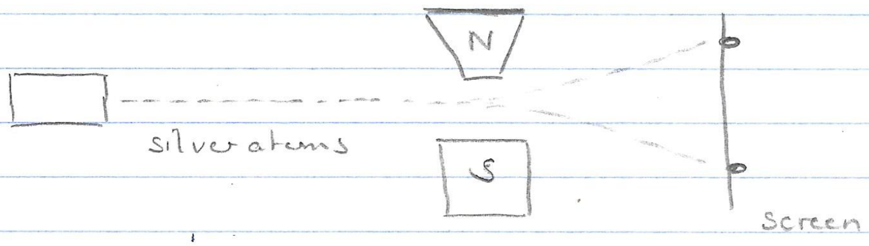
4.7. Stern - Gerlach experiment

In the original Stern - Gerlach experiment silver atoms where sent through an non - uniform (inhomogeneous) magnetic field

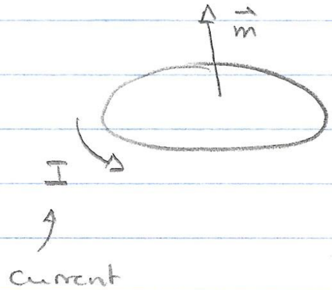


Result: Atoms are deflected either up or down but the distribution at the screen showed <u>two</u> <u>discrete</u> peaks only

→ There must be a <u>quantization</u> of the magnetic moment of the atoms.

<u>Remember</u>:

- A current loop has a magnetic moment



$$\vec{m} = I \, \vec{a}$$

($\vec{m}$: magnetic moment; $\vec{a}$: area vector)

with $\vec{a} = \pi r^2 \hat{a}$ ($\hat{a}$: always perpendicular to area)

Directions given by right - hand - rule.

- The magnetic moment is directly related to the orbital angular momentum $\vec{L}$.

- Interaction of magnetic moment with magnetic field $\vec{B}$

  -> Magnetic field $\vec{B}$ exerts torque such that the magnetic moment vector precedes about the direction of the magnetic field lines.

  => projection of magnetic field vector onto direction of $\vec{B}$-field does not change while current loop interacts with $\vec{B}$-field.

  -> Non-uniform (inhomogeneous) magnetic field deflects systems with magnetic moment along the magnetic field lines.

  Strength of deflection depends on projection of magnetic moment vector onto direction of $\vec{B}$-field (which does not change for current loop, see above).

Quantum mechanics:

- Atoms have orbital angular momentum (in simplified picture: think about Bohr model -> current loop)

  => Atoms have magnetic moment and therefore will behave as discussed above when interacting with non-uniform magnetic field.

- Modern quantum theory shows the following quantization of orbital angular momentum

$$L^2 = l(l+1)\hbar^2 \qquad \text{with } l = 0, 1, 2, 3, \ldots$$

for magnitude of orbital angular momentum.

$$L_z = m_l \hbar \qquad \text{with } m_l = -l, -(l+1), \ldots, 0, \ldots, l$$

for projection on one of axis (here z-axis)

=> There are $2l+1$ different values for the projection of the orbital angular momentum

=> Projection of magnetic moment vector onto $\vec{B}$-field has $2l+1$ different values.

Thus, in a Stern-Gerlach experiment we expect that due to the orbital angular momentum there are $2l+1$ different directions in which the atoms should be deflected.

But: This is always an odd number and in the Stern-Gerlach experiment for silver atoms (and later also for hydrogen atoms) we observe only two (even) kind of deflections

=> There must be some other effect (property of atoms) that contributes to the magnetic moment.