

PHYS 353 Solid State Physics
 Supplemental Problems
 Part 2. Crystal Dynamics

2-1. Show that if you substitute the proposed wave solution of Eq. (2.8) into the Newton's Second Law expression of Eq. (2.7), you do get the dispersion relation of Eq. (2.9).

2-2. Consider the dispersion relation for the one-dimensional atomic chain stated in Eq. (2.9).

- Find an expression for the group velocity of a displacement wave traveling along the chain. Recall that the group velocity is dk/dk .
- Find an expression for the maximum angular frequency that the chain can support.
- What is the group velocity if this maximum frequency is the main frequency of the group? Explain why this answer makes sense if you examine the graph of the dispersion relation.
- Find an expression for the phase velocity of a wave at this maximum frequency.

2-3. Let's model copper (fcc lattice with a basis of one atom) as a one-dimensional chain and calculate approximate values for different quantities.

Elastic modulus: $1.2 \times 10^{12} \text{ N/m}^2$
 Density: 8.92 g/cm^3
 Atomic mass: 63.55 amu ($1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$)
 Lattice constant: $3.6 \text{ \AA}$

- Find the speed of sound in copper using Eq. (2.3).
- Recall that these sound waves have very long wavelengths compared to a . Show that in this limit, the dispersion relation in Eq. (2.9) gives the speed to be $a\sqrt{K/M}$.
- By equating your answers to (a) and (b), find a value for the spring constant K .
- With this spring constant, show that the maximum frequency that can be supported by the chain is around $3 \times 10^{12} \text{ Hz}$.
- If electromagnetic radiation with this frequency hits a copper object, then it should be strongly absorbed since its energy can be strongly coupled into lattice vibrations. In what part of the spectrum is light with this frequency?

2-4. Let's model gallium arsenide (fcc lattice with a two-atom basis) as a one-dimensional chain with two types of atoms and calculate approximate values for different quantities.

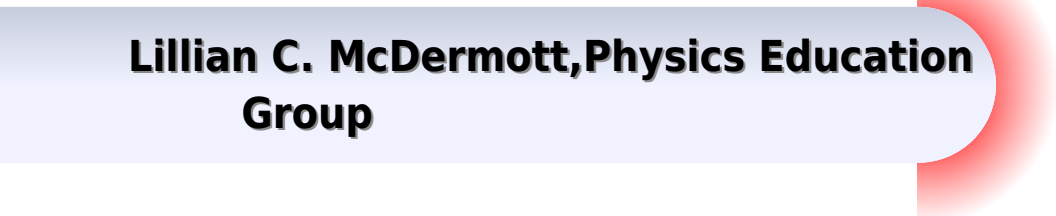
Elastic modulus: $7.55 \times 10^{10} \text{ N/m}^2$
 Density: 5.32 g/cm^3
 Atomic masses: Ga 69.72 amu As 74.92 amu ($1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$)
 Lattice constant: $5.65 \text{ \AA}$

- Find the speed of sound in GaAs using Eq. (2.3).
- These sound waves are near point O in the dispersion relation plot in Fig. 2.7. Using this fact, find an approximate value for the spring constant for the chain.
- Now show that the maximum frequency supported by the chain is around $4 \times 10^{12} \text{ Hz}$. This vibration is near point A on the optical branch of the dispersion equation plot. What type of light has this frequency?

2-5. Eq. (2.29) gives the heat capacity due to a single mode of lattice vibration.

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Group**



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