PHY 251 Fall 2009: homework problem set 2, due PHY 251 drop box in room A-129 by noon on Friday, Sep. 18.

1. Dick and Jane are each carrying an exact meter stick (according to them in their frame of reference). Dick goes past you at mach ten or 3000 m/s, while Jane goes past you at half the speed of light. How much shorter than 1 meter does Jane's meter stick appear to you? How much shorter than 1 meter does Dick's meter stick look to you?

2. A smug city slicker bets a farmer that he can't get his 10 m long ladder into a 8 m long shed. The farmer, who reads Einstein each day after milking his cows, takes him up on the bet. He tells the city slicker to stand to the side of the shed and look in the windows at each end, and the farmer then runs fast as he can through the shed while carrying the ladder. How fast does the farmer have to run to win the bet? While on the run, how long does the shed appear to the farmer, and does the farmer ever think his ladder is entirely inside the shed? (3 answers required).

3. You tune your radio in your car to your favorite radio station which plays all Barry Manilow all the time: 88.1 MHz. However, you find instead that you are receiving the death metal station WIKD which broadcasts at 106.1 MHz. How fast are you going, and in which direction relative to WIKD?

4. Which carries more energy: a kilogram of gasoline, a kilogram of TNT or dynamite (which releases about 15 MJ per kg), or a 200 micrometer diameter drop of water if all of its mass could be converted into energy? (Hint: use Wikipedia to remind yourself of the heat of combustion).

5. In a quest to win either a Darwin Award or a Nobel Prize, you decide that you want to build a particle accelerator in your dorm. You use unshielded terminals to hook up an accelerating voltage of 200 kiloVolts, and also build a 0.2 Telsa magnet using soldered paper clips for the windings. If it is an electron that you accelerate, what is its kinetic energy? Momentum? Radius of curvature in the magnetic field?

6. The LHC at CERN will accelerate protons up to an energy of 7 TeV, or 7×10^{12} eV. Calculate the momentum of such a proton. How different from the speed of light is its velocity?

7. Radiation pressure can be described using the momentum of a photon. Use conservation of momentum to derive an expression for the acceleration a of a mass m that has absorbed N photons of energy $E = h\nu$ each over a time t.

8. Use your results from the previous problem to calculate the acceleration you might experience in a solar sailing race. Let's say that you, your space "shell," and your absorptive solar sail together weigh 1000 kg. Let's assume that your solar sail is a square 2 km on a side, that it's absorptive, that it's facing dead-on to the sun, and that the sun's output of 1366 W/m^2 is all visible light ($\lambda = 500$ nm).

9. Calculate the peak output wavelength for an object heated to a temperature of 10^5 K.

10. Calculate the number of photons per second emitted by a low power Bluetooth radio transmitter (1 mW at 2.4 GHz).