KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
Particle Physics (Phys. 441)

Assignment # 1
Due to Monday October 18, 2004

1. Yukawa predicted that a light mass particle should be the mediator for the strong force. Use hand-wave argument to calculate the mass of this particle.(5 pts.)

2. Convert the following MKS units into natural units, i.e. in terms of energy (GeV):

   (a) 1 N. (5 pts.)

   (b) Newton's gravitational constant G. (5 pts.)

3. Use the uncertainty principle to determine the range of a force in terms of the mass of the mediator. Use this relation to find the range of the:

   (a) electromagnetic force. (5 pts.)

   (b) weak force. (5 pts.)

4. Consider two protons that are separated by 1 fm. Estimate the order of magnitudes of the four forces, i.e., find the ratio

$$F_{strong} : F_{em} : F_{weak} : F_{gravitational}$$

   (20 pts.)

5. At what energy scale does the weak interaction become significant? (5 pts.)

6. Calculate the ratio of the tauon lifetime τ_τ to the muon lifetime τ_μ. You may use the following branching ratios: B($\mu^- \to e^- \bar{\nu}_e \nu_\mu$) = 1 and B($\tau^- \to e^- \bar{\nu}_e \nu_\tau$) = 0.177. Compare your result with the experimental ratio. (You can obtain the experimental lifetimes from the particle data book which is available online at http://pdg.lbl.gov/). (20 pts.)

7. Examine the following processes, and state for each one whether it is possible or impossible. In the former case, state the leading interaction that is responsible and draw the Feynman diagram for the process; in the latter case cite a conservation law that prevents it from occurring

   (a) $e^+ e^- \to \tau^+ \tau^-$. (2 pts.)

(b) $e^+ e^- \rightarrow \pi^+ \pi^-$. (2 pts.)

(c) $e^- p \rightarrow e^- n \pi^+$. (2 pts.)

(d) $\bar{\nu}_e e^- \rightarrow \nu_e e^+$. (2 pts.)

(e) $e^+ e^- \rightarrow \bar{\nu}_\mu \nu_\mu$. (2 pts.)

(f) $p \bar{p} \rightarrow \Sigma^+ \Sigma^-$. (2 pts.)

(g) $\Omega^- \rightarrow \Xi^0 K^-$. (2 pts.)

Numerical Analysis:

As has been mentioned in class, the QCD coupling constant α_s depends on the momentum transfer, Q^2, between particles. To a good approximation, it is given by

$$\alpha_s(Q^2) = \frac{12\,\pi}{(11N_c - 2N_f)\ln(Q^2/\Lambda^2)}$$

where:
N_f is the number of flavors; u, d, s, ...,
N_c is the number of colors.
Λ is a scale parameter that must be determined experimentally. The value of Λ is not exact but it ranges from 0.1 GeV to 0.4 GeV.

1. Use Any program to plot a graph of $\alpha_s(Q^2)$ from $Q^2 = 1$ GeV^2 to $Q^2 = 2000$ GeV^2 for the following cases:

   (a) for $\Lambda = 0.1$ GeV.

   (b) for $\Lambda = 0.2$ GeV.

   (c) for $\Lambda = 0.3$ GeV.

2. Find $\alpha_s(1)$, $\alpha_s(10)$ and $\alpha_s(100)$ in the above three cases.

3. What is the condition that makes the QCD coupling constant behaves like the QED coupling constant,i.e. screening effects rather that antiscreening.

(16 pts.)