NYU Physics 1—Problem set 7

Due Tuesday 2009 November 3 at the beginning of lecture.

**Problem 1** A Japanese Shinkansen (bullet train) (of mass $M = 10^6$ kg), moving at $v_S = 300$ km h$^{-1}$ with respect to the tracks, hits and collides elastically with a superball (of mass $m = 30$ g), which is initially at rest. The front face of the train is inclined at an angle of $\theta = 45$ deg to the horizontal, as shown here in the rest frame of the tracks.

(a) Draw a diagram of the ball–train system, just before the collision, in the center-of-mass rest frame. Clearly show the velocities of the ball and train in this frame.

(b) Draw a diagram, just after the collision, in the center-of-mass frame. Clearly show the velocities.

(c) Draw a diagram, just after, back in the rest frame of the tracks. What is the final speed and direction of the ball, immediately after the collision, in the rest frame of the tracks?

**Problem 2** What is the peak force between two pool balls in a pool shot? Estimate the momentum transferred to the object ball in a hard pool shot. Estimate (or look up) masses and velocities. For how long are two pool balls in contact? The time can be approximated by the length of time it takes a sound wave to cross a pool ball. Put it all together and compare it to the force of gravity or the normal force from the table on each ball.

**Problem 3** (a) Imagine an ideal car of mass 1000 kg with a cross-sectional area $A = 3$ m$^2$, drag coefficient 1 (so the air-resistance force is exactly $(1/2) \rho A v^2$) producing total mechanical power of $P = 130$ hp. At time $t = 0$, the car is traveling at $5$ m s$^{-1}$ in the $x$ direction. Use a spreadsheet to compute the velocity as a function of time if the driver puts “petal to the metal” for the next 20 s (with a 0.1 s time-step) on a flat, straight, $x$-direction road. You will have to use the fact that the force accelerating the car is the power over the velocity (why?) but subtracting off the air resistance force.
Make a plot of the velocity of the car as a function of time, with axes clearly labeled. Note that this is only a “first-order” integration: You only need to keep track of the velocity, not the position.

(b) Why did I not have you start at a velocity of 0 m s$^{-1}$? What would limit the acceleration in the first fraction of a second in this case—for a car starting from rest? It isn’t the power of the engine!