

21. (a) The field of a dipole along its axis is given by Eq. 30-29:

$$B = \frac{\mu_0}{2\pi} \frac{\mu}{z^3} ,$$

where μ is the dipole moment and z is the distance from the dipole. Thus,

$$B = \frac{(4\pi \times 10^{-7} \text{ T}\cdot\text{m/A})(1.5 \times 10^{-23} \text{ J/T})}{2\pi(10 \times 10^{-9} \text{ m})} = 3.0 \times 10^{-6} \text{ T} .$$

- (b) The energy of a magnetic dipole $\vec{\mu}$ in a magnetic field \vec{B} is given by $U = -\vec{\mu} \cdot \vec{B} = -\mu B \cos \phi$, where ϕ is the angle between the dipole moment and the field. The energy required to turn it end-for-end (from $\phi = 0^\circ$ to $\phi = 180^\circ$) is

$$\Delta U = 2\mu B = 2(1.5 \times 10^{-23} \text{ J/T})(3.0 \times 10^{-6} \text{ T}) = 9.0 \times 10^{-29} \text{ J} = 5.6 \times 10^{-10} \text{ eV} .$$

The mean kinetic energy of translation at room temperature is about 0.04 eV. Thus, if dipole-dipole interactions were responsible for aligning dipoles, collisions would easily randomize the directions of the moments and they would not remain aligned.