Quiz 4

NAME: _____ **SCORE:** _____

Subject: Introduction to Nuclear and Particle Physics
Date: Tuesday 7th March 2023
Duration: 60 minutes
Credits: 16 points, each question is worth 1 point

This quiz consists of closed-book concept questions. Provide answers to the following items.

mesons: $D^0(c\bar{u})$, $K^-(s\bar{u})$, $\pi^+(u\bar{d})$, $\pi^-(d\bar{u})$, $\pi^+(u\bar{u}), (\bar{d}d)$

1. Are the following processes possible or impossible? If impossible, which conservation law is violated? If possible, which force is involved in the interaction?

   $e^- + p^+ \to \nu_e + \pi^0$ impossible (baryon number conservation)

   $\bar{\nu}_e + p \to n + e^+$ possible (weak force)

   $\pi^0 \to \gamma + \gamma$ possible (electromagnetic)

   $\mu^- \to e^- + \bar{\nu}_e$ impossible (lepton number conservation)

   $\pi^+ + n \to \pi^- + p$ impossible (charge conservation)

2. Briefly explain what is the asymptotic freedom.

   The coupling constant for the strong force varies with distance: large distance - large, short distance - small, this running constant is due to the quark and gluon polarization, which shield the colours of quarks.

3. What type of interaction (trough which force) do we have if there are neutrinos involved in the interaction?

   weak interactions (weak force) neutrinos only interact trough the weak force

4. Briefly explain why can gluons couple to other gluons directly and form glueballs?

   gluons carrie colour, so they can couple to quarks and gluons. A structure with only gluons is a glueball.

5. What is the overall colour of a neutron? Briefly explain.

   neutrons are coulorless. All natural particles are coulourless. So they have the same amount of all coulors

6. Can muons (μ) interact trough the strong force?

No, they don't carrie colour

7. Briefly explain what is the OZI rule?

Reactions where particles couple trough high energy gluons only are surpressed compared to reactions with low energy gluons

8. Briefly explain what is a semi leptonic process?

A weak interaction that involves both quarks and leptons.

9. Which ones are the stable particles in nature?

$e^-, \nu, p^+, \gamma, (n^0)$

10. Is flavour conserved in the weak interaction? Briefly explain.

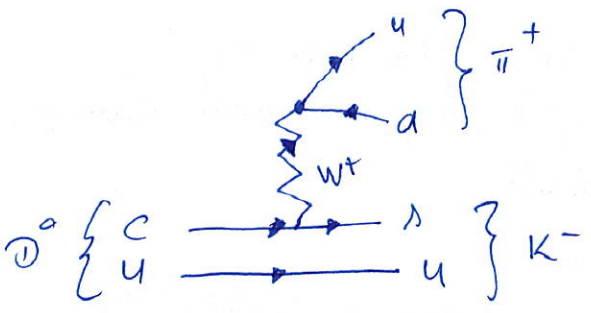
No, the weak interaction doesn't conserve flavour. u quarks for example can be converted into d quarks in β decay.

11. Why does the neutron have a relatively long lifetime compared to other particles that decay trough the weak interaction?

The lifetime depends on the mass difference of the particles involved in decays. Since the proton is almost the same mass as the neutron, the neutron has a relatively long lifetime.

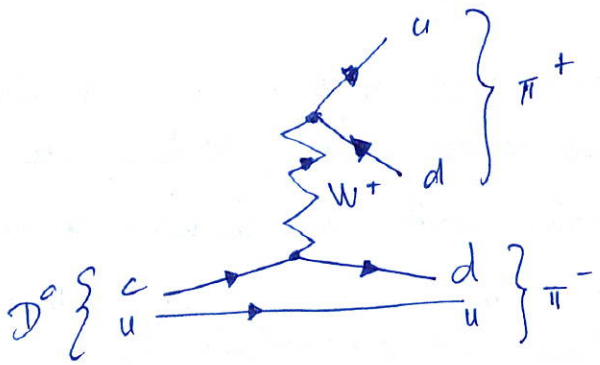
12. Draw Feynman diagrams for these decays: $D^0 \to K^- + \pi^+$, $D^0 \to \pi^- + \pi^+$ Which of these decays is more likely to happen? Briefly state why.

$D^0 \to K^- + \pi^+$



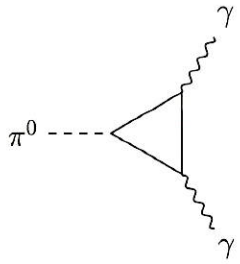
$\Rightarrow$ more likely to happen
neither vertex crosses generations

$D^0 \to \pi^- + \pi^+$

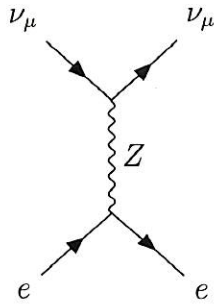


$\to$ less likely
$\to$ one vertex crosses generations
$c \to d$

13. What processes do the following Feynman diagrams represent?



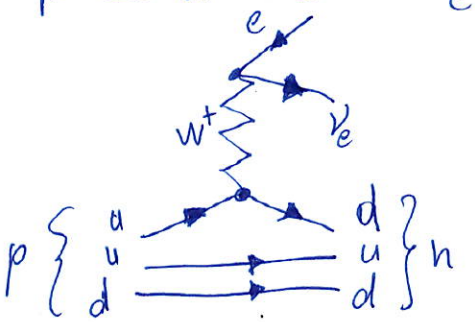
pion decays $\pi^0 \to \gamma + \gamma$
or annihilation of $d + \bar{d}$ or $u + \bar{u}$



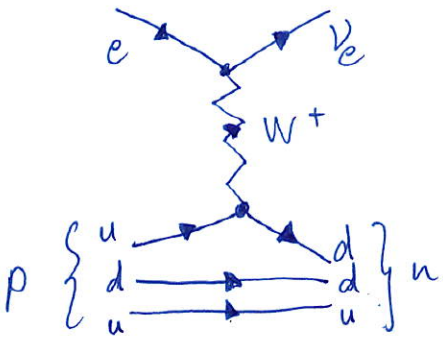
$\nu_\mu + e \to \nu_\mu + e$
electron-neutrino scattering

14. Draw a Feynman diagram for β^+ decay.

$p^+ \to n^0 + e^+ + \nu_e$



15. Draw a Feynman diagram for electron capture. $e^- + p^+ \to n^0 + \nu_e$



16. Draw a Feynman diagram for muon decay: $\mu^- \to \nu_\mu + e^- + \bar{\nu}_e$.