Physics with neutrons 1

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Exercise sheet 8
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Exercise 8.1

Highly oriented pyrolytic graphite (HOPG) is used as one of the most efficient monochromators for thermal and cold neutrons. In addition, HOPG is used as a filter for neutrons. Graphite has a hexagonal crystal structure. Along the $[00l]$ direction, the crystal planes are regularly stacked thus exhibiting the properties of a single crystal. Within the hexagonal planes, the atomic sheets are oriented randomly, i.e. like a powder. Calculate the energies for the cut-offs of the first few reflections (002), (004), (006), (101), (102), (103), (104), (105) and (106). The lattice constants are $a = 2.4612$ Å and $c = 6.7079$ Å. The stacking along the c-direction is such that the peaks with $(00l)$, l odd, are extinguished.

Exercise 8.2

We are interested in $\mathbf{Q}$, but we measure $\mathbf{k_i}$ and $\mathbf{k_f}$ (all measured in Å^{-1}) which are connected via

$$\mathbf{Q} = \mathbf{k_f} - \mathbf{k_i} \ . \tag{1}$$

1. Draw some possible scattering triangles for both elastic and inelastic scattering. What is the meaning of the direction of the $\mathbf{k}$ and $\mathbf{Q}$? Which experimental constraints do you expect?
2. Which absolute values $|\mathbf{Q}|$ can be reached in a scattering experiment as a function of $|\mathbf{k_i}|$, $|\mathbf{k_f}|$, and the scattering angle 2θ?
3. Show that this relation reduces to Bragg's law in the case of elastic scattering.
4. Basically, there are two classes of spectrometers: some fix $\mathbf{k_i}$, others $\mathbf{k_f}$ during an experiment. (It can also be varied which however requires a reconfiguration of the instrument.) Two examples at the FRM II are the time-of-flight spectrometer TOFTOF which works with a fixed $\mathbf{k_i}$ and the triple axis spectrometer PUMA which fixes $\mathbf{k_f}$. What are the consequences for the scattering triangles that can be realized during an experiment?
5. The energy change of the neutron is defined as $\Delta E = E_f - E_i$ (all measured in meV) with

$$E_{i/f} = \frac{\hbar^2 k_{i/f}^2}{2m_n} \ .$$

Which are the limits of ΔE for TOFTOF and PUMA, respectively?

EXERCISE 8.3

The dipole moment of a neutron precesses within an external magnetic field with the Larmor frequency

$$\omega_L = \gamma |\vec{B}|. \tag{2}$$

A magnetic guide field of the order of $\sim 1\,\mathrm{mT}$ prevents the depolarisation of a polarised neutron beam. If the guide field turns slow enough along the neutron flight path, the neutron polarisation will follow. Simulate the adiabatic $\pi/2$-transition of a fully polarised neutron beam and plot the $x-$, $y-$ and $z-$component along the flight path. Find a relation between the wavelength λ, the magnetic field $\vec{B}$ and the frequency ω_B the magnetic field turns along the flight path for which the transition is adiabatic.