Physics 130 General Relativity Seminar
Assignment 2 January 28, 2013

General topic: **Special Relativity : Old and New Ideas**

Part 1: Readings

Hartle: Ch 4 - Principles of Special Relativity

Hartle: Ch 5 - Special Relativistic Mechanics

You must do the readings BEFORE attempting the problems in order to get a good grasp of the overall content of the week's material to be understood. A problem should then make you look more carefully at specific parts of the readings that are necessary for the solution of that particular problem!

Prior to discussing any problems, we will deal with any questions and/or discussion of the readings.

Admonition #1 Admonition #2

Doing homework assignments by yourself. Copying off some "smart friend" cheats the other students in the class, and it cheats you and your friend. Identical-looking assignments will be referred to me by the grader. You may discuss general physics principles behind the questions with other students - and I encourage you to participate in study groups.

Participating in class. Sitting there like a vege while other students think hard and bother to answer questions is parasitic, intellectually. Contribute.

Part 2: Problems

1. All problems will be discussed in seminar.
2. Random choice of presenter.
3. Quality/correctness of presentation = 50% Seminar grade.

4. If a problem is not solved by anyone, then it will be done in seminar.

Hartle Problems

1. Hartle 4.12 Shortest distance
2. Hartle 4.15 For all frames ....
3. Hartle 5.06 What is the particle doing?
4. Hartle 5.07 Accelerated Particle
5. Hartle 5.12 Linear Accelerator
6. Hartle 5.13 Threshold energy

Boccio Extra Problems

1. **Twins In Relativity**

   Consider a pair of twins that are born somewhere in spacetime. One of the twins decides to explore the universe. She leaves her twin brother behind and begins to travel in the $x-$direction with constant acceleration $a = 10\,\frac{m}{sec^2}$ as measured in her rocket frame. After 10 years according to her watch, she reverses the thrusters and begins to accelerate with a constant acceleration $-a$ for a while.

   (a) At what time on her watch should she again reverse her thrusters so she ends up home at rest?

   (b) According to her twin brother left behind, what was the most distant point on her trip?

   (c) When the sister returns, who is older, and by how much?

2. **Relativistic Rocket**

   (a) If a rocket has engines that give it a constant acceleration of (relative to its instantaneous inertial frame, of course), and the rocket starts from rest near the earth, how far from the earth (as measured in the earth's frame) will the rocket be in 40 years as measured on the earth? How far after 40 years as measured in the rocket?

(b) Compute the proper time for the occupants of a rocket ship to travel 30,000 light years from the Earth to the center of the galaxy. Assume they maintain an acceleration of for half the trip and decelerate at for the remaining half.

(c) What fraction of the initial mass of the rocket can be payload in part (b)? Assume an ideal rocket that converts rest mass into radiation and ejects all of the radiation out the back with 100% efficiency and perfect collimation.

3. **High Energy Kinematics**

   (a) In a high energy accelerator, the energy available to create new particles is the energy in the center-of-mass(CM) frame. Consider a proton with momentum $1\,\frac{TeV}{c}$ incident on a target proton at rest. What is the available CM energy?

   (b) Next consider a $1\,TeV$ proton heading east colliding with a $1\,TeV$ pro ton headed west. What is the available CM energy? What momentum would be needed in a fixed-target experiment to obtain the same available energy?

   (c) A Λ_0 baryon ($m_\Lambda = 1115.7\,MeV$) decays into a proton ($m_p = 938.3\,MeV$) and a negative pion ($m_\pi = 139.6\,MeV$). What is the momentum of the proton or pion in the CM frame?

   (d) The decaying Λ_0 has momentum $28.5\,\frac{GeV}{c}$ in the lab frame. What is the maximum angle between the proton and the pion in the lab?

4. **Accelerated Motion**

   (a) Consider a particle moving along the $x-$axis with velocity u and acceleration a, as measured in frame S. S moves relative to S with velocity v along the same axis. Show that

$$\frac{du}{dt} = \frac{1}{\gamma^3}\frac{1}{(1+u'v)^3}a'$$

   (b) Suppose that S is chosen to be the instantaneous rest frame of the particle and $a = 9.806\,\frac{m}{s^2}$. That is, $u' = 0$, $a' = g$, and $u = v$. Using the result from part (a), derive expressions for u (velocity as measured in S) and x as a function of time. Write x as a function of τ, the proper time as measured along the particles worldline, and evaluate for $\tau = 20$ years. Discuss the significance of this result for space travel. You can use $dt/d\tau = \gamma$ to derive an expression for τ as a function of t.

Part 3: LaTeX Writeups

Random choice of writers announced at end of seminar.

Turn in by email to instructor BEFORE next seminar.

Part 4: Grading

All grades based on weekly seminars work (as in old-style seminars). No exams.