Universität Konstanz

Integrated Physics Course IV
Exp.- Section - Atomic Physics
SoSe 19

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Problem Set 1

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Exercise 1: "Show and tell" (1 cross)

Quantum mechanics has become indispensable in current research and plays an increasing role in our everyday life.

a) Many Nobel prizes have been awarded to discoveries related to quantum mechanics. Do a little research on the Nobel prizes awarded in physics and pick up the one/s you consider the most important (who, when, what and how does it work).

b) List some examples of applications of quantum mechanics in our society.

c) A little bit of Scifi and creativity. Which future applications could be realized by means of quantum effects/properties?

Exercise 2: Particle diffraction (1 cross for a+b and c+d)

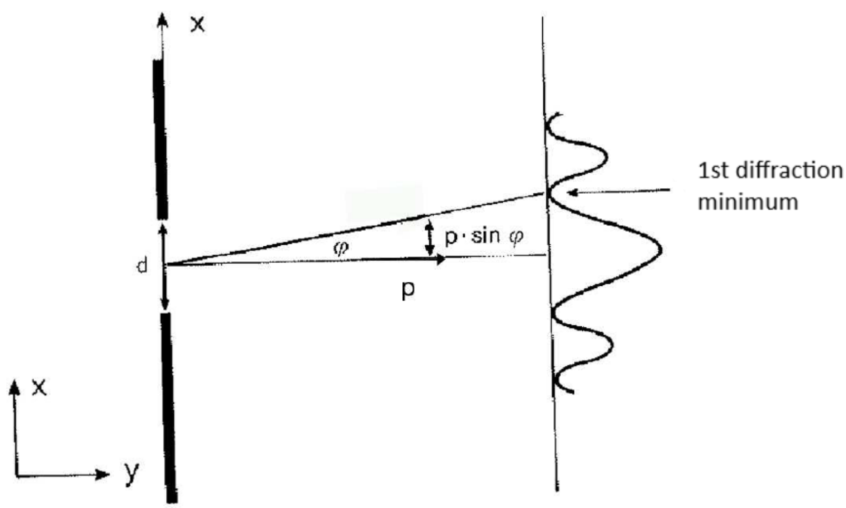
During the lecture, you have learned that particles can experience diffraction in the same way as light does. The sketch below represents the intensity distribution of a beam - e.g. of molecules - measured on a screen placed at a distance p after a slit of width d.

a) The distribution of momentum in the x direction has a series of maxima and minima. One way of estimating the mean value of the momentum in x direction is to take the value corresponding to the first diffraction minimum. Use your optics knowledge to estimate p_x. Express the value of $\Delta x \cdot \Delta p_x$ as well.

b) Express the intensity distribution known from optics as a probability density $|\phi(p_x)|^2$ and compute $\Delta p_x = \sqrt{\langle p_x^2 \rangle - \langle p_x \rangle^2}$ for $d = 4 \cdot 10^{-5}\, m$ and $\lambda = 560\, nm$. Use the small angle approximation for $p_x = p \sin\varphi$, even if this leads to an underestimation of the momentum for large angles. Use mathematical software to numerically evaluate the integrals.

c) Sketch the diffraction pattern when a second slit of same width d is placed at a distance B from the first one, given $d << B$ and $d \sim \lambda$.

d) How does the pattern on the screen look like when the particle beam is reduced to a very few individual particles? Make a sketch of the pattern.



Exercise 3: De Broglie wavelength (1 cross)

a) A body of mass $m = 4\,g$ moves with speed $v = 100\,m/s$. How thin does the slit have to be so that the body produces a diffraction pattern after going through the slit? Show and explain why such a body does not exist.

b) A neutron has a kinetic energy of 10 MeV. Let's assume we send a beam of neutrons to an object, how big does it have to be such that we can observe the neutrons' diffraction pattern? Is there such an object?

c) Obtain an electron's De Broglie wavelength if it is accelerated from its rest position to 200V. What objects could be used to demonstrate the wave properties of this electron?