Particles Questions (ANSWERS) for A-level Physics

BASIC

1. Which particle mediates the electromagnetic force?

The (virtual) photon

2. What is the charge of a down quark?

-1/3 (elementary charge)

3. What is the relative mass of a neutron compared to a proton?

Roughly equal (the neutron is very slightly heavier than a proton)

4. What is the definition of a fundamental particle (sometimes called an elementary particle)?

A particle that cannot be broken down further – it is not made up of smaller particles.

5. How many types of quarks are there?

There are actually six in total (up, down, strange, top, bottom, and charm) but you only need to be familiar with up, down and strange for A-level.

6. What combination of quarks forms a proton?

uud (two ups and one down)

7. Which type of fundamental particle is the electron?

An electron is a lepton

8. What is the name given to the force that holds quarks together inside protons and neutrons?

The strong nuclear force

INTERMEDIATE

9. What are baryons and how do they differ from mesons?

- *Baryons and mesons are both hadrons*
- *Baryons are made up of 3 quarks*
- *Mesons are made up from 1 quark and 1 antiquark*

10. Which interaction is responsible for beta decay?

Weak nuclear force (a quark changes flavour as a neutron turns into a proton and only a weak interaction can change a quark)

11. State the conservation laws that apply to particle interactions.

- *Charge is conserved*
- *Lepton number is conserved*
- *Baryon number is conserved*

[strangeness is conserved in strong interactions. Momentum & energy must also be conserved]

12. What is the difference between a hadron and a lepton?

A hadron is not fundamental, it is made up of quarks and experiences the strong nuclear force. A lepton is a fundamental particle and does not experience the strong nuclear force.

13. Name two mesons and the quarks that make them up.

Any two from: π^+ *is* $u\bar{d}$, π^- *is* $\bar{u}d$, π^0 *is either* $\bar{u}u$ *or* $\bar{d}d$

κ^+ *is* $d\bar{s}$, κ^- *is* $\bar{d}s$, κ^0 *is* $s\bar{s}$

14. Explain what is meant by quark confinement.

Quarks do not exist in isolation, they only exist with other quarks to form other particles.

15. What property is conserved in all fundamental interactions, including weak interactions, even when some symmetries are violated?

Charge is a physical property and it is always conserved in any interaction

ADVANCED

16. What are neutrinos, and why are they difficult to detect?

Neutrinos are leptons. They have no charge and almost no mass and so very rarely interact with other particles. This makes them difficult to detect.

17. How does the mass-energy equivalence principle ($E=mc^2$) relate to particle physics experiments in accelerators?

Particles are accelerated so that they gain kinetic energy which is then converted into other massive particles when they collide.

18. What are gauge bosons, and what role do they play in the Standard Model?

Guage bosons are virtual particles that are the force carriers during particle interactions.

PARTICLE INTERACTIONS

19. Is the following interaction allowed according to conservation laws? $\pi^+ \rightarrow \mu^+ + \nu_\mu$

Charge:	$+ \rightarrow + + 0$	✓	
Baryon:	$0 \rightarrow 0 + 0$	✓	*Yes, this is possible*
Lepton:	$0 \rightarrow -1 + 1$	✓	

20. Determine whether the following decay is allowed: $n \rightarrow p + e^- + \bar{\nu}_e$

Charge:	$0 \rightarrow + + - + 0$	✓	
Baryon:	$1 \rightarrow 1 + 0 + 0$	✓	*Yes, this is possible*
Lepton:	$0 \rightarrow 0 + 1 + -1$	✓	*[this is beta minus decay – learn it]*

21. Is the following process possible? $\Sigma^+ \rightarrow p + \pi^-$

Charge: $^+ \rightarrow {}^+ + {}^-$ ✗ *not possible*

22. Can this interaction occur? $K^0 \rightarrow \pi^+ + e^- + \bar{\nu}_e$

Charge:	$^0 \rightarrow {}^+ + {}^- + {}^0$ ✓	
Baryon:	$0 \rightarrow 0 + 0 + 0$ ✓	*Yes, this is possible*
Lepton:	$0 \rightarrow 0 + 1 + -1$ ✓	

23. Check whether the following interaction is possible: $p + \bar{p} \rightarrow \gamma + \gamma$

Charge:	$^+ + {}^- \rightarrow 0 + 0$ ✓	
Baryon:	$1 + 1 \rightarrow 0 + 0$ ✓	*Yes, this is possible*
Lepton:	$0 + 0 \rightarrow 0 + 0$ ✓	*[this is proton anti-proton annihilation]*

24. Can the following reaction occur according to conservation laws? $n \rightarrow p + e^-$

Charge:	$^0 \rightarrow {}^+ + {}^-$ ✓	
Baryon:	$1 \rightarrow 1 + 0$ ✓	*No, this is not possible*
Lepton:	$0 \rightarrow 0 + 1$ ✗	

25. Is the following interaction possible based on conservation laws? $\nu_\mu + n \rightarrow p + \mu^-$

Charge:	$0 + 0 \rightarrow {}^+ + {}^-$ ✓	
Baryon:	$0 + 1 \rightarrow 1 + 0$ ✓	*Yes, this is possible*
Lepton:	$1 + 0 \rightarrow 0 + 1$ ✓	

26. Is the following process possible? $\Sigma^- \rightarrow n + e^- + \bar{\nu}_e$

Charge:	$- \rightarrow 0 + - + 0$ ✓	*Yes, this is possible*
Baryon:	$1 \rightarrow 1 + 0 + 0$ ✓	*[a sigma particle is a strange baryon but strangeness*
Lepton:	$0 \rightarrow 0 + 1 + -1$ ✓	*does not need to be conserved because this is a weak*
		Interaction because quarks change flavour]

27. Can this interaction occur? $K^+ \rightarrow \pi^0 + \pi^+$

Charge:	$+ \rightarrow 0 + +$ ✓	*[this is a strong interaction as it involves only hadrons*
Baryon:	$0 \rightarrow 0 + 0$ ✓	*so we need to check for strangeness]*
Lepton:	$0 \rightarrow 0 + 0$ ✓	*Strangeness:* $+1 \rightarrow 0 + 0$ ✗ ∴ *not possible*

28. Check whether the following interaction is possible: $\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu$

Charge:	$+ \rightarrow + + 0 + 0$ ✓	
Baryon:	$0 \rightarrow 0 + 0 + 0$ ✓	
Lepton:	$-1 \rightarrow -1 + 1 + 1$ ✗	∴ *not possible*

29. Can the following reaction occur according to conservation laws? $p + p \rightarrow p + n + \pi^+$

Charge:	$+ + + \rightarrow + + 0 + +$ ✓	*Strangeness:* $0 + 0 \rightarrow 0 + 0 + 0$ ✓
Baryon:	$1 + 1 \rightarrow 1 + 1 + 0$ ✓	*[checking the rest energy, however, we can see that*
Lepton:	$0 + 0 \rightarrow 0 + 0 + 0$ ✓	*there is 141MeV more rest energy after the interaction*
		but this is low enough to be achievable by accelerating the protons]

30. Is the following interaction possible based on conservation laws? $p + p \rightarrow p + n + e^+ + e^-$

Charge:	$+ + + \rightarrow + + 0 + + + -$ ✗	∴ *not possible*