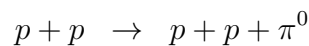


## Prelims: Special Relativity: II

1. The  $K^0$  meson can decay at rest into a pair of charged  $\pi$  mesons. Given that the rest masses of the  $K$  and  $\pi$  are  $498$  and  $140 \text{ MeV}/c^2$  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  $10 \text{ eV}$  of energy per molecule.
3. Energy from the Sun arrives at the Earth (above the atmosphere) at a rate of about  $1400 \text{ W m}^{-2}$ . 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  $50 \text{ GeV}$ . (a) What fraction of this is kinetic energy? (b) What is the momentum of the electron? (c) What is its speed?
5. A  $\pi^0$  meson whose rest mass is  $135 \text{ MeV}/c^2$  is moving with a kinetic energy of  $1 \text{ GeV}$ . 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  $\pi^0$  mesons can be formed by the reaction



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

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  $1 \text{ TeV}$  ( $1000 \text{ GeV}$ ) 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  $10 \text{ GeV}$  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  $Q = Q_0[1 + (Q_0/2Mc^2)]$ .