J08T.1 - Graphene

Problem

Graphene is a new material that consists of an essentially two-dimensional array of carbon atoms. The velocity of sound is $c_s \sim 10^4$ m/s, and the area density of the material is ~ 6 atoms/nm^2 (1 nm $= 10^{-9}$ m).

a) Estimate the Debye temperature Θ_D. Explain clearly how this quantity is defined in relation to experiment, and what physical picture you are using when you make your estimate. By "estimate" we mean to give an approximate numerical answer in Kelvin.

b) Derive an expression for the contribution of phonons to the specific heat at constant volume, C_V. Find the limiting behaviors at high and low temperature, and use these limits to make a sketch of C_V vs. T. Label the axes with numbers to set the scale of your graph, and be clear about units.

c) What is different in this problem from the textbook example of a three-dimensional crystal? Derive an expression not for the average energy, but for the mean-square displacement of one atom in the two-dimensional array. Do you see any problems?