HOMEWORK 7, THERMAL PHYSICS (PHY306)

1. The temperatures of the planet surfaces are maintained by radiation from the Sun. By making the approximation that the Sun is a black body, but the planets are grey bodies with albedo $A = 0.2$ (this means that it reflects a fraction A of the incident energy), calculate the mean planet temperatures T_i where $i = Venus, Earth, Mars, Jupiter$. Take the Sun surface temperature $T_{Sun} = 6000K$, and its radius $R_{Sun} \approx 7 \cdot 10^8\, m$. The planet distances from the Sun are

$$\big(D_V \approx 1.1; D_E \approx 1.5; D_M \approx 2.3; D_J \approx 7.8\big) \cdot 10^{11}\, m$$

2.Using the data from problem 1, calculate how many photons falling per m^2 per second on Earth from the Sun. Compare it to the number of cosmic microwave background (CMB) photons passing per m^2 per second anywhere in Universe. ($T_{CMB} = 2.7K$).

3.At high temperatures the gas of phonons is described by classical equipartition theorem, e.g. its specific heat per mole $C(T) \to C_{high} = 3R$. When Einstein used his model for specific heats of solids, all substances showed reasonable agreement except for one, the diamond! Using Debye model, estimate what fraction of that classical asymptotic value $C(T)/C_{high}$ is, for the table salt and the diamonds at room temperature $T = 300K$, using corresponding values of their Debye temperatures $\Theta_{NaCl} = 320K, \Theta_{diamond} = 1860K$. (Hint: plot the integrand of (24.25) and estimate the area till the corresponding upper limits $x_D = \Theta/T$ in both cases.)

4.The lightest mesons, called pions, form approximately ideal gas at the end of high energy heavy ion collisions. There are three types of them, π^+, π^0, π^-.
(a) Using ultrarelativistic relation between the energy and momentum $E_p = cp$ with c the speed of light, calculate the partition function Z, the pressure p, the energy density $u = U/V$ and the entropy S of the pion gas.
(b)A fireball of the pion gas is created in volume $V_i = 100 fm^3$ at temperature $T \approx 160\, MeV$. It then adiabatically expands to volume $V_f = 800\, fm^3$: what final temperature T_f would it have then? How much does the internal energy U of the gas change? Where does the energy go?