PHYS-3301 Winter Homework 7 Due 7 Mar 2018

This homework is due in the dropbox outside 2L26 by 10:59PM on the due date. You may alternately email a PDF (typed or black-and-white scanned) or give a hardcopy to Dr. Frey.

1. **Moving Mirror and Reflected Light**

   A mirror moves past a lightbulb at speed $c/2$. As described in the lightbulb's frame, the following events happen:

   A. The mirror passes the lightbulb at time $t = -L/c$.
   B. The lightbulb flashes at time $t = 0$.
   C. At time $t = L/c$, when the mirror is a distance L/c from the bulb, the flash of light hits the mirror.
   D. At time $t = 2L/c$, the reflected light reaches the lightbulb.

   (a) Find the proper time between events A and B.

   (b) Find the proper time between events A and C.

   (c) Find the proper time between events B and C.

   (d) Find the proper time between events B and D.

2. **Harmonic Motion Time Delays**

   A rocket flies back and forth around a resting space station with position $x = A\sin(\omega t)$ (t is the time on the space station). The period of motion is $2\pi/\omega$.

   (a) *inspired by Barton 6.4* First, assume $\omega A \ll c$. (This motion is then similar to a nonrelativistic mass on a spring or nonrelativistic pendulum.) Find the proper time on the rocket as a function of space station time t. Chose integration constants so that $\tau = 0$ at $t = 0$. Make appropriate approximations.

   (b) Sketch $\tau(t)$ for one period $0 < t < 2\pi/\omega$ and show for reference the 45-degree line $\tau = t$. Then find the difference between the total elapsed time t and the total elapsed proper time of the rocket over one period (this is the "time delay").

   (c) Find the time delay over one period in the case that $\omega A = c$. As a fraction of the period, is the time delay larger in this case or for $\omega A \ll c$?

3. **Ultrarelativistic Velocity Addition** *from Hogg 4.8*

   A neutral pion particle (π^0) of mass M is produced at rest with respect to the lab frame. In one possible but rare decay, it produces an electron and positron (anti-electron) which move off in opposite directions, each with mass m and relativistic γ factor of $\gamma = M/2m \approx 100$.

   (a) Since γ is so large, the speed of the electron or positron relative to the lab can be written as $u/c = 1-\epsilon$. Find ϵ to the lowest order in the small number m/M (that is, if ϵ is written as a power series in m/M, find the power series out to the lowest power with a nonzero coefficient) and then to 1 significant digit.

   (b) Relative to the electron, what is the positron's speed? Again, write the relative speed as $u/c = 1-\tilde{\epsilon}$ and find $\tilde{\epsilon}$ to lowest order in m/M and to 1 significant digit.

4. **Cosmic Rays** *from Resnick & Halliday*

   Cosmic rays are subatomic particles accelerated by astrophysical objects (like neutron stars and supernova remnants) that eventually reach the earth. Most of them are protons. Suppose

one cosmic ray proton approaches the earth from due north, and a second approaches the earth from due south. Both move at speed $3c/5$ in the rest frame of the earth. What is the relative speed of the protons (the speed of one proton in the rest frame of the other)?