Physics 008 **Problem Set #7** **Fall 2008**

My Lectures from : Purcell Appendix A
pages 451-455 = review of Physics 5
pages 456-458 = new stuff
Web Notes : Lecture Notes #5b
pages 1-11 = review of Physics 5
pages 12-20 = new stuff
Other Notes: Physics 6 Relativity Notes (Boccio)
pages 1-65 = review of Physics 5 & 7
pages 66-93 = new stuff

You should read parts of readings that review Physics 5 BEFORE I start lecturing on Special Relativity. Some of the problems(1-6) below will check to see if you understand the old material.

My class lectures will come from the new stuff as indicated above. The remaining problems(7-12) below are on the new stuff.

Know how to do from Physics 5

1. **What is that spaceship doing? -** Two radar pulses sent out from the earth at 6:00 AM and 8:00 AM one day bounce off an alien spaceship and are detected on earth at 3:00 PM and 4:00 PM. You are not sure, however, which reflected pulse corresponds to which emitted pulse, Is the spaceship moving toward earth or away? If its speed is constant (but less than c), when will it (or did it) pass by the earth? Drawing a spacetime diagram will make this problem easy.

2. **More events in different frames** - In the solar system frame, two events are measured to occur 3.0 hr apart in time and 1.5 hr apart in space. Observers in an alien spaceship measure the two events to be separated by only 0.5 hr in space. What is the time separation between the events in the alien's frame?

3. **They are simultaneous somewhere -** The space and time coordinates of two events as measured in a frame S are as follows:

$$Event\ 1: x_1 = x_0, t_1 = x_0/c \quad , \quad Event\ 2: x_2 = 2x_0, t_2 = x_0/2c$$

(a) There exists a frame in which these two events are simultaneous. Find the velocity of that frame(S') with respect to S.

(b) What is the value of at which both events occur in the new frame S'?

4. **Can you save them? -** In 2095 a message arrives at earth from the growing colony at Tau Ceti (11.3 y from earth). The message asks for help in combating a virus that is making people seriously ill (the message includes a complete description of the virus genome). Using advanced technology available on earth, scientists are quickly able to construct a drug that prevents the virus from reproducing. You have to decide how much of the drug can be sent to Tau Ceti.

   The space probes available on short notice could either boost 200 g of drug (in a standard enclosure) to a speed of 0.95, 1 kg to a speed of 0.90, 5 kg to a speed of 0.80, or 20 kg to a speed of 0.60 relative to the earth.

   The only problem is that a sample of the drug in a standard enclosure at rest in the lab is observed to degrade due to internal chemical processes at a rate that will make it useless after 5.0 y. Is it possible to send the drug to Tau Ceti? If so, how much can you send?

5. **The Strange World of Relativity -** Solve this problem with the Lorentz transformation equations and with a spacetime diagram. At noon a rocketship passes the earth with a velocity of 0.8c. Observers on the ship and on earth agree that it is noon.

(a) At 12:30 PM as read by a rocketship clock, the ship passes an interplanetary navigational station that is fixed relative to the earth and whose clocks read earth time. What time is it at the station?
(b) How far from earth (in earth coordinates) is the station?
(c) At 12:30 PM rocketship time the ship reports by radio back to earth. When (earth time) does the earth receive the signal?
(d) The station on earth replies immediately. When (by rocket time) is the reply received?

6. **Red or Green? -** There is a spaceship shuttle service from the earth to Mars. Each spaceship is equipped with two identical lights, one at the front and one at the rear. The spaceships normally travel at a speed v_0, relative to the earth, such that the headlight of a spaceship approaching the earth appears to be green ($\lambda = 5 \times 10^{-7} m$) and the taillight of a

departing spaceship appears to be red ($\lambda = 6 \times 10^{-7} m$).

(a) What is the value of v_0?

(b) One spaceship accelerates to overtake the spaceship ahead of it. At what speed must the overtaking spaceship travel (relative to the earth) so that the taillight($\lambda = 6 \times 10^{-7} m$) of the Mars-bound spaceship ahead of it looks like a headlight ($\lambda = 5 \times 10^{-7} m$)?

New from Physics 8

7. **Center-of-Mass Frame** - In the laboratory frame a particle of rest mass m_0 and a speed v is moving towards a particle of rest mass m_0 that is at rest. What is the speed of the inertial frame in which the total momentum of the system is zero? This frame is called the **center of mass** or **zero momentum** frame.

8. **Proton Dynamics** - A proton with a kinetic energy of $10^{10} eV$ collides with a proton at rest. Find

(a) the velocity of the center of mass

(b) the total momentum and total energy in the laboratory frame

(c) the kinetic energy of the particles in center of mass frame

9. **Total energy** - Two particles of rest mass m_0 approach each other with equal and opposite velocity v in the laboratory frame. What is the **total energy** of one particle as measured in the rest frame of the other?

10. **Relativistic collision** - A particle of rest mass m_1 and velocity v_1 collides with a stationary particle of mass m_2 and is absorbed by it. What is the velocity and rest mass of the final compound system?

11. **Relativistic decays** - A strange, neutral particle called a kaon (K_S^0) can decay into two charged pions($\pi^\pm$). The kaon has a mass of $498 MeV/c^2$, and the pions each have a mass of $140 MeV/c^2$.

(a) If the K_S^0 is at rest in the lab frame when it decays, what is the speed of the resulting pions?

(b) Now assume that the kaon is travelling at 0.99c with respect to the lab frame. What is the greatest speed that one of the pions can have in the lab frame? The least speed?

12. **Threshold energy** - A reaction that can produce antiprotons in an accelerator is

$$p + p \rightarrow p + p + p + \bar{p}$$

where the first proton is a part of a beam, the second is at rest in the target, and $\bar{p}$ is an antiproton. Both the proton and the antiproton have the same rest mass ($=0.94 \times 10^9$ eV). At threshold, all four final particles have essentially zero velocity with respect to each other. What is the beam energy in that case?