic oscillator** (3 Punkte)
Show that the Feynman propagator for the quantum harmonic oscillator is given by

$$\tilde{G}(\omega) = \frac{1}{m} \frac{i}{\omega^2 - \omega_0^2 + i\epsilon}.$$

- (2) **Chapter 19 Expanding the S-matrix: Feynman diagrams** (3 Punkte)

- (a) Read and digest all of Chapter 19.
(b) Describe in your own words why it is advantageous to draw and work out Feynman diagrams in momentum space.

- (3) **Translation of Feynman diagrams into numerical expressions** (4 Punkte)
Write down the momentum-space amplitudes for the processes shown in the Feynman diagrams in Fig. 19.6.

- (4) **Feynman diagrams for the ABA theory** (4 Bonus-Punkte)
Consider the ABA theory which is defined by the Lagrangian

$$\mathcal{L} = \frac{1}{2} \partial_\mu \phi_A \partial^\mu \phi_A - \frac{1}{2} m_A^2 \phi_A^2 + \frac{1}{2} \partial_\mu \phi_B \partial^\mu \phi_B - \frac{1}{2} m_B^2 \phi_B^2 - \frac{g}{2} \phi_A \phi_B \phi_A$$

and describes the interactions of two scalar fields.

- (a) Draw the interaction vertex using a bold line for the A-field and a dashed line for the B-field.
(b) Draw the Feynman diagrams that contribute to the scattering amplitude $\langle q_A | \hat{S} | p_A \rangle$ up to fourth order in g (here, p_A refers to an A-particle in momentum state p). Write down the expressions for the amplitudes of the connected diagrams among them. You may ignore symmetry factors.
(c) Repeat (b) for $\langle q_B | \hat{S} | p_B \rangle$.
(d) Draw the Feynman diagrams that contribute to the A-particle scattering amplitude $\langle q_{A1} q_{A2} | \hat{S} | p_{A2} p_{A1} \rangle$ up to fourth order.
(e) Give the symmetry factors for the diagrams in (b) – (d).