# Physics with Neutrons I

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**Exercise sheet 2**

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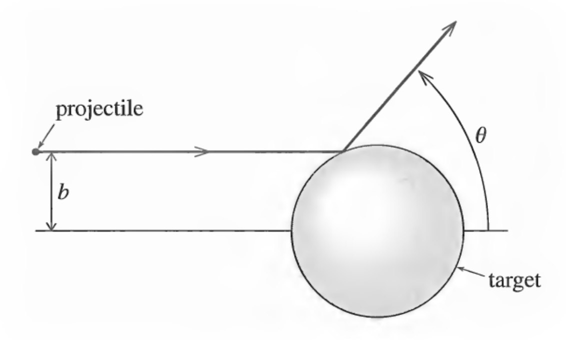
## Due on 24.11.2017

wiki.mlz-garching.de/n-lecture05:index

## 1. Hard-sphere scattering

- Assume a sufficiently numerous assembly of circular, two-dimensional targets with radius $R$ enclosed within an area $A$ of arbitrary shape. Now send in a beam of projectiles of negligible size ($R_{\text{projectile}} \ll R$) to impinge upon the target assembly. We will assume that the scattering is purely classical and that each target (and projectile) can be approximated as a hard sphere. Derive an expression for the number of projectiles that get scattered in relation to the number of incident particles and the area of a single target.

- Consider the following two-dimensional scattering experiment depicted below, in which the projectile and target interact only via a hard-sphere contact force. Assuming the target to have a radius $R$, give the length $b$ in terms of the scattering angle $\theta$ and evaluate the differential scattering cross-section $|\frac{db}{d\theta}|$. Integrate over all possible scattering angles and find the total cross-section.




- In the three-dimensional case, the projectiles passing through an incident cross-sectional annulus $d\sigma = 2\pi b\, db$ are scattered from a hard sphere of radius $R$ into a solid angle $d\Omega = 2\pi \sin\theta\, d\theta$. Give the differential cross-section $\frac{d\sigma}{d\Omega}$ in terms of $R$. What is the total cross-section $\sigma$?

## 2. Hard-core potential

Turning now to a wave description of the scattering process, we recall the scattering amplitude $f$, described by

$$f = -\frac{m_n}{2\pi\hbar^2} \int_{\text{sample}} d^3r \, V(\mathbf{r}) \exp(-i\mathbf{Q} \cdot \mathbf{r}),$$

where $V(\mathbf{r})$ is the scattering potential.

- Give the above expression for $f$ assuming a spherically symmetric potential $U(r)$ and the polar axis in the direction of the scattering vector $\mathbf{Q}$.

- Calculate the differential and total cross-section of scattering from a spherically symmetric potential well with radius $R$. The potential is defined as $U(r) = -U_0\theta(R - r)$, where $\theta$ is the Heaviside function.