

55. The magnetic dipole moment is $\vec{\mu} = \mu(0.60\hat{i} - 0.80\hat{j})$, where $\mu = NiA = Ni\pi r^2 = 1(0.20\text{A})\pi(0.080\text{m})^2 = 4.02 \times 10^{-4} \text{ A}\cdot\text{m}^2$. Here i is the current in the loop, N is the number of turns, A is the area of the loop, and r is its radius.

(a) The torque is

$$\begin{aligned}\vec{\tau} &= \vec{\mu} \times \vec{B} = \mu(0.60\hat{i} - 0.80\hat{j}) \times (0.25\hat{i} + 0.30\hat{k}) \\ &= \mu \left[(0.60)(0.30)(\hat{i} \times \hat{k}) - (0.80)(0.25)(\hat{j} \times \hat{i}) - (0.80)(0.30)(\hat{j} \times \hat{k}) \right] \\ &= \mu[-0.18\hat{j} + 0.20\hat{k} - 0.24\hat{i}] .\end{aligned}$$

Here $\hat{i} \times \hat{k} = -\hat{j}$, $\hat{j} \times \hat{i} = -\hat{k}$, and $\hat{j} \times \hat{k} = \hat{i}$ are used. We also use $\hat{i} \times \hat{i} = 0$. Now, we substitute the value for μ to obtain

$$\vec{\tau} = \left(-0.97 \times 10^{-4} \hat{i} - 7.2 \times 10^{-4} \hat{j} + 8.0 \times 10^{-4} \hat{k} \right) \text{ N}\cdot\text{m} .$$

(b) The potential energy of the dipole is given by

$$\begin{aligned}U &= -\vec{\mu} \cdot \vec{B} = -\mu(0.60\hat{i} - 0.80\hat{j}) \cdot (0.25\hat{i} + 0.30\hat{k}) \\ &= -\mu(0.60)(0.25) = -0.15\mu = -6.0 \times 10^{-4} \text{ J} .\end{aligned}$$

Here $\hat{i} \cdot \hat{i} = 1$, $\hat{i} \cdot \hat{k} = 0$, $\hat{j} \cdot \hat{i} = 0$, and $\hat{j} \cdot \hat{k} = 0$ are used.