MIDTERM - Modern Physics
Solutions - Part 1
By Keven Roy

QUESTION 1 [20 points]

An object of mass 4m traveling at $\vec{v} = 0.9c\hat{x}$ collides head on with an object of mass 6m traveling at $\vec{v} = -0.6c\hat{x}$ to form a single object in the final state. [All masses are rest masses].

Part a)

Find the mass and velocity of this object. [15 points]

Part b)

Show that the invariant mass of the initial state equals the mass of the final state object. [5 points]

QUESTION 2 [20 points]

Part a)

In frame S two events occur with the space-time coordinates $(x_1, y_1, z_1, t_1) = (a, 0, 0, \frac{a}{c})$, and $(x_2, y_2, z_2, t_2) = (5a, 0, 0, \frac{a}{5c}$. There is a reference frame S′ in which these two events are simultaneous (assume the origins of S and S′ coincide at $t = t' = 0$). Find the velocity of the S′ frame with respect to frame S, as well as the time these events occur in S′. [10 points]

Q. 2 (b)

Q. Bob (at large negative x) runs toward the origin of reference frame S at speed 0.8c, while Anna (at large positive x) runs toward the origin at 0.6c. If Bob carries a pole of length $3m$ (in his rest frame) oriented in the direction in which he runs, what length would Anna measure for the rod in her reference frame? [10 points]

Q. 3

Q. Assume that a laser beam with 2mW of power and a wavelength of 311nm is incident on a metal photo-cathode. If the electrons emitted from the photo-cathode have a maximum velocity of 0.002c, answer the following questions:

(a) If the quantum efficiency of the photo-cathode is 75%, how many electrons per second leave the metal? [6 points]

(b) What is the maximum kinetic energy of the ejected electrons? [4 points]

(c) What is the work function of the metal? [6 points]

(d) If the power of the laser were doubled, how would the answers to these questions change? [4 points]