

## MAGNETIC FIELD OF A SPHERE IN A UNIFORM FIELD

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References: Griffiths, David J. (2007) Introduction to Electrodynamics, 3rd Edition; Prentice Hall - Problem 6.18.

If we place a linear magnetic sphere in a uniform magnetic field  $\mathbf{B}_0 = B_0 \hat{\mathbf{z}}$ , we can find the magnetic field inside the sphere using the method of successive approximations we used for a dielectric sphere in an electric field.

We start by assuming that the only field present is the uniform field, which then induces a magnetization within the sphere:

$$(1) \quad \mathbf{M}_0 = \frac{\chi_m}{\mu} \mathbf{B}_0$$

We then find the field produced by this magnetization (which is done by Griffiths in example 6.1):

$$(2) \quad \mathbf{B}_1 = \frac{2}{3} \mu_0 \mathbf{M}_0 = \frac{2\mu_0 \chi_m}{3\mu} \mathbf{B}_0$$

This field produces another bit of magnetization:

$$(3) \quad \mathbf{M}_1 = \frac{\chi_m}{\mu} \mathbf{B}_1 = \frac{2\mu_0 \chi_m^2}{3\mu^2} \mathbf{B}_0$$

which in turn produces a bit more field:

$$(4) \quad \mathbf{B}_2 = \frac{2}{3} \mu_0 \mathbf{M}_1 = \left( \frac{2\mu_0 \chi_m}{3\mu} \right)^2 \mathbf{B}_0$$

The process repeats so that for the  $n$ th iteration we get

$$(5) \quad \mathbf{B}_n = \left( \frac{2\mu_0 \chi_m}{3\mu} \right)^n \mathbf{B}_0$$

The total field is then the sum of all the individual contributions:

$$(6) \quad \mathbf{B} = \mathbf{B}_0 \sum_{n=0}^{\infty} \left( \frac{2\mu_0\chi_m}{3\mu} \right)^n$$

$$(7) \quad = \mathbf{B}_0 \frac{1}{1 - \frac{2\mu_0\chi_m}{3\mu}}$$

$$(8) \quad = \mathbf{B}_0 \frac{1}{1 - \frac{2\chi_m}{3(1+\chi_m)}}$$

$$(9) \quad = \mathbf{B}_0 \frac{3 + 3\chi_m}{3 + \chi_m}$$

Unfortunately, the same method doesn't work for finding the field outside the sphere, since that field is not constant in space.

#### PINGBACKS

Pingback: Magnetostatic formulas from electrostatic formulas