8.012 Physics I: Classical Mechanics
Fall 2008

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

Physics 8.012: Physics (Mechanics) I **Fall Term 2008**

PROBLEM SET 8

Collaboration policy: You are encouraged to freely discuss homework problems with other 8.012 students and teaching staff. However, **you must write up your solutions completely on your own**—do not simply copy solutions from other students. You are **forbidden from consulting solutions from previous years or from the web.** Violations of this policy may result in disciplinary action.

Reading: Kleppner & Kolenkow, Chapter 7

0. **Collaboration and discussion.** Please list the names of all the students with whom you discussed these homework problems. Also be sure to write down your name and recitation section clearly on the first page.
1. Kleppner & Kolenkow, Problem 6.33 [10 points]
2. Kleppner & Kolenkow, Problem 6.39 [10 points]
3. Kleppner & Kolenkow, Problem 6.40 [10 points]
4. Kleppner & Kolenkow, Problem 6.41 [10 points]
5. Kleppner & Kolenkow, Problem 7.2 [10 points]
6. Kleppner & Kolenkow, Problem 7.3 [10 points]
7. Kleppner & Kolenkow, Problem 7.4 [10 points]

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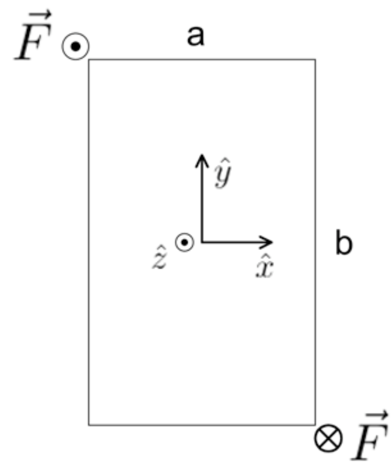
8. **Rectangular Symmetry.** [15 points]



A flat, uniform rectangle with sides of length a and b is at rest in free space (there are initially no external forces acting). You strike two opposite corners with equal and opposite forces $\vec{F}$ as indicated for a short time period Δt.

(a) [5 pts] Calculate the moments of inertia of the rectangle about horizontal ($\hat{x}$) and vertical ($\hat{y}$) axes passing through its center of mass. Note that this does not require calculating the moment of inertia tensor. Verify your answers by showing that these moments of inertia satisfy the perpendicular axis theorem, $I_x + I_y = I_z$, where I_z is the moment of inertia about an axis coming out of the page ($\hat{z}$) through the center of mass (which you should also calculate).

(b) [10 pts] Calculate the spin vector ($\vec{\omega}$) and angular momentum vector ($\vec{L}$) immediately after the strike. Show that these are not parallel, and that the spin vector points along the opposite diagonal from where the forces were applied if $a \neq b$.

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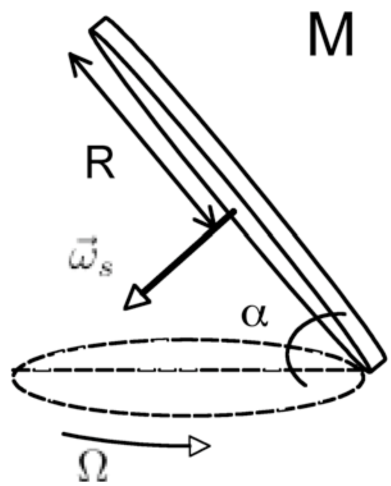
9. **Euler's Disk.** [15 points]



If you spin a coin (a solid uniform disk) about a vertical axis on a table, it will eventually lose energy and begin to wobble. Wobbling motion can basically be described as the rolling of the coin without slipping while tilted from horizontal by an angle α. Assume that once the coin starts to wobble, it falls sufficiently slowly tht you can assume α is constant and the center of mass remains at a fixed point. Let ω_s be the spin frequency of the coin, and Ω be the frequency at which the contact point traces a circle on the table.

(a) [5 pts] Show that the total angular velocity vector $\vec{\omega}$ of the coin has magnitude $\Omega \sin \alpha$ and points in a direction from the contact point up through the center of mass of the coin.

(b) [5 pts] Show that:

$$\Omega = 2\sqrt{\frac{g}{L \sin \alpha}} \tag{1}$$

and discuss what happens at the limits of α. It helps to verify that the direction of $\vec{\omega}$ is along one of the principal axes of the coin.

(c) [5 pts] Show that, when viewed from above, the face of the coin appears to rotate with frequency

$$\Omega = 2(1 - \cos \alpha)\sqrt{\frac{g}{L \sin \alpha}}. \tag{2}$$

Verify these results by spinning a coin yourself!