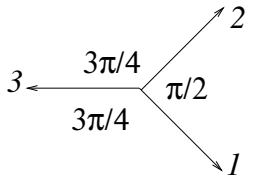
PHYS-3301 Winter Homework 11 Due THURSDAY 5 April 2018

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. **3-Body Kaon Decay**

   A K meson (also known as a *kaon*) of mass M can decay into three π mesons (also called *pions*), each of mass m. In this problem, a kaon decays at rest. Pions #1 and #2 move off perpendicularly to each other and at an angle of $3\pi/4$ to pion #3 (in a plane). See the figure below.

   Find the energy E_1 of pion #1. *Hint:* First show that pions #1 and #2 have the same energy using spatial momentum conservation. Then use 4-momentum conservation.

2. **Reflected Sound** *based on Barton*

   Consider a police car situated to the left of a large tractor-trailer truck. The sound of the police siren reflects off the back of the truck and back to the police officer. In the police car's frame, the initial sound frequency is ω. In the two situations below, what is the frequency of the reflected wave that the police officer hears? *Hint:* In the rest frame of the reflecting surface, the reflected sound wave has the same frequency as the incident sound wave.

   (a) In a frame with no wind, the police car moves at speed $u < c_s$ toward the truck, which is stationary.

   (b) In a frame with no wind, the truck moves at speed $u < c_s$ toward the police car, which is stationary. If your answer is different than the previous part, explain.

3. **Spaceship Communications**

   Space station ES10 sits at galactic coordinates $x = 0$ lyr, $y \equiv y_0 = 3$ lyr. The station is able to receive radio signals in the range of $\omega_1 = 3$ MHz to $\omega_2 = 25/3$ MHz. Suppose that the experimental starship NX-02 travels along the x axis at constant speed $u = 4c/5$, passing $x = 0$ at $t = 0$ according to the spacestation. The starship broadcasts its positions at frequency $\omega_E = 5$ MHz. From what positions x can the space station receive the starship's signal?

4. **Fast Orbit**

   The star S-2 orbits the (presumed) black hole at the center of our galaxy with the highest known orbital speed of any astrophysical object. Consider a simplified model of its orbit as a perfect circle with a period of $T \approx 15$ yr and orbital speed of $u \approx 0.02c$. Also suppose that the earth is in the same plane as S-2's orbit at a distance much greater than the size of the orbit. S-2 emits a spectral line of frequency $\omega \approx 8 \times 10^{14}$ Hz; what is the difference of the observed frequency at earth to the emitted frequency as a function of emitted time t? Let $t = 0$ be the distance of closest approach between S-2 and earth. Give the formula first in terms of variables and then calculate numerical values. Work to 1 significant figure. You may safely assume that the earth's orbital speed around the sun and the sun's orbital speed around the center of the galaxy are negligible.