Physics 492 Homework XII, due Fri Apr 11

Reading: Chapters 10 and 12

Problems:

1. Within the simple quark model, calculate the value of the cross-section ratio $R = \sigma(e^+ + e^- \to \text{hadrons})/\sigma(e^+ + e^- \to \mu^+ + \mu^-)$, in $e^+ e^-$ collisions at $\sqrt{s} = 2.4$, 8 and 30 GeV. You can use the approximation $\beta = 1$ for the relevant quarks at different energies.

2. In 1956 Sakata proposed a model with three fundamental quarks having the following quantum numbers:

	j	B	S	t	t_3
u	1/2	1	0	1/2	1/2
d	1/2	1	0	1/2	-1/2
s	1/2	1	-1	0	0

where j, B, S, and t, are the spin quantum number, baryon number, strangeness, and isotopic spin quantum number, respectively.
(a) Given the empirical relation for hadrons: $Q/e = t_3 + (B + S)/2$, what should be the charges of the three quarks? (b) Assign quark combinations to nucleons, pions, kaons, and Λ. (c) Why is the Sakata model not used?

3. Williams, Problem 12.2.

4. Williams, Problem 12.18.
Hint: If the neutrino mass is zero, then all neutrinos travel at the speed of light, irrespective of energy. If the neutrino mass is nonzero, then the speed v and energy E are related by

$$E = \frac{m\,c^2}{\sqrt{1 - v^2/c^2}}$$

Assume that the energy spread of the detected neutrinos is from 4 to 12 MeV.

5. Accelerator problem

In a high-energy physics accelerator, particles of charge $\pm e$, energy E and mass m travel around a ring of radius R in a magnetic field $\vec{B} = B\,\hat{k}$.

(a) Derive a formula for R in terms of e, m, B and E.

HINT: For a circular orbit

$$\begin{aligned} \vec{r}(t) &= R\,(\hat{\imath}\cos\omega t + \hat{\jmath}\sin\omega t) \\ \vec{v}(t) &= \omega\,R\,(-\hat{\imath}\sin\omega t + \hat{\jmath}\cos\omega t) \end{aligned}$$

where $\omega = v/R$. The equation of motion is

$$\frac{d\vec{p}}{dt} = e\,\vec{v} \times \vec{B}, \qquad \text{where} \quad \vec{p} = \frac{m\,\vec{v}}{\sqrt{1 - v^2/c^2}}$$

(b) The Fermilab Tevatron is an accelerator for protons and antiprotons at particle energy of 0.9 TeV. The radius of the accelerator is 1 km. Determine the magnetic field B.

Reminder: The term paper is due on Wednesday, April 16.