QUANTUM PHYSICS I

PROBLEM SET 4

due October 30, before class

A. Blackbody radiation and the temperature of the Earth

In this problem we will make a simple model of the global energy balance of the Earth and estimate its temperature. The main source of energy on Earth is the Sun. Both the Sun and the Earth can be approximated by blackbodies, but the Earth reflects, instead of absorbing, about 35% of the energy received (it is said the *albedo* of the Earth is 0.35).

i) Integrate the Planck radiation law over all frequencies to find the total energy (per unit of area and time) emitted by a blackbody (the resulting expression is known a *Stefan-Boltzman law*).

ii) Calculate the power (energy per unit time) the sun radiates as a function of its surface temperature T_s and radius R_s.

iii) Find the fraction of the energy above absorbed by the Earth as a function of its albedo a and distance from the Sun r and the Earth radius R_E. (hint: the energy emitted by the sun is spread uniformly over a sphere of radius r when it reaches the Earth and only a fraction shines upon the Earth).

iv) In equilibrium, the amount of energy absorbed by the Earth is emitted back to space. Equate the result from iii) to the power emitted by the Earth ($4\pi R_E^2 \sigma T_E^4$) and find the temperature of the Earth in equilibrium. Plug the values: $r = 150 \times 10^9 m$
$R_s = 7 \times 10^8 m$
$T_s = 5,800 K$
$R_E = 6,400 km$
to find the temperature of the Earth at equilibrium.

The temperature you'll find is reasonably close to the correct average temperature of the Earth, but a little lower. The main ingredient missing in our model is the fact that some gases (mostly carbon dioxide) in the Earth's atmosphere absorb some of the radiation emitted by the Earth, acting as a blanket and making it warmer. This is called the "greenhouse effect". The temperature of the Earth depends crucially on the amount of these gases in the atmosphere.

B. Photoelectric effect applet

Go to `http://lectureonline.cl.msu.edu/~mmp/kap28/PhotoEffect/photo.htm` (or use the link on the class webpage). Play with the applet until you can predict, qualitatively, what the current is going to be. If you do that and learn how to predict the outcome before runnign the applet just write "I did" in your write-up. Yes, I'll trust you. Or maybe will ask you in class ...