AS.171.201/207 Homework 1 – Zakamska – Fall 2017

Problem 1 (3 points). What are the masses and charges of the proton and the electron in CGS and MKS systems (two significant digits and the power of 10)? 1 eV (electron-Volt) is defined as the energy an electron gains upon traversing a potential difference of 1 Volt. Calculate 1 eV in ergs and in Joules. Calculate proton's and electron's rest energy mc^2 in eV.

For your midterms and final examinations, you will find it useful to know the values of the speed of light, the mass of the electron and the mass of the proton in CGS and MKS, as well as the rest energies in eV. For your home and lab assignments, if you need any physical constants not explicitly specified, look them up and provide a reference. It is not enough for this problem to look up the value of eV or mc^2 online; you need to show the calculation starting from particle masses and charges.

Problem 2 (3 points). The frame S and and the frame S' are not moving relative to one another, and the clocks are synchronized. Suppose we have an event with space-time coordinates (ct', x', y', z'). Write down in matrix form the transformation from the frame S' into the frame S for the following cases:

- The origins of the frames S' and S coincide, the x' axis is aligned with the y axis, the y' axis is aligned with the z axis and the z' axis is aligned with the x axis.
- The origins of frames S' and S coincide, their z axes are aligned with one another, but the $x' - y'$ plane of S' is rotated by an angle ϕ counter-clockwise relative to the the $x - y$ plane of S.
- The axes are aligned, but the origin of the coordinate system S' is located at (x_0, y_0, z_0) as measured in S.

Problem 3 (3 points). The radius of our galaxy is 3×10^{20} m. (a) Calculate this size in light-years. (b) Can an astronaut, in principle, travel from the center to the edge of our galaxy in a normal lifetime? Explain, using both time-dilation and length-contraction arguments. Which frame do time-dilation arguments apply in? Which frame do length-contraction arguments apply in? (c) What constant velocity would she need to make the trip in 30 years of the astronaut's (proper) life-time?

Problem 4 (3 points). A pole vaulter, holding a 16 ft long pole parallel to his direction of motion, runs with speed $v = 0.9c$ through an 8 ft long shed which is open at each end. Is it possible to close sliding doors at each end of the shed such that the pole is entirely in the shed before it strikes the exit door? Discuss the situation from the point of view of the pole-vaulter and an observer on the shed roof.

Problem 5 (3 points). A beam of unstable K^+ mesons traveling at $v = 0.8c$ passes through two detectors placed in sequence 8 meters apart. The particles suffer negligible deflection and loss of speed in passing through the detectors but produce electrical signals which can be counted. A beam of mesons is fired and 1000 particles are recorded passing through the first detector. The second detector records 200 K^+ mesons. Determine the rest-frame half-life of the K^+ meson. (In the rest-frame of decaying particles, the number of particles drops exponentially with time and the rest-frame half-life is the amount of time that it takes for the number to be reduced by a factor of two.)