

**Problem H**

Consider a tennis racket to be a flat, two-dimensional shape. The normal to the plane of the racket is a principal direction, which we will take to be  $\hat{\mathbf{e}}_1$ . The direction along the handle is another principal direction, which we take to be  $\hat{\mathbf{e}}_2$ , and finally, the direction in the plane of the racket perpendicular to the handle is  $\hat{\mathbf{e}}_3$ .

(a) Make a sketch showing these principal directions on the racket, with the origin at the center of mass.

(b) For a real tennis racket, the moment of inertia values are typically  $\lambda_1 = 1.5 \times 10^{-3} \text{ kg}\cdot\text{m}^2$ ,  $\lambda_2 = 36.5 \times 10^{-3} \text{ kg}\cdot\text{m}^2$ , and  $\lambda_3 = 35.0 \times 10^{-2} \text{ kg}\cdot\text{m}^2$ . Consider flipping the racket about the  $\hat{\mathbf{e}}_3$  axis, rotating it with frequency  $\omega_3$ . The initial rotation will typically include some tiny amount of non-zero  $\omega_1$  and  $\omega_2$  as well.

By what factor will the initial  $\omega_1$  value increase in the time it takes for the racket to complete one oscillation about the  $\hat{\mathbf{e}}_3$  axis? Comment on your result.