Prelims: Special Relativity: II

1. The K^0 meson can decay at rest into a pair of charged π mesons. Given that the rest masses of the K and π are 498 and 140 MeV/c^2 respectively, show that the speeds of the pions are 0.83c in the rest frame of the K^0.

2. Calculate the mass lost when 1 million tonnes of TNT explodes. Assume that the chemical reaction releases 10 eV of energy per molecule.

3. Energy from the Sun arrives at the Earth (above the atmosphere) at a rate of about 1400 W m^{-2}. How fast is the sun losing mass due to energy radiation?

4. An electron accelerated from the Stanford Linear Accelerator (SLAC) in California has a total energy of 50 GeV. (a) What fraction of this is kinetic energy? (b) What is the momentum of the electron? (c) What is its speed?

5. A π^0 meson whose rest mass is 135 MeV/c^2 is moving with a kinetic energy of 1 GeV. It decays in flight into two photons whose paths are along the direction of motion of the meson. Find the energies of the two photons.

6. Neutral π^0 mesons can be formed by the reaction

$$p + p \;\rightarrow\; p + p + \pi^0$$

   What is the threshold kinetic energy for π^0 production by this process if the target proton is stationary? (Masses of π^0 and proton are 135 and 938 MeV/c^2.)

7. What is the threshold kinetic energy for production of an electron-positron pair by collision of an incident electron with a stationary electron i.e. for

$$e^- + e^- \;\rightarrow\; e^- + e^- + (e^+ + e^-)$$

8. The Tevatron at the Fermi National Accelerator Laboratory in the USA carries two beams of 1 TeV (1000 GeV) protons moving in opposite directions, so that for proton-proton collisions the centre of mass frame is also the laboratory frame. What proton energy must an accelerator provide to get the same centre of mass energy when bombarding a stationary hydrogen target?

9. An electron of energy 10 GeV strikes a proton at rest. What is the velocity of the electron-proton CM system? What energy is available to produce new particles?

10. (i) Show that a free electron moving in a vacuum at velocity v cannot emit a single photon. (ii) A hydrogen atom in an excited state can emit a single photon, why is this different from (i) above?

11. An atom in an excited state of energy Q_0 above the ground state moves towards a scintillation counter with speed v. The atom decays to its ground state by emitting a photon of energy Q (as recorded by the counter), coming completely to rest as it does so. If the rest mass of the atom is M, show that $Q = Q_0[1 + (Q_0/2Mc^2)]$.