Modern Physics

Stern-Gerlach Experiment

Problem 1.- In a simplified version of the Stern-Gerlach experiment, the gradient of the magnetic field is *dBz/dz* = 20T/cm, the speed of the beam is 930 m/s and the length of the magnet is 7.1cm. Knowing that the z-component of the magnetic moment of the silver atom is 1 Bohr magneton, what is the separation between the two beams after traversing the magnet?

Solution: The magnetic force on the silver atom due to its dipole moment is given by the equation:

$$F = \mu \frac{dB}{dz} = 9.27 \times 10^{-24} \, \frac{\mathrm{J}}{\mathrm{T}} \times 2000 \frac{\mathrm{T}}{\mathrm{m}} = 1.854 \times 10^{-20}\,\mathrm{N}$$

The orientation of the dipole could be up or down, giving two deflections, one up and the other down. The acceleration due to this force is:

$$a = \frac{F}{m} = \frac{1.854 \times 10^{-20}\,\mathrm{N}}{1.78 \times 10^{-25}\,\mathrm{kg}} = 1.04 \times 10^{5} \,\frac{\mathrm{m}}{\mathrm{s}^2}$$

Where we used the mass of the most common isotope of silver (^{107}Ag).
The time needed to traverse the length of the magnet is:

$$t = \frac{L}{v} = \frac{7.1 \times 10^{-2}\,\mathrm{m}}{930\mathrm{m/s}} = 7.63 \times 10^{-5}\,\mathrm{s}$$

And the deflection due to the magnetic force is:

$$d = \frac{1}{2} a t^2 = \frac{1}{2} 1.04 \times 10^{5} \,\frac{\mathrm{m}}{\mathrm{s}^2} \left(7.63 \times 10^{-5}\,\mathrm{s}\right)^2 = 304\mu\mathrm{m}$$

The separation between the two beams is twice this deflection, so 608μm.