FYS3500 - Problem set 4

Spring term 2019

Updated: Problem 6a $\mu \to \mu^+$
Updated: Problem 1 – only 1 configuration for each state
Updated: Problem 5 – corrected reaction

Problem 1 – in class: Shell model

a) The ground-state spin of ^{17}F is $J^\pi = 5/2^+$, and of the first excited state it is $J^\pi = 1/2^+$. The second excited state is $J^\pi = 1/2^-$. Give the configurations for protons and neutron of in the ground-state and first excited state and for the second excited state.

Problem 2 – in class: Particle physics intro

a) What are elementary particles?

b) What are the force carriers of the different processes?

c) Argue for the existence of antiparticles using the Dirac picture of the vacuum. Name at least one experimental evidence of antiparticles.

Problem 3

Draw the topologically distinct Feynman diagrams that contribute to the following process in lowest order

a) $\gamma + e^- \to \gamma + e^-$,

b) $e^+ + e^- \to e^+ + e^-$,

c) $\nu_e \bar{\nu}_e$ elastic scattering. (Hint: There are (at least) two such diagrams for each reaction)

Problem 4

Draw one forth-order diagram for each of the reactions

a) $\gamma + e^- \to \gamma + e^-$,

b) $e^+ + e^- \to e^+ + e^-$

c) and the two forth-order diagrams for $e^- + \mu^+ \to \nu_e + \bar{\nu}_\mu$.

Problem 5

For total centre-of-mass energies up to a fre GeV, the cross-section for the reaction $\nu_e + e^+ \to \mu^+ + \nu_\mu$ is given by $\sigma = G_F^2 E^2/\pi$ in natural units, where G_F is the Fermi coupling constant. What is the cross-section in (pico)barns at an energy of E=3 GeV?

Problem 6

Which of the following reactions are allowed, and which are forbidden, by the conservation laws appropriate to weak interactions?

a) $\nu_\mu + p \to \mu^+ + n$,

b) $\nu_e + p \to e^- + \pi^+ + p$,

c) $\nu_\tau + e^- \to \tau^- + \nu_e$

d) $\tau^+ \to \mu^+ + \bar{\nu}_\mu + \nu_\tau$.

Problem 7

In MS, sec. 2.3.1. it is stated that electron neutrinos interact with electrons in a different wat from muon and tauon neutrinos. Justify this remark by considering the lowest-order Feynman diagrams for $\nu_e + e^- \to \nu_e + e^-$ and $\nu_\mu + e^- \to \nu_\mu + e^-$.

Problem 8

Which of the following reactions are allowed, and which are forbidden? If they are allowed, classify intro strong, electromagnetic and weak reactions.

a) $\Lambda \to \pi^+ + e^- + \bar{\nu}_e$

b) $\pi^- \to \pi^0 + e^- + \bar{\nu}_e$

c) $p + \bar{p} \to \pi^+ + \pi^- + \pi^0$

d) $\Lambda + p \to K^- + 2p$

e) $K^+ \to \pi^0 + \mu^+ + \bar{\nu}_\mu$

f) $K^+ \to \pi + + e^- + \bar{\nu}_e$

g) $K^- \to \pi - + e^+ + e^-$

h) $\gamma + p \to \pi^- + n$

i) $D^- \to K^+ + 2\pi^-$

j) $\pi - + p \to n + e^- + e^+$