NYU Engineering Physics 1—Problem set 8

Due Thursday 2004 March 25 by 4:30pm at Irene Port’s office in Meyer 424.

**Problem 1:** Compute the angular momentum $L_{\text{orbit}}$ of the Earth’s orbital motion around the Sun. Treat the Earth as a point particle on a circular orbit. Compute the angular momentum $L_{\text{spin}}$ of the Earth’s spin. Treat the Earth as a uniform sphere spinning in place once per day. You will have to look up the moment of inertia $I$ of a uniform sphere, and maybe some Solar System data. Give your answers in SI units and also give the ratio $L_{\text{spin}}/L_{\text{orbit}}$. Also compute the kinetic energies of the spin and orbital motions. Again, give your answers in SI units and also give the ratio.

**Problem 2:** In a pool shot, the cue ball (mass $m$), moving initially with momentum $\vec{p}_{\text{ci}}$, hits the five ball (also mass $m$), initially at rest. After the elastic collision, the five ball moves at momentum $\vec{p}_{5f}$, at an angle $\theta$ to the cue ball’s initial momentum vector. The cue ball recoils with momentum $\vec{p}_{cf}$.

Draw a vector diagram showing the three momenta. Use conservation of momentum, conservation of energy, and geometry to show that the final momenta $\vec{p}_{5f}$ and $\vec{p}_{cf}$ are perpendicular. You might use the fact that $KE = p^2/(2m)$.

Note that the final momenta are only perpendicular in the particular case of equal masses.

**Problem 3:** A heavy round pipe of mass $m$, radius $R$, and moment of inertia $I$ sits at rest on the horizontal bed of a parked truck, a distance $L$ from the end of the truck bed. At time $t = 0$, the truck starts to accelerate forwards with acceleration $a$, at which point the pipe begins to roll without slipping on the truck bed. Give all your answers with respect to the stationary ground, not the moving truck.

(a) During the acceleration, when the truck is moving at speed $v_t$ and the pipe is moving at speed $v_p$ (with respect to the ground) and the pipe is
spinning at angular speed $\omega_p$, what is the condition (ie, equation relating $v_t$, $v_p$, $\omega_p$, and $R$) for rolling without slipping on the truck bed?

(b) Draw a free body diagram for the pipe, showing all forces, for $t > 0$.

(c) At what time $t_f$ does the pipe fall off the back of the truck?

Do not solve this problem with pseudo-forces; your equations and free-body diagrams should only show real forces (such as gravity, friction, normal forces, etc.).

**Problem 4—optional (not for credit):**

(a) A typical golfer can hit a golf ball about 300 yards. Under the assumption that you can ignore air resistance, estimate the speed at which the club head is moving just before it strikes the ball. Assume that the club head is ten times as massive as the ball.

(b) Now check your assumption about air resistance by figuring that the air is (on average) “at rest” with respect to the ground, that the air is made up primarily of $N_2$ molecules, and that air molecules collide elastically with the ball during its trajectory. Compare the very approximate force you calculate with the force due to gravity. Note that this is not a realistic model for the force of air resistance, but it is also not insane.

(c) Now, against logic, assume that the ball’s trajectory follows the no-air calculation. How much work is done by the ball on the air? Compare that work to the ball’s initial kinetic energy.

(d) Was it reasonable to assume no air resistance?

**Problem 5—optional (not for credit):** Why were you allowed to ignore friction during the pool shot in Problem 2? Consider the magnitudes of the forces, or the work they do through the duration of the impact.