Háskóli Íslands
Raunvísindadeild
Eðlisfræði

Haust 2017

Eðlisfræði þéttefnis I

Dæmablað 7

Skilafrestur 12. October 2017 kl. 15:00

1. **Grafín bognunarháttur – Graphene bending mode** (20)

   Til viðbótar við hina venjulegu hljóð- og ljóshætti, þá er í frístandandi grafín þynnu líka bognunarháttur. Þetta er þversum háttur með tvístrun $\omega(q) = aq^2$, þar sem a = fasti. Gera skal ráð fyrir að tvístrunarlögmálið gildi fyrir $0 \leq q \leq q_{\mathrm{D}}$. Finna skal framlag þessa bognunarháttar til eðlisvarmans í tveimur jaðar tilfellum:

   (a) $k_{\mathrm{B}}T \gg \hbar\omega_{\mathrm{D}}$

   (b) $k_{\mathrm{B}}T \ll \hbar\omega_{\mathrm{D}}$

   þar sem $\omega_{\mathrm{D}} \equiv \omega(q_{\mathrm{D}})$.

   In addition to the usual acoustic and optical modes, a free-standing membrane of graphene supports a bending mode. This is a transverse mode with dispersion $\omega(q) = aq^2$, where a = const. Assume that this dispersion law holds for $0 \leq q \leq q_{\mathrm{D}}$. Find the contribution of the bending mode to the specific heat in two limiting cases:

   (a) $k_{\mathrm{B}}T \gg \hbar\omega_{\mathrm{D}}$

   (b) $k_{\mathrm{B}}T \ll \hbar\omega_{\mathrm{D}}$

   where $\omega_{\mathrm{D}} \equiv \omega(q_{\mathrm{D}})$.

   (Próf desember 2016)

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} ?

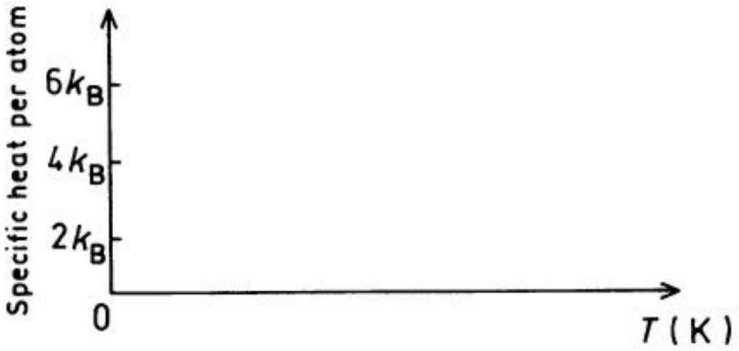
(c) Ef að hljóðhraðinn við lágar tíðnir er 5×10^5 m/s, hvað er þá góð nálgun fyrir ω_{D} ?

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. **Thermal conduction** (10)

Explain why electrons carry a net energy but not a net current in the case of thermal conduction.

4. **Low-temperature specific heat in d dimensions and for nonlinear dispersion** (15)

   Consider small lattice vibrations in a d-dimensional crystal in harmonic approximation.

   (a) For the Debye model, i.e. a linear dispersion $\omega = c\,|k|$ of all phonon modes, calculate the phonon density of states and show that it varies as ω^{d-1}. What is the Debye frequency ?

   (b) Determine the phonon contribution to low-temperature specific heat.

   (c) Investigate what would happen for a nonlinear phonon dispersion $\omega \sim |k|^{\nu}$ (anomalous sound). Show that the low-temperature specific heat would vanish as $T^{d/\nu}$ in d dimensions.