AQA

A Level

A Level Physics

Particles (Answers)

Name:

Total Marks: /30

1. This question explores the fundamental forces that are invoked in the standard model and that act at the quantum level.

Total for Question 1: 10

(a) State the three fundamental interactions that are described by the Standard Model. [2]

Solution: Electromagnetic, strong nuclear, weak

(b) Describe the nature of the strong nuclear force and sketch a graph to show its variation with distance. [4]

Solution: It acts between all nucleons but is effective only at very short range. It is repulsive below 0.5 fm and attractive between about 0.5 and 3 fm.
Sketch of F against r should illustrate the above. Global minimum between 0.5 and 3 fm; tending towards zero with increasing r; tending to infinity at low r.

(c) Explain the repulsion between two positively charged particles in terms the quantum-scale interactions and exchange particles. [2]

Solution: Virtual photons are the exchange particle for the EM interaction. They are exchanged in both directions (conserving momentum) but exist only for a very small amount of time. Possible analogy to a ball being thrown repeatedly between two stationary people.

(d) Calculate the wavelength of a 5.0 MeV photon. [2]

Solution: 2.5×10^{-13} m

2. This question will asses your knowledge of the classification of particles and of the transformations that can take place between these classes.

Total for Question 2: 14

(a) In the Standard Model, all particles can be classified as either leptons, mesons, baryons or photons. Give an example of a lepton and a baryon and, if either are not fundamental particles, state what they are made of. [3]

Solution: Lepton Fundamental; electron or neutrino (and antiparticles)
Baryon 3 quarks; proton, neutron (and antiparticles)

(b) Express the β^+ decay equation in terms of the transformation of hadrons and leptons. [2]

Solution: ${}_{1}^{1}p \rightarrow {}_{0}^{1} n + {}_{1}^{0} e + v_e$

(c) Express the β^- decay equation in terms of the transformation of fundamental particles. [2]

Solution: $d \rightarrow u + {}_{-1}^{0} e + \bar{v}_e$

(d) State the charges on the following quarks and their antiparticles. [3]

i. Up

Solution: up: 2/3, anti-up: -2/3

ii. Strange

Solution: strange: -1/3, anti-strange: 1/3

iii. Down

Solution: down: 1/3, anti-down: -1/3

(e) By considering the charge of the individual quarks involved, show that the net charges of a proton and an anti-proton are of equal magnitude but opposite polarity. [1]

Solution: Proton: $uud = 2(2/3) + (-2/3) = 2/3$
Anti-proton: $\bar{u}\bar{u}\bar{d} = 2(-2/3) + (2/3) = -2/3$

(f) Muons are created by cosmic rays high in the atmosphere (at altitudes of about 15000 m) and should have a lifetime of approximately 2 μs. Briefly explain why a muon, with a velocity of 29.8 cmns^{-1}, can be observed at sea level. [3]

Solution: In classical mechanics, we would expect the muons to take 50 μs to reach earth, by which time most would have decayed. However, the muons are travelling very fast ($0.98c$). This introduces relativistic effects: in the reference frame of the earth and its observers, the time of the muons slows down sufficiently for a significant proportion to reach earth (in the muon's reference frame they take exactly the same amount of time to decay).

3. Reactions and interactions can be represented by both equations and diagrams. Just as in classical Newtonian mechanics, there are conservation laws that can be used to ascertain whether a certain reaction can take place.

Total for Question 3: 6

(a) State the quarks that a K^+ particle is made from. [1]

Solution: Anti-strange, up

(b) K^+ decays via the weak interaction to produce three pions. Which pions are produced? [1]

Solution: $2\pi^+, \pi^-$

(c) Show that strangeness is not conserved in this reaction. [1]

Solution: Conservation of S: +1 vs 0 + 0 + 0. Therefore, S is not conserved.

(d) Sketch a Feynman diagram to illustrate the reaction below. The exchange particle for this reaction is the W^- particle. [3]

$$\mu^- \longrightarrow e^- + \bar{\nu}_e + \nu_\mu$$

Solution: Muon with a straight line; this divides into a wavy W^- line and a straight mu-neutrino line. At the other end of the wavy line, two straight lines emerge: one for e^-; one for $\bar{\nu}_e$.