Name(s): PHY-222 (Fall 2018), 09/03/18

Homework Assignment #1

(*Due Date*: Wed, 09/12, 04:10 pm, in class; Show all your work for full/partial credit)

1.1 *Kinetic Theory of Gases* *(3 pts.)*
An ideal gas (n=0.1mol) of oxygen atoms (m_O=16u with 1u=$1.66 \cdot 10^{-27}kg$), equivalent to N=$N_A/10$ atoms (N_A=$6 \cdot 10^{23}$), is held in a cubic container (volume $V = 0.1m^3$) at temperature T=300 K (Boltzmann constant k_B=$1.38 \cdot 10^{-23} m^2kg/s^2K$).

(a) Calculate the average kinetic energy, $\bar{K}$, and speed, $\bar{v}$, of the atoms.

(b) Focus on one of the vertical walls of the container and calculate the average force $F = \Delta p/\Delta t$ exerted on it by one atom. Assume Δt to be the time it takes for an atom to move back and forth across the box, and a momentum transfer of $\Delta p = 2\bar{p}$ for each collision with the wall.

(c) Calculate the gas pressure using: (i) $p = F_{\text{tot}}/A$ assuming $N/3$ atoms to collide with a wall; (ii) the ideal-gas law.

1.2 *Time Dilation* (cf. Prob. 1.5.10+13 in textbook) *(3 pts.)*
The neutron (n) is an unstable particle (decaying as $n \to pe^-\bar{\nu}_e$) with an "average" lifetime of $\tau_n = 882s$, *i.e.*, its abundance decreases as $N(t) = N_0 \exp(-t/\tau_n)$ after initial production. Suppose n's are produced on Mars (for example, by a nuclear reactor) emitted in the direction of Earth, $55 \cdot 10^6\, km$ away.

(a) If the neutron is produced at a speed of 0.1c, how much time will pass in: (i) the Earth-Mars rest system; (ii) the neutron's rest system?

(b) What percentage, $P(t)$=$N(t)/N_0$, of neutrons makes it to Earth: (i) with; or (ii) without the effect of special realtivity?

(c) Repeat parts (a) and (b) for an initial speed of 0.5c.

1.3 *Doppler Effect* (cf. Prob. 1.5.16 in textbook) *(1 pts.)*
The 580 nm sodium emission line of a star is observed to be red-shifted to 650 nm, as measured by an Earth-based telescope. Determine the velocity of the star, assuming it is oriented along the Earth-star connection line.

1.4 *Lorentz Transformation* (cf. Probs. 1.6.19+21 in textbook) *(3 pts.)*
An observer standing on Earth observes spaceship travel.

(a) Two spaceships are heading in the same direction toward Earth, one at v_1=0.95c and the other one at v_2=0.85c relative to Earth. What is the speed of spaceship-1 as seen from the captain in spaceship-2?

(b) Two other spaceships are heading toward Earth from opposite directions, at speeds of v_3=0.8c and v_4=0.9c relative to Earth. What is the speed of spaceship-4 as seen from the captain in spaceship-3?

(c) If spaceship-1 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 has landed on Earth?