Physics with neutrons 1

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Winter semester 2015/16
Exercise sheet 3
Due 2015–Nov–06

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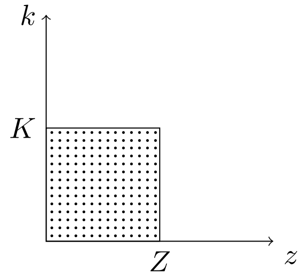
Exercise 3.1

Consider a one-dimensional movement (along the z-axis) of $N \gg 1$ neutrons. The state of a single neutron is defined by its position in space z and wave vector k (we neglect the neutron spin). This state can be represented as a point in phase space. Let the density of these points be constant at time $t = 0$ in the area $0 \leq z \leq Z$ and $0 \leq k \leq K$ and zero elsewhere.
Calculate and sketch the phase space developing in time (i) for a force-free movement and (ii) in the gravitational field $\mathbf{g} = g\mathbf{e_z}$. Explain why the enclosed volume in phase space and the density of points is constant.



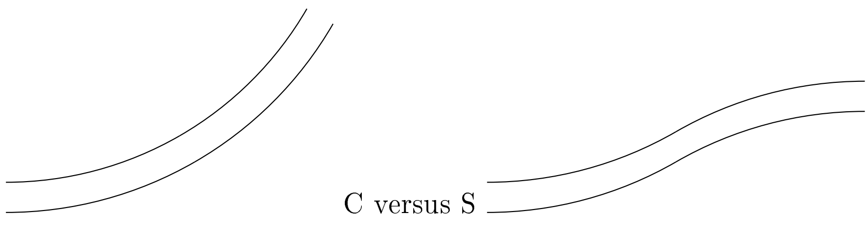
Exercise 3.2

Look up the dispersion relation for magnons in ferromagnetic chains. Calculate the zone boundary energy of such a magnon with spin $S = 1$, a lattice constant $a = 2\,\text{Å}$ and different exchange constants $J = 1\,\text{meV}$ and $J = 30\,\text{meV}$. Draw the scattering diagrams for a neutron scattering experiment to measure the energy of magnons with a momentum transfer $Q = 0.05\,\text{Å}^{-1}$ within the first Brillouin zone using neutrons with $k_f = 2.57\,\text{Å}^{-1}$. Consider magnon creation and annihilation.
Finally, draw the dispersion curves for the two magnons within the kinematic plane given by

$$Q = \left[\frac{2m_n}{\hbar^2}\left(2E_i \mp \hbar\omega - 2\cos\Theta\sqrt{E_i \cdot (E_i \mp \hbar\omega)}\right)\right]^{1/2}.$$

Exercise 3.3

1. To reduce the amount of γ radiation and fast neutrons that arrive at the instruments, many neutron guides are curved (C-shaped) so that no direct line of sight on the neutron source is possible. Modern neutron guides are usually S-shaped (SANS-1, TOFTOF,... at FRM-II).



C versus S

What is the advantage of the S shape?

2. Suggest forms of neutron guides that

   a) focus a parallel beam onto a point-like sample

   b) focus a point-like source onto a point-like sample

   to increase the flux at small samples. What is the drawback of this focussing?