Teoria do Campo – Problem Series 2

Curso de Engenharia Física Tecnológica – 2017/2018

`Due on the 25/5/2018`

`Version of 15/04/2018`

2.1 Evaluate the traces necessary for Compton scattering (Eqs. (5.27), (5.28) e (5.29))

$$\sum_{s,s'} |\mathcal{M}_1|^2 = \text{Tr}\left[(\not{p}' + m)\Gamma_1(\not{p} + m)\overline{\Gamma}_1\right]$$

$$\sum_{s,s'} |\mathcal{M}_2|^2 = \text{Tr}\left[(\not{p}' + m)\Gamma_2(\not{p} + m)\overline{\Gamma}_2\right]$$

$$\sum_{s,s'} (\mathcal{M}_1\mathcal{M}_2^\dagger + \mathcal{M}_1^\dagger\mathcal{M}_2) = \text{Tr}\left[(\not{p}' + m)\Gamma_1(\not{p} + m)\overline{\Gamma}_2\right] + \text{Tr}\left[(\not{p}' + m)\Gamma_2(\not{p} + m)\overline{\Gamma}_1\right]$$

and show that the final result can be written as Eq. (5.32),

$$\frac{1}{4}\sum_{s,s'}\sum_{\lambda,\lambda'}\{|\mathcal{M}_1|^2 + |\mathcal{M}_2|^2 + \mathcal{M}_1\mathcal{M}_2^\dagger + \mathcal{M}_1^\dagger\mathcal{M}_2\} = 2e^4\left[\left(\frac{k}{k'}\right) + \left(\frac{k'}{k}\right) - \sin^2\theta\right]$$

Note: These are complicated traces. You should learn how to use FeynCalc to evaluate these traces.

2.2 Consider in the SM of electroweak interactions the following processes:

$i)\ e^-e^+ \to \nu_e\overline{\nu}_e$ $\qquad ii) H \to W^+W^-\gamma$

$iii)\ H \to \gamma\gamma$ $\qquad iv)\ e^-e^+ \to W^+W^-$

a) Use the program QGRAF to find the diagrams that contribute in lowest order. Neglect the Higgs interactions with fermions except in *iii)*.

b) **Draw** the diagrams and indicate the relative signs among the diagrams. Do not do any calculations.

2.3 Consider the process $\nu_e(p_1) + e^-(p_2) \to \nu_e(p_3) + e^-(p_4)$ in the SM.

a) Evaluate the differential cross section in the CM frame, as a function of the center of mass energy, $\sqrt{s}$, and scattering angle θ defined as the angle between the incoming ν_e and outgoing ν_e. Neglect the fermion masses.

b) Evaluate now the total cross section in the CM frame, as a function of the center of mass energy, $\sqrt{s}$, assuming that $\sqrt{s} \ll m_W, m_Z$. Show that it can be written as

$$\sigma = \frac{\lambda}{\pi} G_F^2 s$$

Determine the constant λ.

c) Make a plot of the total cross section as a function of $\sqrt{s}$, for 0.1 GeV$< \sqrt{s} < 200$ GeV, using the results of a). Superimpose the results of b). Check the validity of the approximation.

d) Use CalcHEP to evaluate this same process. Superimpose the points from CalcHEP on your plot. **Note**: You should check that the physical constants are the same in both cases.