PROBLEM SET 6

Reading:

- Kittel & Kroemer Ch. 4, pp. 102-110
- Kittel & Kroemer Ch. 5, pp. 117-144

1. K&K problem 4.8 (*Heat shields*).

2. K&K problem 4.19 (*Reflective heat shield and Kirchoff's Law*).

3. K&K problem 4.18 (*Isentropic expansion of photon gas*). Before answering (a) and (b), explain why $\tau V^{1/3}$ has been constant since the cosmic black-body radiation decoupled from matter. You may wish to read through problem 17.

4. K&K problem 4.12 (*Heat capacity of photons and phonons*)

5. K&K problem 4.14 (*Heat capacity of liquid ^{4}He at low temperatures*)

6. *Active transport* (from K&K 5.4). The concentration of potassium K^+ ions in the internal sap of a plant cell may exceed by a factor of 10^4 the concentration of K^+ ions in the pond water in which the cell is growing. The chemical potential of the K^+ ions is higher in the sap because their concentration n is higher there. Estimate the difference in chemical potential at 300 K and show that it is equivalent to a voltage of 0.24 V across the cell wall.

7. *States of positive and negative ionization* (from K&K 5.7). Consider a lattice of fixed hydrogen atoms. Suppose that a neutral atom can exist in either its ground state, of energy $-\Delta/2$, or an excited state of energy $\Delta/2$. Alternatively, it can exist as a positive ion with energy $-\delta/2$ or a negative ion with energy $\delta/2$.

    a. Show that the average number of electrons per atom can be calculated as $\langle N\rangle = \phi\, d(\ln \jmath)/d\phi$, where $\phi = e^{\beta\mu}$ and μ is the chemical potential. Find $\jmath$.

    b. Find a condition for the average number of electrons per atom to be unity in terms of δ, β, and ϕ.

    c. If the average number of electrons per atom is unity, what is the value of the chemical potential?

    d. Give a physical explanation for the value of the chemical potential that you found. Does it depend on the energies of the ground and excited states? Why or why not?