Elastic scattering of neutrons

\[ E' = \text{reduced} \]

\[ E \quad \rightarrow \quad E' \quad \text{photons} \]

\[ E_f = E_i - \hbar \omega \]

\[ p_f = p_i - \hbar k \]

\[ \Rightarrow E' = \text{increased} \]

\[ \text{neutron absorbs a photon} \]

\[ E_f = E_i + \hbar \omega \]

\[ p_f = p_i + \hbar k \]

Use cons. of energy + cons. of momentum to analyze problem.

Next page

Worked problem: Which exact photon produced peak A?

(Hint: ___ ___ ___ ___ ___ ___ ___)

(Answer: ___ ___ ___ ___ ___ ___ ___)
Fig. 3-21. Dispersion curves in copper (Cu) along the dashed lines shown for the first Brillouin zone in Fig. 3-19. Data are from E. C. Svensson, B. N. Brockhouse, and J. M. Rowe, *Phys. Rev.* 155, 619 (1967).

Fig. 3-21. Dispersion curves in copper (Cu) along the dashed lines shown for the first Brillouin zone in Fig. 3-19. Data are from E. C. Svensson, B. N. Brockhouse, and J. M. Rowe, Phys. Rev. 155, 619 (1967).

Fig. 5-3. Directions of incident and scattered neutrons for the spectrum in Fig. 5-2.

Fig. 5-2. Inelastic scattering of neutrons from copper. Reprinted with permission from J. Phys. Chem. Solids 23, J. Sosnowski and J. Kuzubowski, "Phonon dispersion relations for copper single crystal in the [100] direction," Copyright 1962, Pergamon Press, Ltd.
Chapter 5: "Phonons II, Thermal Properties"

Last lecture:

\[(n + \frac{1}{2}) \hbar \nu = \text{energy for all phonons with frequency } \nu.\]

How many phonons is that?

Answer: \[N_{\text{phon}} = \frac{1}{e^{(\mu - \epsilon)/kT} - 1} \]

\[k = k_B = 1.38 \times 10^{-23} \text{ J/K} \quad \text{Not wavevector}\]

Kittel: sometimes \(\mu = kT\)

Where does that come from?

Two major results of phonons 36a: What's likelihood of a given energy state \(E\) being occupied?

**Bose-Einstein Distribution**

\[N_{\text{Bose}} = \frac{1}{e^{(\epsilon - \mu)/kT} - 1} \]

For particles in Bose-exclusion

(for photons, phonons, etc.)

"Bosons"

\(\mu = \text{"Chemical Potential"}

needs if you have a fixed # of particles \(N\) \(E = \mu N\)

\(\mu = \text{constant}\)

For photons/phonons \(\mu = 0\) because you can add (take away) photons with no problem.

**Fermi-Dirac Distribution**

\[N_{\text{Fermi}} = \frac{1}{e^{(\epsilon - \mu)/kT} + 1} \]

For particles in Pauli-exclusion

(electrons, protons, neutrons, etc.)

"Fermions"

**Planck's Distribution**

\[N_{\text{Planck}} = N_{\text{Bose}} \frac{e^{E/kT}}{2E} \]

if \(E > \mu\), all three are the same.