Physics 213 **Problem 5** **Week 5**

Temperature of the Planets

In this problem we will estimate the temperature of some planets. To accomplish this, you will need to know the following information:

	Radius	Albedo	Actual Temperature	Estimated Temperature
Sun	7×10^8 m		5800 K	
Venus' Orbit	1.1×10^{11} m	65%	735 K	251K
Earths' Orbit	1.5×10^{11} m	30%	290 K	256K
Mars' Orbit	2.3×10^{11} m	15%	213.5 K	217K
Jupiters' Orbit	7.8×10^{11} m	52%	418 K	102K

The albedo of a planet is the percent of solar radiation that gets reflected by the atmosphere. This radiation doesn't contribute to the heat budget of the planet.

(1) Assume the Sun is a 'blackbody'. Although the Sun is much hotter (and hence emits more energy) then the planets, a planet only receives a small fraction of it. Write down a formula for the Sun's flux at a planet as a function of its orbital radius.

$J_r = \sigma T_s^4 (R_s/R)^2$

(2) For a planet's temperature to remain approximately constant, the thermal radiation it receives from the Sun is balanced by the thermal radiation it emits. Also assuming the planets are a blackbody, write down a formula to estimate the temperature of a planet as a function of its orbital radius and albedo. Assume that the planet absorbs as a disc but radiates as a sphere. Compute the estimated temperatures for the four planets listed above. Which planets does this accurately compute the temperature for?

Planet's Flux at its surface: σT_E^4

$\sigma T_E^4 \, 4\pi (R_e^2) R^3 = \pi (R_e^2) \sigma T_s^4 (R_s/R)^2$
$T_E = (T_s^4/4(R_s/R)^2)^{1/4}$

Mars is quite close and Earth is not too far away.

(3) Calculate the maximum wavelength radiated by the Sun and the Earth.
$\lambda T = 2.898e-3$ m-K

Earth: 1.035e-5 m
Sun: 499 nm

(4) We notice that our estimate for the temperature of the Earth is off by 35 K This is because we've ignored any effect of greenhouse gases. Assume that greenhouse gases reflect approximately 35% of the emitted by the Earth back to the Earth. Now, compute the temperature of the Earth. How does it compare to the actual temperature?

Now we get 285K which is quite close.

Notice, that Venus' temperature is significantly off. This is because Venus' reflects approximately 99% of the radiation emitted by Venus back to Venus. If you were to redo part (d) for Venus you will get approximately the right temperature.