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 $\lambda_1 = 36.5 \times 10^{-3}\,\mathrm{kg{\cdot}m^2}$, $\lambda_2 = 1.5 \times 10^{-3}\,\mathrm{kg{\cdot}m^2}$, and $\lambda_3 = 35.0 \times 10^{-3}\,\mathrm{kg{\cdot}m^2}$. (Notice that $\lambda_1 = \lambda_2 + \lambda_3$.) Consider flipping the racket about the $\hat{\mathbf{e}}_3$ axis, rotating it with frequency ω_3. The initial rotation will typically include some tiny amount of non-zero ω_1 and ω_2 as well.

By what factor will the initial ω_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.