1. **Pluto's** orbit is far more eccentric than those of the major planets' orbits:

Aphelion: 7,375,927,931 km
Perihelion: 4,436,824,613 km

a. Determine the solar flux (watts/m^2) at each of these distances.
b. Assume the albedo is 0.7 in both cases. Determine the radiative equilibrium temperature at both distances.

2. Titan vs Earth atmospheric mass

How much mass is in a column of Titan's atmosphere relative to a column of Earth's air? Assume the two atmospheres are made up of the same gases (which is almost true because both are dominated by N_2). Assume Titan's surface pressure is 1.5 bars and its surface gravity is 1.35 m/s^2.

3. **Calculate the heat capacities** (both C_v and C_p) of He, H_2 and N_2 in both J/mole/K and in J/kg/K.

4. Rotational energy levels of a diatomic molecule

a. Calculate the first 4 energy levels of each of the 3 rotational modes of N_2.
b. Use the Boltzmann distribution to show that one of the 3 modes will not be populated at typical Earth temperatures.

The impact of doubling CO_2 on Earth's surface temperature

5. In the first figure in the notes on the motivation of studying atmospheric science, the IR radiative flux from Earth's atmosphere into the surface is 324 watts/m^2.

a. Based on the Stephan-Boltzmann law, what is the temperature of the atmospheric level that is radiating into the surface?
b. Assuming the Earth's surface temperature is 288 K and the atmospheric temperature decreases vertically at a rate of 6.5 K/km, at what atmospheric altitude is the IR radiation into the surface coming from?

6. The outgoing IR radiation to space of 235 watts/m^2 is composed of 3 terms: 165 watts/m^2 from the atmospheric gas, 30 watts/m^2 from the atmospheric clouds and 40 watts/m^2 from the surface.

a. Take the atmospheric portion: 165 + 30 = 195 watts/m^2. Based on the Stephan-Boltzmann law, what is the temperature that it is radiated from?
b. Assuming the same atmospheric temperature structure as in the previous problem, what altitude in the atmosphere is this being radiated from?
c. Assume that increasing CO_2 in the atmosphere causes the atmospheric portion of the IR watts/m^2 to decrease by 4 watts/m^2, how much cooler is the new radiating temperature?
d. How much higher is the new radiating altitude than the original?

7. Assuming the vertical temperature gradient remains at 6.5 K/km, how much must the surface temperature increase to bring the Earth back into equilibrium?