May 27, 2009 Exercise Sheet 2

**Computational Methods in Particle Physics**

University of Zurich and ETH Zurich

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## Question 1: Spinor formalism for massive vector bosons

(a) Verify that the following relations are valid for the polarisation vectors of massive vector bosons

$$\begin{aligned} p^\mu \varepsilon^0_\mu(p,n,m) &= 0 \\ \varepsilon^\pm \cdot \varepsilon^\mp &= -1 \\ \varepsilon^0 \cdot \varepsilon^0 &= -1 \\ \varepsilon^\pm \cdot \varepsilon^0 &= 0\,. \end{aligned}$$

(b) Show that the completeness relation is fulfilled:

$$\sum_{\lambda=+,-,0} \varepsilon^\mu_\lambda \, (\varepsilon^\nu_\lambda)^* = -g^{\mu\nu} + \frac{p^\mu p^\nu}{p^2} \tag{1}$$

## Question 2: Generalized Unitarity

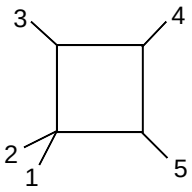


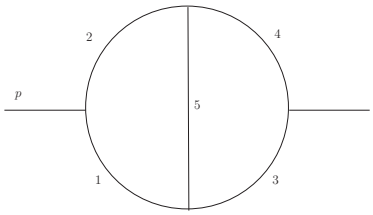

Figure 1: Box integral with propagator 1 pinched, $p_{12}^2 \neq 0$.

Using quadruple cuts, compute the coefficient of a box integral occurring in the pure Yang-Mills theory amplitude $A_5^{1-\text{loop}}(1^-, 2^-, 3^+, 4^+, 5^+)$, shown in figure 1. The integral is given by ($p_{ij} = p_i + p_j$, $i\delta$ terms are implicit)

$$I_4^D(S \setminus \{1\}) = \int d\bar{l} \frac{1}{l^2 (l+p_{12})^2 (l+p_{123})^2 (l-p_5)^2}\,. \tag{2}$$

*please turn*

## Question 3: "Kirchhoff rules" for multi-loop graphs




Determine the functions $\mathcal{F}$ and $\mathcal{U}$ for the graph shown in figure 2 using the topological cutting rules.