Physics with neutrons 1

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Exercise sheet 12
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Exercise 12.1

We are interested in $\mathbf{Q}$, but we measure $\mathbf{k_i}$ and $\mathbf{k_f}$ (all measured in $^{-1}$) 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 12.2

Most neutron experiments measure the scattering function $S(\mathbf{Q}, \omega)$. Neutron Spin-Echo (NSE) was introduced by Ferenc Mezei in the 1970s as a means of directly measuring $I(\mathbf{Q}, \tau)$, i.e. the Fourier-transform of the scattering function, the intermediate scattering function.

Derive the spin-echo condition for (quasi-)elastic scattering at a sample which links a change in the neutron energy to a change of the polarisation phase. Why is it possible to use a broad wavelength band $\delta\lambda/\lambda \sim 10^{-1}$ of incoming neutrons?