6 Electromagnetism and Dynamics

6.1 (a)(i) Determine the magnitude of the magnetic dipole moment.

The magnitude of the magnetic dipole moment μ is:

$$\mu = NIA = 10 \times 5.0 \text{ A} \times (0.80 \text{ m} \times 0.50 \text{ m}) = 20 \text{ A m}^2$$

6.2 (a)(ii) Determine the magnitude of the initial magnetic torque on the loop.

The torque is $\tau = \mu B \sin\theta$. Initially, the loop is horizontal, so its moment $\vec{\mu}$ is vertical. The field $\vec{B}$ is horizontal, so $\theta = 90°$.

$$\tau_{\text{mag}} = \mu B \sin(90°) = (20 \text{ A m}^2) \times (0.50 \text{ T}) = 10 \text{ N m}$$

6.3 (b) Calculate the net torque acting on the pulley.

Torque from the mass: $\tau_{\text{mass}} = rF_g = r(mg) = (0.10 \text{ m})(5.0 \text{ kg} \times 9.81 \text{ m/s}^2) = 4.905 \text{ N m}$. The torques are in opposite directions.

$$\tau_{\text{net}} = \tau_{\text{mag}} - \tau_{\text{mass}} = 10 - 4.905 = 5.095 \text{ N m} \approx 5.10 \text{ N m}$$

6.4 (c)(i) Calculate the change in potential energy of the magnetic dipole.

Potential energy is $U_{\text{mag}} = -\mu B \cos\theta$. Initial state: $\theta_i = 90° \implies U_i = 0$. Final state (upright): $\vec{\mu}$ aligns with $\vec{B}$, so $\theta_f = 0° \implies U_f = -\mu B \cos(0°) = -10$ J.

$$\Delta U_{\text{mag}} = U_f - U_i = -10 \text{ J}$$

6.5 (c)(ii) Calculate the speed of the mass at this position.

Use conservation of energy: $E_i = E_f$. $E_i = K_i + U_{g,i} + U_{\text{mag},i} = 0 + 0 + 0 = 0$. The loop rotates 90°, so the mass moves up by $h = r\Delta\theta = 0.10 \times \frac{\pi}{2} = 0.05\pi$ m. $E_f = K_f + U_{g,f} + U_{\text{mag},f} = \frac{1}{2}mv^2 + mgh + U_f$.

$$\begin{aligned} 0 &= \frac{1}{2}mv^2 + mgh + (-\mu B) \\ \frac{1}{2}(5.0)v^2 &= 10 - (5.0)(9.81)(0.05\pi) \\ 2.5v^2 &\approx 10 - 7.705 = 2.295 \\ v &= \sqrt{\frac{2.295}{2.5}} \approx 0.958 \text{ m/s} \end{aligned}$$

The speed is approximately **0.96 m/s**.