Magnets in Matter Homework Solutions

1. A toroid with inner radius of 19 cm and an outer radius of 21 cm is filled with liquid oxygen. The toroid has 4000 turns and carries a current of 10 A. The liquid oxygen has a susceptibility of 4×10^{-3}.

What is the magnetization at the mean radius of the toroid?

The applied magnetic field of the toroid is

$$B_{app} = \frac{\mu_0 NI}{2\pi r}$$

So the magnetization is then

$$M = \frac{\chi_m B_{app}}{\mu_0} = \frac{\chi_m}{\mu_0}\frac{\mu_0 NI}{2\pi r} = \frac{\chi_m NI}{2\pi r} = \frac{\left(4\times10^{-3}\right)(4000)(10)}{2\pi(0.2)} = 127\, A\,m^{-1}$$

What is the magnetic field *B*?

$$B = B_{app} + \mu_0 M = B_{app} + \chi_m B_{app} = (1+\chi_m)\frac{\mu_0 NI}{2\pi r} = \left(1+4\times10^{-3}\right)\frac{\left(4\pi\times10^{-7}\right)(4000)(10)}{2\pi(0.2)} = 0.04016\,T$$

What is the percentage increase in *B* produced by the liquid oxygen?

$$\%increase = \frac{B - B_{app}}{B} = \frac{(1+\chi_m)B_{app} - B_{app}}{(1+\chi_m)B_{app}} = \frac{\chi_m}{1+\chi_m} = \frac{\left(4\times10^{-3}\right)}{1+\left(4\times10^{-3}\right)} = 3.98\%$$

2. A long thin iron-core solenoid has 450 turns of wire per meter, and a 20-mA current flows through the wire. Under these conditions, the susceptibility of the iron is 3000. What is the magnitude of the magnetic field *B* inside the solenoid?

The field generated by the current is

$$B_{app} = \mu_0 nI$$

So the total field is

$$B = B_{app} + \mu_0 M = (1+\chi_m)B_{app} = (1+\chi_m)\mu_0 nI = (1+3000)\left(4\pi\times10^{-7}\right)(450)\left(20\times10^{-3}\right) = 339\,G$$