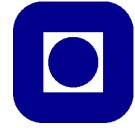


FY3403 Particle physics  
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**Problem 14. Averaged scattering amplitude and cross section**

Consider the spin-averaged amplitude for electron-muon scattering:

$$\langle |\mathcal{M}|^2 \rangle = \frac{g_e^4}{4(p_1 - p_3)^4} \text{Tr}\{\gamma^\mu(\not{p}_1 + mc)\gamma^\nu(\not{p}_3 + mc)\} \times \text{Tr}\{\gamma_\mu(\not{p}_2 + Mc)\gamma_\nu(\not{p}_4 + Mc)\} \quad (1)$$

where  $m$  is the electron mass,  $M$  is the muon mass,  $p_1$  corresponds to the incoming electron,  $p_2$  is the incoming muon,  $p_3$  is the outgoing electron, and  $p_4$  is the outgoing muon. Compute the traces in this expression and evaluate the resulting expression in the CM-frame under the assumption of high-energy scattering ( $m, M \rightarrow 0$ ). Finally, obtain the CM differential cross section expressed with (among other things) the electron energy  $E$  and the scattering angle  $\theta$ .

**Problem 15. Loop diagram**

Consider the vacuum polarization diagram (see *e.g.* Griffiths book chapter 7) where a virtual photon momentarily splits into an electron-positron pair. This is a fourth-order correction to lepton-lepton' scattering (*e.g.* electron-muon scattering). Derive in detail the scattering amplitude  $\mathcal{M}$  for this process (it is sufficient to write down the amplitude in integral form: you do not have to evaluate the traces and perform the integration).