NATIONAL OPEN UNIVERSITY OF NIGERIA

University Village, Nnamdi Azikiwe Expressway, Plot 91, Cadastral Zone, Jabi, Abuja

FACULTY OF SCIENCES

Department of Pure and Applied Science

JANUARY 2018 EXAMINATION QUESTION

COURSE CODE: PHY401

COURSE TITLE: ELEMENTARY PARTICLE PHYSICS

COURSE UNIT: 3 units

TIME:3 HOURS

ANSWER QUESTIONS ONE AND ANY FOUR OTHER QUESTIONS

Necessary constants and Hints

Some Particles and Their Properties

Category	Particle Name	Symbol	Anti-particle	Mass (MeV/c^2)	B	L_e	L_μ	L_τ	S	Lifetime(s)	Principal Decay Modes[a]
Leptons	Electron	e^-	e^+	0.511	0	+1	0	0	0	Stable	
	Electron–neutrino	ν_e	$\overline{\nu}_e$	$< 7eV/c^2$	0	+1	0	0	0	Stable	
	Muon	μ^-	μ^+	105.7	0	0	+1	0	0	2.20×10^{-6}	$e^-\overline{\nu}_e\nu_\mu$
	Muon–neutrino	ν_μ	$\overline{\nu}_\mu$	< 0.3	0	0	+1	0	0	Stable	
	Tau	τ^-	τ^+	1 784	0	0	0	+1	0	$< 4 \times 10^{-13}$	$\mu^-\overline{\nu}_\mu\nu_\tau$, $e^-\overline{\nu}_e\nu_\tau$
	Tau–neutrino	ν_τ	$\overline{\nu}_\tau$	< 30	0	0	0	+1	0	Stable	
Hadrons											
Mesons	Pion	π^+	π^-	139.6	0	0	0	0	0	2.60×10^{-8}	$\mu^+\nu_\mu$
		π^0	Self	135.0	0	0	0	0	0	0.83×10^{-16}	2γ
	Kaon	K^+	K^-	493.7	0	0	0	0	+1	1.24×10^{-8}	$\mu^+\nu_\mu$, $\pi^+\pi^0$
		K_S^0	$\overline{K}_S^0$	497.7	0	0	0	0	+1	0.89×10^{-10}	$\pi^+\pi^-$, $2\pi^0$
		K_L^0	$\overline{K}_L^0$	497.7	0	0	0	0	+1	5.2×10^{-8}	$\pi^\pm e^\mp \overline{\nu}_e$, $3\pi^0$ $\pi^\pm \mu^\mp \overline{\nu}_\mu$
	Eta	η	Self	548.8	0	0	0	0	0	$< 10^{-18}$	2γ, 3π
		η'	Self	958	0	0	0	0	0	2.2×10^{-21}	$\eta\pi^+\pi^-$
Baryons	Proton	p	$\overline{p}$	938.3	+1	0	0	0	0	Stable	
	Neutron	n	$\overline{n}$	939.6	+1	0	0	0	0	920	$pe^-\overline{\nu}_e$
	Lambda	Λ^0	$\overline{\Lambda}^0$	1 115.6	+1	0	0	0	−1	2.6×10^{-10}	$p\pi^-$, $n\pi^0$
	Sigma	Σ^+	$\overline{\Sigma}^-$	1 189.4	+1	0	0	0	−1	0.80×10^{-10}	$p\pi^0$, $n\pi^+$
		Σ^0	$\overline{\Sigma}^0$	1 192.5	+1	0	0	0	−1	6×10^{-20}	$\Lambda^0\gamma$
		Σ^-	$\overline{\Sigma}^+$	1 197.3	+1	0	0	0	−1	1.5×10^{-10}	$n\pi^-$
	Xi	Ξ^0	$\overline{\Xi}^0$	1 315	+1	0	0	0	−2	2.9×10^{-10}	$\Lambda^0\pi^0$
		Ξ^-	Ξ^+	1 321	+1	0	0	0	−2	1.64×10^{-10}	$\Lambda^0\pi^-$
	Omega	Ω^-	Ω^+	1 672	+1	0	0	0	−3	0.82×10^{-10}	$\Xi^0\pi^0$, Λ^0K^-

[a] Notations in this column, such as $p\pi^-$, $n\pi^0$ mean two possible decay modes. In this case, the two possible decays are $\Lambda^0 \rightarrow p + \pi^-$ and $\Lambda^0 \rightarrow n + \pi^0$.

