Physics with neutrons 1

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Exercise sheet 2
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Exercise 2.1

Neutrons from fission ($E \approx 2MeV$) are slowed down to the thermal regime ($E \approx 20meV$) by scattering with the atoms of a moderator material. We assume that the scattering is purely elastic and nonrelativistic. Calculate the energy loss per collision event depending on the mass of the moderator atoms and on the scattering angle. How many collisions are needed to moderate fission neutrons to thermal neutrons in H2O, D2O and graphite?

Exercise 2.2

From your solid state physics course you should remember the dispersion relation for phonons. Calculate the dispersion of an acoustic phonon of a linear chain of atoms with a lattice constant of $a = 2$ Å. The measured velocity of sound is assumed to be $v_s = 2300m/s$. Draw the scattering diagram for an inelastic neutron scattering experiment with $kf = 2.57$ Å^{-1} at the boundary of the 2nd Brillouin zone. Consider phonon creation and annihilation.

Exercise 2.3

The Maxwell-Boltzmann distribution has been given in the lecture in units of Energy E and particle velocity v. Express the Maxwell-Boltzmann distribution

$$f(v) = \frac{4}{\sqrt{\pi}} \left(\frac{m_n}{2k_bT} \right)^{3/2} v^2 \exp\left(-\frac{\frac{1}{2}m_n v^2}{k_bT} \right)$$

in terms of the particle wavelength λ. Determine $\langle\lambda\rangle, \langle\lambda^2\rangle$ and λ_{max} (i.e. the λ where $f(\lambda)$ is maximal). On the lecture website will find the data file `hfir_spectrum.txt`. It contains a neutron wavelength spectrum (1st column: wavelength in Å, 2nd column: intensity in arbitrary units) measured at the cold source of the HFIR reactor in Oak Ridge, USA. Use a fitting tool to fit the Maxwell-Boltzmann flux distribution to this data and extract the moderator temperature. Remember that the flux distribution is given by

$$\Psi(v) = v \cdot f(v)$$