1) High energy muons are produced high in the atmosphere (at about 8-10 km above the earth) and move with an average velocity of 0.998 c in the direction of the earth. At sea level a high flux of $\sim$ 180 muons /(m^2s) is observed. What is the average energy of these muons? How far would these muons move on average according to non-relativistic mechanics? ($\tau \approx$ 2.2 μs). Would they reach the earth? How does the result change when we apply relativistic mechanics?

2) Particle A (with energy E) collides with particle B, initially at rest. Particles {C_1, C_2, … C_n} are produced. $m_i$is the mass of C_i. Show that the threshold energy for this reaction is given by

$$E = \frac{(M^2 - m_A^2 - m_B^2)}{2m_B}c^2 \qquad \text{with} \qquad M = \sum_{i=1}^{n} m_i$$

Calculate the threshold energy for $p + p \rightarrow p + p + \pi^+ + \pi^-$.

3) Show using the Λ matrix that $p \cdot p$ is invariant under Lorentz transformations.

4) Define a group.