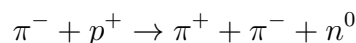


Exam Problems: Physics in Spacetime, Spring 2024

1. Protons (p^+) are bombarded with pions (π^\pm). What is the minimum energy that the pions need to have, according to an observer at rest with respect to the proton, for the reaction



to be possible? (Set $M_{\pi^\pm} = m$ and $M_{p^+} = M_{n^0} = M$.)

2. Two observers currently at the same location observe a small distant object in their direction of travel. One observes the object to be twice as big as the other. What is their relative velocity?
3. Pulsars are neutron stars which emit radio pulses at regular intervals. Alice and Bob count pulses from a very distant pulsar in the y -direction. Alice travels in the x -direction with velocity $u = 24/25$ relative to Bob for seven years, then reverses and returns with the same velocity, while Bob stays at home. At the end of the trip they have counted the same number of pulses. When Alice returns she has aged by 14 years. How much has Bob aged?

Find the angle to the x -axis at which Alice observes the pulsar (for Bob the angle is 90°).

4. Consider a photon-drive rocket, driven by shooting a powerful laser (of fixed power and wavelength) out of its tail. According to an observer the rocket's relative velocity is zero at $\tau = \tau_i$ and v at $\tau = \tau_f$, where τ refers to the rocket's proper time. What is the ratio of the masses M_i/M_f of the rocket at the two times?