Modern Physics 330: HW # 3

#1) A proton with momentum 200 GeV/c in the laboratory collides with a proton at rest. Calculate the total energy in the center-of-momentum frame.

#2) A photon with energy equal to the electron rest energy ($= mc^2$, where m is the electron mass) collides with an electron at rest and scatters at an angle of $\pi/2$. What is the recoil energy of the electron (as a fraction of mc^2)?

#3) A photon of energy 10 eV collides head-on with an electron that has an energy of 10 GeV moving towards the photon. If the photon is back-scattered, what is the final energy of the photon and electron?

#4) What is the minimum photon energy required to produce can electron-positrion pair in a collision with an electron at rest? $\gamma + e^- \rightarrow e^- + e^+ + e^-$ (Note, the mass of the positron is identical to that of the electron.)

#5) Prove that the photo-electic effect cannot work for a free electron, that is the process $\gamma + e^- \rightarrow e^-$ is forbidden by energy-momentum conservation.

#6) A pi-zero has a mass of $m_\pi c^2 = 135$ MeV and decays into two photons. In the laboratory, the pi-zero is moving in the x-direction. After the decay, one photons travels in the positive x-direction, and the other in the negative x-direction. Calculate the laboratory momentum of the pi-zero. Calculate the laboratory speed of the pi-zero a function of the energy difference between the two observed photons.

#7) A pi-zero is produced in the laboratory with momentum of 1 GeV/c and moving in the x direction. It decays into two photons. In the rest frame of the pi-zero, the photons are produced back-to-back, one with an angle of $\theta^\star$ with respect to the x direction. Calculate the angle between the photons in the laboratory frame as a function of the decay angle in the pi-zero rest frame ($\theta^\star$). Fint the angle in the limits $\gamma \gg 1$ and $\gamma \approx 1$.