Problem 1 [Simplest QED process: $e^+e^- \rightarrow \mu^+\mu^-$] Calculate the unpolarized cross section for the process $e^+e^- \rightarrow \mu^+\mu^-$ to lowest order of perturbation theory. Assume that electrons are massless and muons have mass $m_\mu$.

The amplitude for the considered process is given by the following diagram:

We will follow the derivation by M. Peskin, V. Schroeder, *An Introduction to Quantum Field Theory* (Section 5.1).

The final formula for the total cross section should be obtained in the following form:

$$\sigma_{\text{total}} = \frac{4\pi\alpha^2}{3E_{\text{cm}}^2} \sqrt{1 - \frac{m_\mu^2}{E^2}} \left(1 + \frac{1}{2} \frac{m_\mu^2}{E^2}\right),$$

(1)

where $\alpha$ is the fine-structure constant, $E_{\text{cm}}$ is the centre-of-mass energy, $E = E_{\text{cm}}/2$. 