Physics 820 homework due Mon Sep 9

Reading: Chapters 1.5,6,2.1-3

Problems:

1. Consider the rocket from Problem 1.13 in Goldstein. The term $-v' \, dm/dt$ in the rocket equation is called a thrust. For the rocket accelerating outside of a gravitational field ($g = 0$), find the efficiency as a ratio of the final kinetic energy to the work done by the thrust, in terms of the Tsiolkovsky number, the ratio of the initial to final rocket mass. Discuss qualitatively the dependence of the efficiency on the Tsiolkovsky number.

2. Goldstein, Problem 1.14.

3. Problem from the last CM subject exam. Two skaters George and Harry, both of mass $M = 70$ kg, are approaching one another, each with a speed of $v_0 = 2$ m/s. G carries a bowling ball with a mass of $m = 10$ kg.

(i) G tosses the ball toward H at $u = 4$ m/s (relative to the thrower) when they are $D_0 = 30$ m apart.

(a) While the Ball is in the air, what are the velocities (magnitudes and signs) of G, B and H (v_1^G, v_1^B and v_1^H)?

(b) Show graphically the time development of the positions of G, B and H (i.e. plot the positions $x_{G,B,H}$ vs. t); let $x_{G,H}(t = 0) = \mp 15$ m respectively.

(ii) H catches the ball and immediately tosses it back toward G with the same relative speed u (with respect to the thrower).

(a) What are the velocities of G, B and H when the ball is in the air this time (v_2^G, v_2^B, v_2^H)?

(b) Plot this motion on the above graph (i.b). Assuming the two skaters continue to throw the ball back and forth, how will their motion develop according to this graph? (Will they collide?)

(This example is often used as a model of a repulsive exchange force between two objects (G and H) mediated by a third particle (B)).

4. Another problem from the subject exam. A steel cylinder of mass M, radius R, and moment of inertia $I = \frac{1}{2}MR^2$ rests across the width of a flatbed truck. The flatbed floor has length L.

(i) As the truck accelerates at a constant acceleration of $a = \frac{1}{2}g$ in the positive x direction, the pipe starts to roll without slipping (due to static friction force).

(a) Write down the condition for rolling without slipping. (Use the angle of rotation θ and linear coordinate of the center of the pipe x with respect to the ground as variables.)

(b) Plot qualitatively the velocities $v = \dot{x}$ and $\omega = \dot{\theta}$ as a function of time. (It is useful to plot v and ωR alongside each other on the same plot.)

(c) What are the linear and angular velocities (magnitude and direction) of the pipe just before it falls off from the truck?

(ii) After the pipe hits the ground, its motion will, at first, consist of rolling and skidding.

(a) If the coefficient of kinetic friction between the moving cylinder and the level ground is $\mu_k = \frac{1}{4}$, what are the linear and angular accelerations ($\dot{v}$, $\dot{\omega}$) while the cylinder is skidding? Use these results to extend the velocity plot of part (i.b) above.

(b) When the cylinder ceases to skid, what are its linear and angular velocities? (The above graph can be quite helpful here.)

5. Goldstein, Problem 1.23.