Properties of Quarks and Antiquarks

Quarks

Name	Symbol	Spin	Charge	Baryon Number	Strangeness	Charm	Bottomness	Topness
Up	u	$\frac{1}{2}$	$+\frac{2}{3}e$	$\frac{1}{3}$	0	0	0	0
Down	d	$\frac{1}{2}$	$-\frac{1}{3}e$	$\frac{1}{3}$	0	0	0	0
Strange	s	$\frac{1}{2}$	$-\frac{1}{3}e$	$\frac{1}{3}$	−1	0	0	0
Charmed	c	$\frac{1}{2}$	$+\frac{2}{3}e$	$\frac{1}{3}$	0	+1	0	0
Bottom	b	$\frac{1}{2}$	$-\frac{1}{3}e$	$\frac{1}{3}$	0	0	+1	0
Top	t	$\frac{1}{2}$	$+\frac{2}{3}e$	$\frac{1}{3}$	0	0	0	+1

Antiquarks

Name	Symbol	Spin	Charge	Baryon Number	Strangeness	Charm	Bottomness	Topness
Anti-up	$\bar{u}$	$\frac{1}{2}$	$-\frac{2}{3}e$	$-\frac{1}{3}$	0	0	0	0
Anti-down	$\bar{d}$	$\frac{1}{2}$	$+\frac{1}{3}e$	$-\frac{1}{3}$	0	0	0	0
Anti-strange	$\bar{s}$	$\frac{1}{2}$	$+\frac{1}{3}e$	$-\frac{1}{3}$	+1	0	0	0
Anti-charmed	$\bar{c}$	$\frac{1}{2}$	$-\frac{2}{3}e$	$-\frac{1}{3}$	0	−1	0	0
Anti-bottom	$\bar{b}$	$\frac{1}{2}$	$+\frac{1}{3}e$	$-\frac{1}{3}$	0	0	−1	0
Anti-top	$\bar{t}$	$\frac{1}{2}$	$-\frac{2}{3}e$	$-\frac{1}{3}$	0	0	0	−1

1. a. Why are some particles termed elementary particles? **[1 mark]**

   b. What are elementary particles? **[1 mark]**

   c. What are fermions? **[1 mark]**

   d. List 6 elementary particle's detectors that you know **[3 marks]**

   e. Name families and sub-families of elementary particles. **[4 marks]**

   f. Name 2 classes of hadrons. **[2 marks]**

   g. List 4 exact conservation laws. **[4 marks]**

   h. Why are some particles termed strange? **[1 marks]**

   i. What is parity? **[1 marks]**

   j. List 4 types of particle interactions **[4 marks]**

2. Use the law of conservation of lepton number to determine whether each of the following decay schemes can occur

a. $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$ **[4 marks]**

b. $\pi^+ \rightarrow \mu^+ + \nu_e + \nu_\mu$ **[4 marks]**

What conservation law is obeyed or violated by the decay process below

c. $n \rightarrow p + e^-$ **[4 marks]**

3. A stationary positive pion can decay according to

$\pi^+ \rightarrow \mu^+ + \nu$

What is the kinetic energy of the (i) anti-neutrino μ^+ (ii) neutrino. (m_π = 139.6 MeV/c^2, m_μ = 105.7 MeV/c^2) **[12 marks]**

4. Use the law of strangeness conservation to determine whether these reactions can occur

a. $\pi^0 + n \rightarrow K^+ + \Sigma^-$ **[3 marks]**

b. $\pi^- + p \rightarrow \pi^- + \Sigma^+$ **[3 marks]**

c. $\pi^- + p \rightarrow \Lambda^- + \mathrm{K}^0$ **[3 marks]**

d. $p + \bar{p} \rightarrow \Lambda^0 + \bar{\Lambda}^0$ **[3 marks]**

5. a. The wavelength shift in the light from a particular quasar indicates that the quasar has a recessional speed of 2.8 x 10^8 m/s. Approximately how far from us is the quasar?

[3 marks]

b. A particular emission line detected in the light from a galaxy has a detected wavelength λ_{det} = 1.1 λ, where λ is the proper wavelength of the line. What is the galaxy distance from us? (Hubble constant, H = 21.8 mm/s. ly) **[9 marks]**

6. Identify the particle corresponding to the following quark states

a. suu **[6 marks]**

b. dss **[6 marks]**