PHYS-3301 Homework 3 Due 3 Oct 2012

This homework is due in the dropbox outside 2L26 by 11:59PM on the due date. If you wish to turn it in ahead of time, you may email a PDF or give a hardcopy to Dr. Frey.

1. **Moving Maxwell Distribution** *variations on Barton 2.7*

   In the rest frame S' of the gas, the Maxwell distribution for a single component of velocity is

   $$P(u'_x) = \left(\frac{m}{2\pi kT}\right)^{1/2} e^{-m(u'_x)^2/2kT} \ , \tag{1}$$

   where $\vec{u}$ is the velocity of each gas molecule, as we discussed in the class notes.

   (a) Suppose I'm standing by the road and the gas is in a bus driving by at speed v in the x direction (compared to me). What is the distribution of the velocity component u_x in my frame S? *Hint:* You need to think about whether there is a nontrivial Jacobian for the change of integration variables $u'_x \to u_x$.

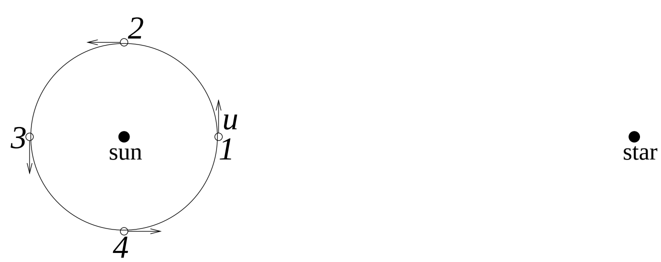
   (b) Calculate the averages $\langle u_x \rangle$ and $\langle u_x^2 \rangle$. *Hint:* You can do this either by explicit integration against the velocity distribution (in which case you need to change integration variables to put the integral into Gaussian form) or by using our rules to change frames.

2. **Stellar Aberration**

   In this problem we will explore more the aberration of starlight that was measured as far back as 1725. In this problem, all speeds of objects are small compared to the speed of light, so you are free to use Newtonian/Galilean relativity. You may want to recall that the speed of light is approximately $c = 3 \times 10^8$ m/s.

   (a) First, to get a feel for how this works, consider the following situation. You're driving in a car, and it's raining. Relative to the fixed earth, the rain falls straight down with speed w, and you drive at speed u. At what angle from the vertical do you see the rain falling?

   (b) Now, suppose there is a star straight overhead compared to your telescope. However, the earth is at position 1 in its orbit around the sun (see the figure below), where the orbital speed of the earth is approximately $u = 30,000$ m/s. At what angle from the vertical must I, standing on the earth, aim my telescope so that light from the star falls down the telescope tube? You may ignore the rotational speed of the earth's surface, which is much smaller than the earth's orbital speed. *Hint:* Recall that $\tan\theta \approx \sin\theta \approx \theta$ for small angles θ.



   Note that the figure is not to scale; the star is far enough away that it is effectively directly overhead (at the appropriate time of day) no matter where the earth is in its orbit. Give the angle in arc-seconds, where 3600 arcsec equal 1 degree.

   (c) At which point(s) as labeled in the figure above is this angle of aberration maximized? At which points is it minimized?