Physics IV
ISI B.Math
Mid Semestral Exam : February 23, 2011

Total Marks: 70. Time: 2 and a half hours
Answer questions 1 and 2 and **any three** from questions 3, 4, 5 and 6

Question 1. Total Marks:10

A train with square shaped compartments of proper length and width L moves at a speed 5c/13 in the x direction wrt the ground. Two balls are thrown simultaneously (in the train frame of reference) from the back of the train to the front and across to the opposite walls as shown in the picture. The speed of each ball wrt to the train is c/3. Let P and Q be the events of the balls hitting the two walls.

a. Calculate how much time elapses and the distance traveled for each ball before they hit the opposite walls as measured by the ground observer. What are the speeds of the two balls in the x and y directions as measured by the ground observer?

b. Are the space-time events P, Q simultaneous wrt to the train? wrt to the ground? Are these events separated by spacelike, timelike or null interval?

Question 2. Total Marks:15

A train and a tunnel have both proper lengths L. The train moves towards the tunnel at speed v. A bomb located at the front of the train is designed to explode when the front of the train passes the far end of the tunnel. A deactivation sensor is located at the back of the train. When the back of the train passes the near end of the tunnel the sensor sends a signal to the bomb to deactivate itself. Analyze the events from both the train and the tunnel point of view, and reach a conclusion as to whether the bomb explodes or not. [Hint: In the train frame locate where the back of the train is when the front reaches end of the tunnel. In the frame of the tunnel, spot the front of the train as the back reaches the tunnel. How long does it take for the deactivation signal to reach the bomb?]

Do any THREE from Q3,4,5,6

Question 3. Total Marks:15

Let L be a 4x4 Lorentz Transformation matrix which is infinitesimally separated from the identity matrix. Write $L = 1 + \beta X$ where β is a small parameter and X is a 4x4 matrix. Show thatηX is an antisymmetric matrix, where η is the standard 4x4 spacetime metric with $\eta_{00} = -\eta_{11} = -\eta_{22} = -\eta_{33} = 1$ and all other matrix elements of η are zero. Write the most general form of X. How many parameters are needed to specify X completely?

Question 4. Total Marks:15

Let $L = e^{\phi X}$ be a two dimensional proper Lorentz Transformation, where ϕ is a real number and X is a 2x2 matrix with $X_{00} = X_{11} = 0$ and $X_{01} = X_{10} = 1$ Expand L in powers of ϕ and X and find an exact closed expression of L. What kind of Lorentz transformation does L represent? Relate ϕ with the velocity v in Lorentz Transformations. [Hint: Calculate X^2 and use it to find L]

Question 5. Total Marks:15

Let L_x and L_y represent two separate Lorentz boosts of equal amounts (same v) in the x and y directions respectively. Calculate the commutator $[L_x, L_y]$to the lowest non-vanishing order of v/c and interpret the result.

Question 6. Total Marks:15

A particle of rest mass m and energy E collides elastically with an identical particle at rest. Assume that the collision is elastic and that both particles scatter at an angle θ relative to the incident direction as shown in the picture. Calculate θ in terms of m and E. What is θ in the relativistic and non-relativistic limits?