Physics with neutrons 1

Michael Leitner, michael.leitner@frm2.tum.de
Winter semester 2016/17
Exercise sheet 6
To be discussed 2016-12-02, room C.3202

Franz Haslbeck, franz.haslbeck@frm2.tum.de

Exercise 6.1

The Liouville theorem states that the phase space density $\rho(q,p)$ is conserved

$$\frac{d\rho}{dt} = 0. \tag{1}$$

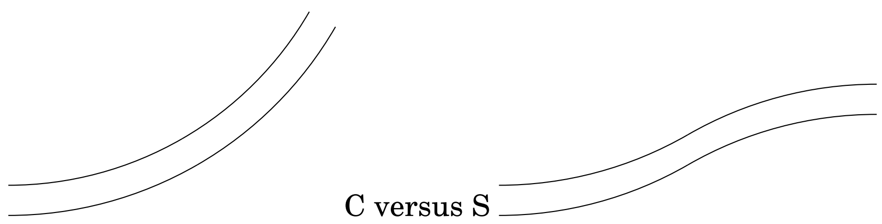
In the tutorial we will derive the Liouville equation

$$\frac{d\rho}{dt} = \frac{\partial\rho}{\partial t} + \sum_{j=1}^{3N} \left(\frac{\partial\rho}{\partial q_j} \dot{q}_j + \frac{\partial\rho}{\partial p_j} \dot{p}_j \right) = 0. \tag{2}$$

1. Consider the case of a neutron beam tube and a neutron guide. What does the Liouville equation state about the neutron beam properties at the entrance and exit? What is the difference between water and neutrons considering the Liouville equation.
2. A neutron guide with cross section A_1 is homogeneously illuminated by neutrons and linearly narrows down towards a sample position with cross section $A_2 < A_1$. How do the neutron beam properties change between the two positions?
3. How do the properties of a parallel neutron beam change if it is reflected on an imperfect wavy surface?

Exercise 6.2

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).



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?

Exercise 6.3

The best measure to describe a photon or particle source is the brilliance given as

$$\Psi = \frac{d^2\Phi}{d\Omega d\lambda}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}\text{Å}^{-1}\mathrm{sterad}^{-1}. \tag{3}$$

The European Synchrotron Radiation Facility (ESRF) has a brilliance of

$$\Psi \approx 10^{21}\,\mathrm{mm}^{-2}\mathrm{s}^{-1}(0.1\%\mathrm{BW})^{-1}\mathrm{mrad}^{-2} \tag{4}$$

where the bandwidth BW is defined as $\frac{\Delta\lambda}{\lambda}$.

1. Estimate the brilliance of a candle in the visible light spectrum.

2. Using the yellow book of ILL calculate the brilliance of the H12 beam tube. Compare it to the ESRF and the candle. Link: `https://www.ill.eu/fileadmin/users_files/Other_Sites/YellowBook2008CDRom/page/pg.htm?rub=1_2`