Quiz 3

NAME: _____ SCORE: _____

Subject: Introduction to Nuclear and Particle Physics
Date: Tuesday 14 February 2023
Duration: 60 minutes
Credits: 20 points, each question is worth 1 point

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

1. What is the neutron reproduction factor?
It is used to control the number of neutrons in nuclear reactions.
It expresses how many neutrons can start nuclear reactions in the next cycle per 1 neutron in the initial cycle. $k=1$ → critical reaction pile, $k<1$ → subcritical, $k>1$ → super critical

2. What are the 4 factors that determine the neutron reproduction factor in controlled reaction?
η – mean number of fission produced fast neutrons (ν)
ε – fast fission fraction
p – resonance capture probability
f – thermal utilization factor

3. What does it mean that a reaction pile is subcritical?
The reactions will stop at an exponential rate. There are two few neutrons to keep the chain reaction going

4. What are conversion or breeder reactors used for?
To produce fissile elements from non-fissile elements

5. What is the mechanism for nuclear fusion? Shortly explain.
The fusing nucleons need to overcome the nuclear potential barrier. This happens trough tunneling → basically a reverse α-decay.

6. Write the most basic fusion reaction for producing deuterium.
$^1H + {}^1H \rightarrow {}^2H + e^+ + \nu_e$

7. Finish the following reaction, what is the name of the reaction? ${}^2H + {}^2H \rightarrow {}^3He + n$
D–D or deuterium-deuterium reaction or : ${}^3H + p$

8. Finish the following reaction, what is the name of the reaction? ${}^3H + {}^2H \rightarrow$ ${}^4He + n$

D-T, deuterium - tritium reaction

9. What is the net fusion process in the Sun? What is the name of the reaction cycles of the fusion in the Sun?

${}^1H + {}^1H + {}^1H + {}^1H \rightarrow He$

proton - proton chain (pp chain)

10. How does the released energy get distributed between the fusion products? Which fusion product caries most of the energy when hydrogen is fusing into helium?

The energy gets distributed based on the mass ratio of the fusion products. e.g. between the He and n.

The n gets most of the energy (70-80 %)

11. How do we get information from the fusion processes inside the Sun? Briefly explain.

There are many neutrinos (ν) produced during the fusion, which escape the core of the Sun undisturbed because they are very weakly interacting particles.

12. How is the plasma confined for controlled nuclear fusion experiments? Name the two basic methods and briefly explain them.

→ magnetic confinement: e.g. tokamak (torus)

→ inertial confinement: e.g. lasers or particle beams

13. Which is the most widely used fusion reaction in nuclear fusion experiments? Briefly explain why this reaction is used?

D-T reaction

Tritium is very rare, it only gets produced as a by product in certain nuclear fission reactors.

However, this reaction produces the most energy at "relatively" low temperatures.

14. Name the 4 first generation elementary particles.

e electron
ν_e electron neutrino
u up quark
d down quark

15. What is the difference between first, second and third generation particles?

The mass. First generation particles are lighter compared to the 2nd and 3rd generation particles.

16. How many different bosons are there? List them.

13: photon, 8 gluons, W^+, W^-, Z, Higgs boson

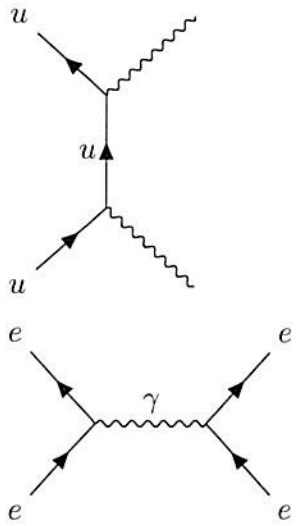
17. What do the internal and external lines represent in Feynman diagrams?

external lines: real particles → what is the interaction
internal lines: virtual particles → how is the interaction happening

18. Can a neutrino participate in a quantum electrodynamical (QED) interaction? Briefly explain.

No, the neutrino doesn't have charge, so it can not participate in QED.

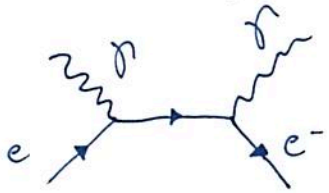
19. What processes do the following Feynman diagrams represent?



$u + \bar{u} \rightarrow \gamma + \gamma$
pair annihilation
or π^0 decay (annihilation)

$e + e^+ \rightarrow e^- + e^+$
electron-positron scattering
Bhabha scattering
or coulomb scattering

20. Draw a Feynman diagram for Compton scattering.



$e^- + \gamma \rightarrow e^- + \gamma$