8.08 Problem Set # 5

March 2, 2005
Due March 9, 2005

Problems:

1. At finite temperature, a semiconductor contains electrons and holes. An electron and a hole can annihilate and release an energy Δ:

$$e + h \leftrightarrow \Delta$$

(You may assume each electron and each hole have an internal energy $\Delta/2$.) Here we assume the electrons and the holes have the same mass m and the temperature is T.

(a) Find the densities of the electrons n_e and the holes n_h in a undoped semiconductor. (In a undoped semiconductor $n_e = n_h$.)

(b) Find the densities of the electrons n_e and the holes n_h in a doped semiconductor. (In a doped semiconductor $n_e - n_h = n_d$ where n_d is the density of doping which is fixed.)

2. If we roll two dices, we get a pair of random numbers (n_1, n_2).

(a) Consider two random numbers

$$k_+ = n_1 + n_2, \qquad k_- = n_1 - n_2.$$

Are k_+ and k_- independent random numbers?

(b) Consider two random numbers

$$m_+ = (n_1 + n_2) \bmod 6, \qquad m_- = n_1 \bmod 6.$$

Are m_+ and m_- independent random numbers?

3. (a) A pendulum is formed by a mass M and string of length L. Calculate the thermal fluctuations of the position of the mass: $\Delta x = \sqrt{\langle (x - \bar{x})^2 \rangle}$. Assume the air temperature is T.

(b) Calculate the value of Δx assuming $M = 1$g, $L = 10$cm, and $T = 300$K.

4. Problem 12.11 in K. Huang's book.