# Physics with neutrons 1

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Exercise sheet 1
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## Exercise 1.1

The Curie-Joliot hypothesis was introduced in the lecture. It was very controversial from the very beginning. In particular the high proton energy could not be explained: based on Compton-scattering a $\gamma$ energy of $h\nu = 55\,\text{MeV}$ is needed to produce a 5.7 MeV proton. Such a high $\gamma$ energy seems to be impossible since the energy of the Po-$\alpha$ radiation is only 5 MeV.
Prove and explain – based on the Compton process – the following expression, which casts the Curie-Joliot hypothesis into doubt:

$$E_p = \frac{2(h\nu)^2}{2h\nu + m_p c^2}$$

The proton rest mass is given by $m_p = 1.6726 \cdot 10^{-27}\,\text{kg}$.

## Exercise 1.2

Complement the following table, assuming nonrelativistic matter waves of neutrons and electrons:

| | $E$ [eV] | $T$ [K] | $\lambda$ [Å] | $v$ [m/s] | $Q_{\max}$ [Å$^{-1}$] |
|---|---|---|---|---|---|
| Light (Red Laser) | | | 6320 | | |
| X-rays (Cu $K_\alpha$) | | | | | |
| Cold neutrons | | | 6 | | |
| Thermal neutrons | | | | 2200 | |
| Hot neutrons | | 2300 | | | |
| Fission neutrons | $2.1\cdot 10^6$ | | | | |
| Electrons | | | | $1.57\cdot 10^6$ | |

Fission neutrons are the ones created in the fission. Then the neutrons are converted to other (much lower) energies to be used in scattering experiments.

$Q_{\max}$ is the theoretical maximal momentum transfer that can be reached in an scattering experiment, defined by

$$Q = \frac{4\pi}{\lambda} \sin\left(\frac{2\theta}{2}\right)$$

where $2\theta$ is the scattering angle.

## Exercise 1.3

Draw the dispersion relations $E$ [eV] vs. $k$ [Å$^{-1}$] for light, neutrons and electrons in vacuum, for example with Matlab/Python. Mark the places of all kinds of radiation from Exercise 1.2 (except for the fission neutrons).

## Exercise 1.4

The $\delta$-function $\delta(f) = \langle\delta|f\rangle = f(0)$ can be defined as the limit of a function series $d_l$ with

$$\delta(f) := \lim_{l\to 0} d_l(f) := \lim_{l\to 0} \langle d_l|f\rangle\,, \qquad \text{(limit after integration)}(*).$$

1. Show that the function series

$$d_l(x) = \begin{cases} 1/l & -l/2 \leq x \leq l/2 \\ 0 & \text{sonst} \end{cases}$$

   can be used to express the $\delta$-function.

2. Using this definition of the $\delta$-function, calculate its Fourier transform.

*Note: The $\delta$-function is not a proper function, due to $(*)$. In mathematics such an object is called distribution.*