Physics with Neutrons I

Alexander Backs
alexander.backs@frm2.tum.de

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Exercise sheet 2 https://wiki.mlz-garching.de/n-lecture06:index

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Probably due on 09.11.2017
The date for the next tutorial will be discussed in the lecture on 07.11.2018

1. Useful Links

- neutron scattering lengths and cross sections for elements and isotopes: https://www.ncnr.nist.gov/resources/n-lengths/
- neutron activation, scattering and transmission calculator: https://www.ncnr.nist.gov/resources/activation/

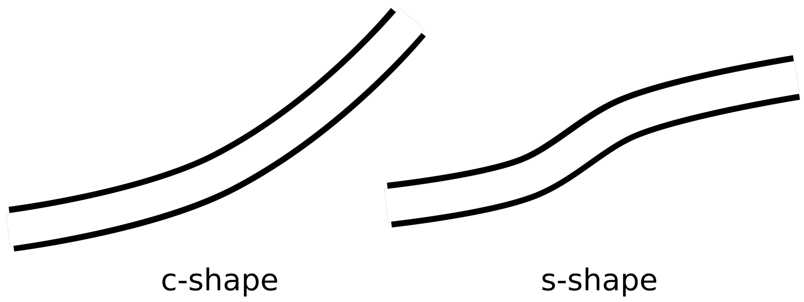
2. Chopper

Time-of-flight instruments, such as TOFTOF at the FRM II and most instruments at spallation sources, often use ^{10}B-coated (neutron absorbing) chopper disks with small notches (transparent for neutrons), rotating very fast (comparable to aircraft engines). In pairs of two these choppers can be used to select a certain velocity (or energy or wavelength) from a white beam of neutrons. The first chopper cuts small bunches out of a continuous beam. This bunch spreads out due to the velocity distribution, until it reaches the second chopper where a small part with a fairly distinct speed is cut out.
What are possible problems and limitations with such devices? How could they be improved?

3. Neutron Optics

- Optical elements for neutrons are very limited, because the refractive index n for neutrons is typically very close to 1. Nickel is one of the elements with the largest $n - 1 = -1.58 \cdot 10^{-5}$ at a wavelength $\lambda = 4$Å. How should a thin focusing lens made of nickel with a focal length $f = 5$m look like?
- Neutron guides are one of the few prevalent optical devices used with neutrons. In principle, they act like glass fibers for light, making use of total reflection at an interface. The most common type consists of rectangular glass tubes, which are evacuated and coated with a layer of nickel on the inside. What is the maximum angle under which neutrons with $\lambda = 4$Å can pass such a guide?
- The refractive index depends on the neutron wavelength like $1 - n^2 \propto \lambda^2$. Which neutrons are best suited for the use of guides?

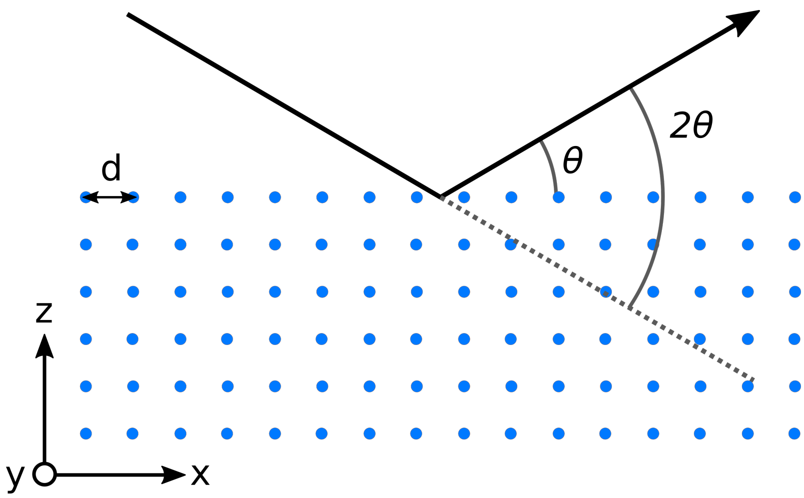
- Neutron guides are often curved in a c-shape or even s-shape. What is the advantage of using guides with a curvature? Is one of these shapes superior?



- Neutron guides can also be used as focusing devices. Suggest a shape to:
  - focus a parallel beam on a point-like sample?
  - focus a point like source on a point-like sample?

4. Bragg Scattering

Bragg Scattering (constructive interference from a periodic structure) is a very important process in neutron experiments, either to investigate unknown structures (crystal lattices) or to use known structures to select specific neutron wavelength (monochromator).



- Assume a cubic crystal lattice with lattice parameter d and neutrons with wavelength λ and derive Braggs law (with n an intefer number):

$$2 \cdot d \cdot \sin\left(\frac{2\theta}{2}\right) = n \cdot \lambda \qquad (1)$$

- How does the scattering intensity depend on the number of atoms in x-, y- and z- direction?

- Numerically compute the angular dependence of the scattering intensity for neutrons with $\lambda = 1\text{Å}$, on a crystal with lattice parameter $d = 4\text{Å}$ and 1,10,100 and 1000 lattice planes in z-direction.