7. Briefly explain what are the β delayed neutrons in nuclear fission?
These are neutrons that are produced from β decay of the fission products.

8. What is the most common fuel in controlled nuclear reactors used for power generation?
^{235}U mixed with ^{238}U

9. How can we extract energy from a nuclear fission reactor to generate electricity?
There is usually a cooling liquid that extracts heat from the reactor. This heat is then used to power a steam turbine for electricity production.

10. What does thermonuclear fusion refer to?
If we achive suitable fusion conditions (high temperature and pressure) trough heating the fuel for fusion.

11. Finish the following reaction: $^1H + ^1H \rightarrow$ $^2H + e^+ + \nu_e$

12. Could we fuse carbon (^{12}C) at the same pressure and temperature as hydrogen? Briefly explain.
No. Heavier elements have higher Coulomb barriers, which means that we need to provide more energy (higher temp. & pressure) to be able to fuse ^{12}C compared to ^1H.

13. What does the reaction rate in nuclear fusion depend on.
The reaction rate depends on the probability of fusion, which depends on the Coulomb barrier, the temperature and the pressure.

Final exam

NAME: _____ SCORE: _____

Subject: Introduction to Nuclear and Particle Physics
Date: Monday 13th March 2023
Duration: 120 minutes
Credits: 30 points, each question is worth 1 point

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

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

baryons: $\Lambda^0(uds)$, $\Sigma^+(uus)$, $\Sigma^-(dds)$

1. Write the reaction fro α decay. What is the theoretical explanation for it decay?

$^{A}_{Z}X_N \rightarrow {}^{A-4}_{Z-2}X_{N-2} + {}^{4}He\ (\alpha)$

The α particle and the daughter nucleus already exist inside the parent nucleus and the α particles tunnels out of the potential barrier.

2. Briefly explain what is the mass defect?

The mass of a nucleus is smaller than ~~them~~ the sum of the mass of the nucleids that are inside it. The mass difference is the binding energy

3. Trough which two forces can we measure the nuclear radius?

- strong force
- electromagnetic force

4. What does it mean that the half life of a particle is 3 days?

If we have an amount of radioactive particles in 3 days half of the particles will decay.

5. Briefly explain what is nuclear fission?

In nuclear fission a heavy nucleus splits in two nucleis.

6. Do elements undergoing nuclear fission produce fission products with the same mass, e.g. do they split in half?

Typically no. Usually there is a ~~heavier~~ heavy and a ~~lighter~~ light fission product.

14. In nuclear fusion the reacting particles typically have relatively small kinetic energies of ~1 - 10keV, which would not be sufficient to overcome the nuclear Coulomb potential. How can nuclear fusion actually happen?

Tunneling

15. Does the strong force conserve flavour?

Yes. the strong force only changes the coulour, but not the flavour

16. Which particle generation do the s and the c quark belong to?

2nd generation

17. Is strangeness conserved in the weak interaction? Briefly explain?

No. the strange quark can decay into other flavours. This is explained by the coupling of the quarks with the Kobayashi-Maskawa matrix

18. Briefly explain what is a purely hadronic process?

A weak interaction only involving quarks.

19. Which particles can interact trough the strong force? Which particle is the force carrier?

quarks. force carrier: gluons

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

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

$\Lambda \rightarrow p + \pi^-$ possible (weak interaction)

$\Sigma^+ + n \rightarrow \Sigma^- + p$ impossible (charge conservation)

$n + \bar{n} \rightarrow \pi^- + \pi^+ + \pi^0$ possible (strong interaction)

$p \rightarrow e^+ + \gamma$ impossible (baryon number, lepton number)

21. Briefly explain what is vacuum polarisation?
~~It is possible that~~ in the vacuum around an electric charge, we have virtual e^- and e^+ which align with the charge and produce a type of polarization that shields the charge.

22. Briefly explain what is isospin? Name an example of a phenomena that can be explained using isospin.
Isospin is a quantum number related to an internal symmetry of the strong force. It can explain why we have bound $p+n$ in a deuteron, but no bound p-p or n-n pairs.

23. What conservation law does rotational symmetry correspond to?
angular momentum, spin

24. What are Abelian groups?
groups, where all elements contute: $R_i R_j = R_j \cdot R_i$

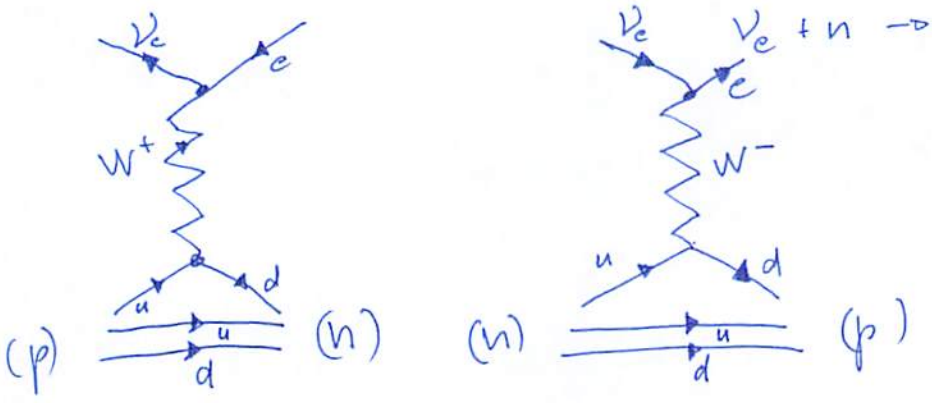
25. What is the Noether theorem?
every symmetry in nature yields a conservation law and every conservation law reflects a symmetry

26. What type of a particle is a spin $\frac{3}{2}$ particle?
fermions, baryons

27. Briefly explain what is an internal symmetry.
A symmetry that is not related to 4D regular space-time, but only to an internal property of a particle. e.g. isospin

28. A quark and antiquark are bound together. What type of a particle do you get? What are the possible spins of the bound particle, if the orbital angular momentum is zero?
a meson. the possible spins are: 0 or 1.

29. Draw a Feynman diagram for inverse β decay. $\bar{\nu}_e + p \to e^+ + n$



30. Draw a Feynman diagram for the following process: $\Lambda \to n^0 + \pi^0$.