Physics with Neutrons I

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Exercise sheet 1

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1. Warm-up exercise

- The typical wavelength of a thermal neutron is 1.8 Å. This corresponds to which energy? Give it in units of eV and Joule.

- The lattice constants of a typical crystal lattice are on the order of magnitude of Å, which makes thermal neutrons an ideal probe to examine crystalline samples. Moreover, electrons, protons and γ-radiation are also used to study crystal lattices. For each of them, calculate the energy that corresponds to a wavelength of 1.8 Å. Also give your answers in units of eV and Joule.

2. The mass of the neutron

J. J. Chadwick discovered neutrons by bombarding a beryllium target with α-particles, thereby producing highly penetrating, uncharged radiation. This radiation was then used to bombard samples of nitrogen gas and paraffin wax, the latter being rich in hydrogen atoms. The maximal energy of the resulting recoil ions produced is, in the case of nitrogen gas, $E_N = 1.5\,\mathrm{MeV}$ and, in the case of hydrogen gas, $E_H = 5.7\,\mathrm{MeV}$. Assuming all collisions to be purely elastic, calculate the mass of the neutral particles and compare it with the modern value of the neutron mass.

3. The Compton process

- In the Compton process, a photon (γ) loses energy via inelastic scattering. The corresponding change in wavelength $\Delta\lambda = \lambda' - \lambda$ can be expressed as follows:

$$\lambda' - \lambda = \frac{h}{m_p c}(1 - \cos\theta),$$

  where m_p is the mass of the particle hit by the photon and θ is the scattering angle. Under the condition of maximal energy transfer, derive an expression for the energy of the particle E_p as a function of the incident energy of the photon $E_\gamma = h\nu$.

- Assuming that the particle is a proton with a rest mass $m_p = 938.27\,\mathrm{MeV}/c^2$, what is the resulting proton energy if the incident photon energy is $E_\gamma = 55\,\mathrm{MeV}$?