Name(s): PHY-222 (Fall 2017), 09/05/17

Homework Assignment #1

(*Due Date*: Thu, 09/14, 05:30 pm, in class; Show all your work for full/partial credit)

1.1 *Momentum Conservation in Moving Frames* (cf. Prob. 1.2.2 in textbook) *(2 pts.)*
Car-1 of mass $m_1 = 1300kg$, initially moving at a speed of 50 mph, collides head on with car-2 ($m_2 = 1000kg$) which is initially at rest. After the collision the 2 cars stick together.

(a) Calculate the momentum and speed of the two cars right after the collision.

(b) Transform initial and final momenta of both cars into a reference frame moving at 25 mph in the direction of the initial velocity of car-1 and check momentum conservation in this moving frame.

1.2 *Time Dilation* (cf. Prob. 1.5.10+13 in textbook) *(2 pts.)*
The positively charged pion (π^+) is an unstable particle with an "average" lifetime of $\tau_\pi = 2.6 \cdot 10^{-8}s$, *i.e.*, its abundance decreases as $N(t) = N_0 \exp(-t/\tau_\pi)$ after initial production. Suppose a π^+ is produced in the atmosphere, 12 km above the Earth surface, with a speed of 0.99998c heading straight down.

(a) How far on average will the pion travel in Earth's rest frame before decaying?

(b) What is the probability the pion to make it to the Earth surface?
(or: out of 1 million such initial pions, how many will hit the Earth surface?)

1.3 *Doppler Effect* (cf. Prob. 1.5.16 in textbook) *(2 pts.)*
A professor argues to a judge that he was running a red light (wavelength λ=650nm) because it appeared orange (wavelength λ=610nm) to him on approach. The red-light fine is \$200, while speeding fines are \$20 for each 10 mph above the speed limit of 60 mph. What kind of speeding fine is the professor looking at?

1.4 *Lorentz Transformation* (cf. Probs. 1.6.19+21 in textbook) *(4 pts.)*
An observer standing on Earth observes spaceship travel.

(a) First, 2 spaceships are heading in the same direction toward Earth, one at $v_1 = 0.8$c and the other one at $v_2 = 0.85$c relative to Earth. What is the speed of spaceship-1 as seen from the captain in spaceship-2?

(b) Then 2 spaceships are heading toward Earth from opposite directions, at speeds of $v_3 = 0.9$c and $v_4 = 0.85$c relative to Earth. What is the speed of spaceship-4 as seen from the captain in spaceship-3?

(c) If spaceship-3 is 0.3 ly (1 ly=1 $lightyear$, the distance light travels in one year) away from Earth, how much older (in seconds) will be (i) the observer, and (ii) the captain, once the spaceship-3 lands on Earth?

(d) If the captain of spaceship-3 (proper length 450 m) instead decides to pass by Earth at its crusing speed (v_3), how long will spaceship-3 be as measured by the observer on Earth?