ADVANCED DYNAMICS — PHY–4241/5227

HOMEWORK 10

(March 14, 2003)

Due on Monday, March 24, 2003

PROBLEM 29

(Griffiths Problem 12.34)

In the past, most experiments in particle physics involved stationary targets: one particle (usually a proton or an electron) was accelerated to high energy E, and collided with a target particle at rest. Far higher *relative* energies are obtainable (with the same accelerator) if you accelerate *both* particles to energy E, and fire them at each other. *Classically*, the energy $\bar{E}$ of one particle relative to the other is just $4E$—not much of a gain (only a factor of 4). But *relativistically* the gain can be enormous. Assuming that the two particles have the same mass (m), show that

$$\bar{E} = \frac{2E^2}{mc^2} - mc^2 \ .$$

Suppose that you use protons ($mc^2 \approx 1$ GeV) with $E = 30$ GeV. What $\bar{E}$ do you get? What multiple of E does this amount to? [Because of the relativistic enhancement, most modern elementary particle experiments involve **colliding beams**, instead of fixed targets.]

PROBLEM 30

(Griffiths Problem 12.35)

In a **pair annihilation** experiment, an electron (mass m) with momentum p_e hits a positron (same mass but opposite charge) at rest. They annihilate producing two photons. (Why couldn't they produce just *one* photon?) If one of the photons emerges at 60° to the incident electron direction, what is its energy?

PROBLEM 31

(Griffiths Problem 12.58)

Calculate the **threshold** (minimum) momentum that a pion must have (in the laboratory frame) in order for the process $\pi + p \to K + \Sigma$ to occur. Note that in the laboratory frame the proton is initially at rest. Use the following *approximate* values for the masses of all the particles:

$$M_\pi c^2 = 150 \text{ MeV} \,, \quad M_K c^2 = 500 \text{ MeV} \,;$$
$$M_p c^2 = 900 \text{ MeV} \,, \quad M_\Sigma c^2 = 1200 \text{ MeV} \,.$$

Hint: Formulate the threshold condition in the center-of-momentum frame.