NYU Physics I—Problem Set 10

Due Thursday 2017 November 16 at the beginning of lecture.

Problem 1: *(a)* A car of mass M is moving at speed v in the x direction. Its center of mass is a height h above the ground. What is the angular momentum of the car with respect to a reference point *on the ground*?

(b) If this same car is accelerating at acceleration a in the x direction, then its angular momentum is changing with time, right? If so, there must be a net torque on the car? What must be the magnitude of that net torque? Again, answer this with respect to a reference point *on the ground*.

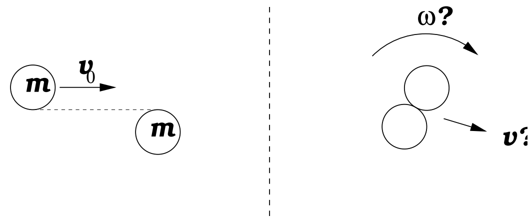
Problem 2: *(a)* A figure skater spins in place on frictionless ice at angular speed ω_i with her hands outstretched. She has a total moment of inertia I_i. As the skater draws her hands into her body, her moment of inertia decreases to $I_f = I_i/2$. Does her kinetic energy K increase, decrease, or stay the same? If it increases, where does the energy come from? If it decreases, where does the energy go to? *Explain all your answers concisely but clearly: What is conserved? That is, think in terms of conserved quantities.*

(b) Now estimate the moments of inertia: I_i of an ice skater with her hands outstretched, and I_f of an ice skater with her hands drawn in. Is the factor of 2 used in part *(a)* reasonable?

Problem 3: *(a)* Immediately after being hit, at $t = 0$, a cue ball of mass M and radius R slides along the felt at speed v_i, not rotating at all. As time goes on, the ball slows down (because of friction) and, at the same time, starts to spin. Draw a free-body diagram for the cue ball. At what time t_{r} does the ball get to the situation of "rolling without slipping"? Assume that there is a coefficient μ of sliding friction. You will have to look up (or compute) the moment of inertia I for a uniform sphere.

(b) Plot $v(t)$ and $R\,\omega(t)$ vs t on a single plot. *Note that the two things I have asked you to plot have the same dimensions.* Clearly label t_{r} on your diagram.

Problem 4: *(a)* A hockey puck (a uniform disk of mass m, radius r, and thickness t), slides without friction on ice with initial speed v_0. It strikes an identical puck tangentially, as shown in the figure, and sticks to it. The second puck is initially at rest and also can slide without friction. What is the final (linear) velocity (speed v and direction) of the stuck-together pucks? What is the moment of inertia I_f and final angular speed of rotation ω of the system around its center of mass? What fraction of the initial kinetic energy (if any) is lost; *ie,* what is $[K_i - K_f]/K_i$?



Draw a clear diagram with a clearly labeled reference point used to compute the angular momentum; recall that any angular momentum calculation is with respect to your chosen origin.

(b) If the pucks had hit dead-on, the stuck-together pucks, after the collision, would not be rotating. Which of your answers (v, ω, and $[K_i - K_f]/K_i$) will be different in this case? If the fractional loss in kinetic energy is different, explain where the difference in energy went.

Extra Problem (will not be graded for credit): In Problem 3, between the initial hit of the cue ball by the cue (that is, when the cue ball wasn't rotating at all) and the end of the cue ball slide (that is, when the cue ball switches to rolling without slipping), how much rotational kinetic energy ($I\,\omega^2/2$) was created? How much linear kinetic energy ($m\,v^2/2$) was lost? How much heat was generated? This extra problem refers to the pool problem above.