Háskóli Íslands
Raunvísindadeild
Eðlisfræði

Haust 2016

Eðlisfræði þéttefnis I

Dæmablað 7

Skilafrestur 25. October 2016 kl. 15:00

1. **Dispersion relation** (15)

   Consider a linear chain in which alternate ions have mass M_1 and M_2, and only nearest neighbors interact.

   (a) Show that the dispersion relation for normal modes is

   $$\omega^2 = \frac{K}{M_1 M_2}\left(M_1 + M_2 \pm \sqrt{M_1^2 + M_2^2 + 2M_1 M_2 \cos ka}\right)$$

   (b) Discuss the form of the dispersion relation and the nature of the normal modes when $M_1 \gg M_2$. (i.e. calculate and draw the normal modes)

   (c) Compare the dispersion relation with that of the monatomic linear chain when $M_1 \sim M_2$. (i.e. calculate and draw the normal modes)

2. **Specific heat** (20)

Hljóðeiginleikar rafsvara yfirgnæfa varmahegðan og aðra eiginleika eins og ljósleiðni. Demantur er einnar atóma rafsvari úr kolefni sem hefur 10^{21} atoms/cm^{-3}.

(a) Rissaðu, varmarýmd (á atóm) sem fall af hitastigi.

(b) Hvernig er T_{Debye} tengt Debye tíðninni ω_{D} ?

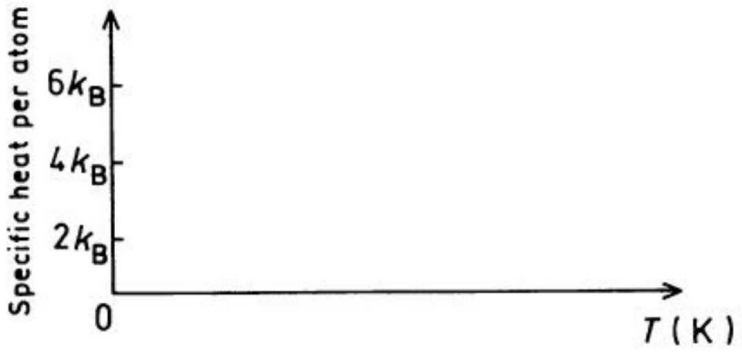
(c) Ef að hljóðhraðinn við lágar tíðnir er 5×10^5 m/s, hvað er þá góð nálgun fyrir ω_{D} ?

Acoustic properties of dielectric solids dominate their thermodynamic behavior and other properties such as photoconducting resistance. Diamond is a monoatomic dielectric solid of carbon having 10^{23} atoms/cm^{-3}.

(a) Sketch, roughly, its specific heat (per atom) as a function of absolute temperature.

(b) How is T_{Debye} related to the Debye frequency ω_{D} ?

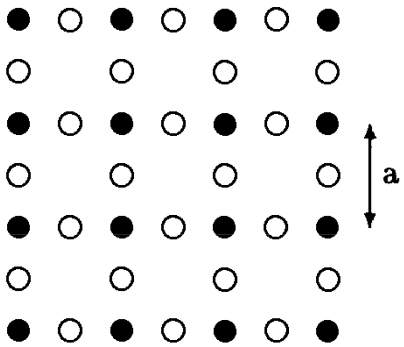
(c) If the acoustic velocity at low frequencies is 5×10^5 m/s, what is approximately the value of ω_{D} ?



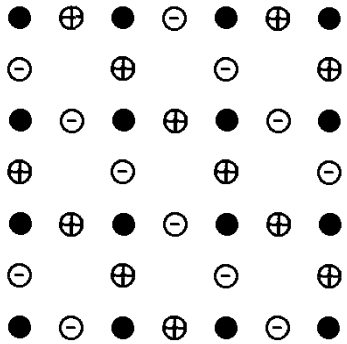
(Próf maí 2016)

3. **Copper Oxide Layers** (15)

The common building blocks for most high temperature (high T_{c}) superconductors are copper oxide layers, as shown below. Assume the distance between copper atoms (filled circles) is a. For simplicity let us also assume that in the third dimension these CuO_2 layers are simply stacked with spacing c, and there are no other atoms in the crystal. In first approximation the layers have a four-fold symmetry; the crystal is tetragonal.



(a) Sketch the Bravais lattice and indicate a possible set of primitive vectors for this crystal. What is the unit cell, and what is the basis ?



(b) In $LaCuO_4$ one discovers, at closer inspection, that the CuO_2 lattice is actually not flat, but that the oxygen atoms are moved a small amount out of the plane ("up" or "down") in an alternating fashion (in the figure a + meand up and a - means down). What is the primitive cell and lattice spacing for this crystal ? What is the reciprocal lattice ? Describe (qualitatively) what happens in the X-ray diffraction pattern as the distortion is decreased gradually to zero.

$LaCuO_4$ is an antiferromagnetic insulator. High temperature superconductivity was discovered in a closely related compound $La_{1-x}Ba_xCuO_4$. See J. G. Bednorz and K. A. Müller, *Z. Physik B* **64**, 189 (1986).