2022 Ph H2 Q6

Section: Particles and Waves

Topic: The Standard Model & Relativity

Questions on the Standard Model and relativity. (a) Identify a quark–antiquark particle. (b) Quark content of kaons, fundamental force in decay. (c) Relativistic time/distance for pions. (d) Explain survival of pions at second detector. (e) Evaluate the building block analogy of the Standard Model.

Worked solution

(a) A quark–antiquark pair forms a meson.

(b)(i) K^- is the antiparticle of K^+ (u + anti-s). So K^- consists of anti-up and strange quarks.

(b)(ii) The W boson mediates the weak interaction.

(c)(i) Time in lab frame: t = d / v
= 30.0 / (0.95c)
= 1.05e-07 s

Answer: 1.05×10^{-7} s

(c)(ii) Distance in pion frame (length contraction):
L' = L / γ
γ = 3.20
L' = 30.0 / 3.20 = 9.4 m

Answer: 9.4 m

(d) In the lab frame, the pions are moving close to c. Relativistic time dilation means their lifetime appears longer, so more survive to reach the second detector. Without relativity, too few would be expected.

(e) The analogy with children's building blocks helps illustrate that all matter is made from a limited set of fundamental particles. However, it oversimplifies — unlike toy blocks, the Standard Model particles differ in mass, charge, spin, and interact via four fundamental forces. So the analogy is useful for accessibility but limited in accuracy.

Final answers

(a) Meson

(b)(i) anti-up + strange

(b)(ii) Weak interaction

(c)(i) t = 1.05e-07 s ≈ 1.05×10^{-7} s

(c)(ii) L' ≈ 9.4 m

(d) Time dilation increases pion lifetime, more detected

(e) Building block analogy highlights basics but oversimplifies

Revision tips

- Mesons = quark + antiquark; baryons = 3 quarks.

- Kaon decay is governed by weak interaction via W boson.
- Relativistic: time dilates, lengths contract.
- Lifetime dilation explains survival of fast-moving particles.
- Analogies can aid understanding but may mislead if taken too literally.