# Homework I

**Suggested reading:**

1. Schwartz, chapter 20.
2. To learn more see Peskin-Schroeder section 6.5.

**due date September 24th**

1. Consider the processes $e^+e^- \to \mu^+\mu^-$ and $e^+e^- \to \mu^+\mu^-\gamma$ in QED and that the charge of the electron ($Q_e$) and the muon one ($Q_\mu$) are arbitrary. Assume that the mass of the electron and the muon are zero. Working in $d = 4 - \epsilon$ dimensions and calculating all the intermediate steps, evaluate:

   (a) the cross section for this process at order $Q_e^2 Q_\mu^2$.

   (b) the one-loop $\mathcal{O}(Q_e^2 Q_\mu^6)$ contribution to $e^+e^- \to \mu^+\mu^-$, separating the infrared and ultraviolet divergences. For that you need to take the limit $\epsilon \to 0$ only after integrating over the Feynman parameters.

   (c) renormalize the ultraviolet divergences from the previous item.

   (d) evaluate the cross section to order $\mathcal{O}(Q_e^2 Q_\mu^6)$ of the process $e^+e^- \to \mu^+\mu^-\gamma$ in $d$ dimensions. Define carefully the phase space in this case.

   (e) Add the previous results showing that the inclusive process $e^+e^- \to \mu^+\mu^-(\gamma)$ is free of infrared divergences.

   Hint: use Mathematica to obtain the poles and finite parts in the limit $\epsilon \to 0$.