Physics 200-04

Assignment 3

1.Doppler shift: A light flashes once a second (according to its own clock). It is traveling with velocity .9c with respect to an observer, in the direction of the positive x direction and at a distance of 1 light day away along the y direction. What is the frequency of the flashes as seen by the observer as a function of time. What is the limiting frequency when the x value is very large and negative, when $x = 0$ and when x is large and positive.

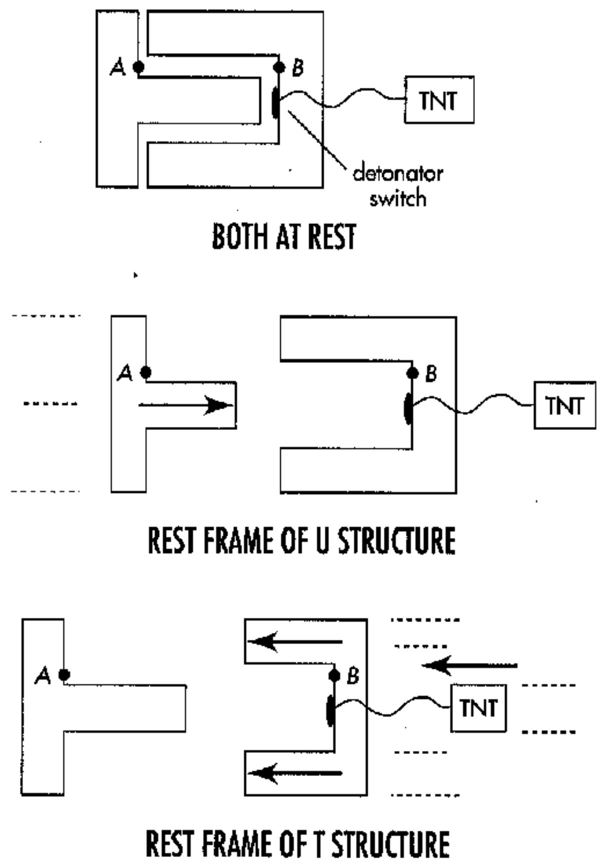
Note: You need to take both the time dilation and the time it takes light to travel the distance into account.

2. A distant star, distance 10^4 light years away, ejects a blob of hot matter at a velocity 12/13 c almost directly toward the observer. The angle that the velocity of blob makes with the direction to the observer is 20 degrees. Looking in the sky at the image of the blob separating from the image of the star, with what velocity would the observer see the blob moving? (Note that taking into account the time it takes light to reach the observer is important.)

Note: when this was first seen by astronomers it caused a huge sensation until the community was convinced about what was happening and that this did not violate special relativity.

3. A structure as in figure 1 is such that the projection of the structure A would just touch the detonator when the flanges of figure A just touch the bars of Figure B. Now A is shot at B at a sizable fraction of the speed of light. In the frame of figure B, A is shortened and thus the flanges will touch the bars of A before the projection touches the detonator, and will stop A before the projection hits the detonator. In A's frame however, B is shorter, and the projection of A hits the detonator before the flanges touch B and the bomb is detonated.

Is the bomb detonated or not? What is wrong with the argument that predicts the opposite?



EXERCISE 6-5. ***Both at rest:*** *The leg of the T almost reaches the detonator switch when both the T and the U are at rest. Points* A *and* B *are used in part b of the exercise.* ***Rest frame of U structure:*** *The leg of the moving T is Lorentz contracted in the rest frame of the U. Does this mean that the explosion will not take place?* ***Rest frame of T structure:*** *The legs of the moving U are Lorentz-contracted in the rest frame of the T. Does this mean explosion will take place?*

4. Thomas Precession: Consider a particle moving with velocity v in the x direction from the point of view of some observer. In the frame of the particle, the particle now picks up a small velocity δv in the y direction.

a) Show that the matrix representing the Lorents transformation from the observers frame to the particle;'s old frame is

$$L_v = \begin{pmatrix} \cosh(\mu) & -\frac{v}{c}\cosh(\mu) & 0 & 0 \\ -\frac{v}{c}\cosh(\mu) & \cosh(\mu) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

where $\cosh(\mu) = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$, while the transformation from the particle's old frame to the particle's new frame, to linear order in δv is

$$L_\delta = \begin{pmatrix} 1 & 0 & -\frac{\delta v}{c} & 0 \\ 0 & 1 & 0 & 0 \\ -\frac{\delta v}{c} & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Show that the transformation from the point of view of the observer to the new frame of the particle is the product of a boost with velocity $(v, \frac{\delta v}{\cosh(\mu)}, 0)$

$$L_{v,\delta} = \begin{pmatrix} \cosh(\mu) & -\frac{v}{c}\cosh(\mu) & -\frac{\delta v}{c} & 0 \\ -\frac{v}{c}\cosh(\mu) & \cosh(\mu) & (\cosh(\mu)-1)\frac{\delta v}{v\cosh(\mu)} & 0 \\ -\frac{\delta v}{c} & (\cosh(\mu)-1)\frac{\delta v}{v\cosh(\mu)} & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

and a rotation about the z axis with small angle $\delta\theta$. Show that $L_{v,\delta}$ is a Lorentz transformation (to first order in δv), and find what the angle $\delta\theta$ is in terms of v and δv.

Note that the expression for a general rotation about the z axis is

$$R_{z,\theta} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & cos(\theta) & sin(\theta) & 0 \\ 0 & -sin(\theta) & cos(\theta) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Ie show that

$$L_{\delta v} L_v = R_{z,\delta\theta} L_{v,\delta v}$$

for the appropriate $\delta\theta$ and keeping terms only to first order (linear order) in δv. This angle of rotation is the Thomas Precession angle.

Note that if you calculating to first order in some quantity, all terms which are of order that quantity squared may be neglected.