Tutorial 1

(1) (i) Convert the following quantities to SI units : 23.5 GeV/c , 15 keV
(ii) Do the inverse of (i) for the following quantities : 5×10^{-27} kg, 3×10^{-21} J.

(2) Imagine that a spaceship travels at a constant speed faster than light. An astronaut at one end of the spaceship (the back end wrt the direction of motion) fires a laser which hits the front end causing the spaceship to explode. By considering the above in different frames show that the first postulate of special relativity is violated.

(3) The muon has a mean lifetime of 2.2μs. Muons are produced by the interactions of cosmic rays in the upper atmosphere. Measurements of the muon flux at the surface of the earth were surpising at first as many more were detected than would naively be expected.
Estimate the fraction that would be expected at the earth's surface using
(i) classical physics.
(ii) special relativity.
You may assume that the distance from the production point of the muon and the surface of the earth is 10km and that the muon speed is $0.98c$.

(4) Particle A (energy E) hits particle B (at rest) producing particles C and D. Show that the threshold energy for the reaction to take place is given by $E = c^2 \dfrac{\left(m_C + m_D\right)^2 - m_A^2 - m_B^2}{2m_B}$.

(5) Two particles C and D emerge from a collision and their total energy after the collision is $E = E_C + E_D$ in the centre-of-mass frame, where E_C and E_D are the energies of C and D, respectively.
Show that
(i) $\dfrac{dE}{dp_f} = c^2 p_f \dfrac{E}{E_C E_D}$ where p_f is the 3-momentum of either final state particles in the centre of mass frame.
(ii) $\dfrac{dE}{dp_f} = v_c + v_D$ where v_c and v_D are the speeds of C and D, respectively, in the centre of mass frame.

(6) A particle (ρ) decays into two charged pions with energies of 2.5 GeV and 1.17 GeV, and which separate at an angle of 24^o. The charged pion has a mass of 0.14 GeV/c^2. Calculate the rest mass of the ρ.