

MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
Experimental Study Group

Physics 8.012, Fall 2010

Problem Set 5

Due: Friday, October 15

Reading: Kleppner and Kolenkow, *An Introduction to Mechanics*, Chapter Three

Problems: Chapter 3: 14, 15, 16, 18, 20

**Problem 1: K&K 3.14: Two people jumping off cart**

$N$  people, each of mass  $m_p$ , stand on a railway flatcar of mass  $m_c$ . They jump off one end of the flatcar with velocity  $u$  relative to the car. The car rolls in the opposite direction without friction.

- (a) What is the final velocity of the car if all the people jump at the same time?
- (b) What is the final velocity of the car if the people jump off one at a time?
- (c) Does case (a) or (b) yield the largest final velocity of the flat car? Give a physical explanation for your answer.

**Problem 2: K&K 3.15**

A rope of mass  $m$  and length  $l$  lies on a frictionless table, with a short portion  $l_0$  hanging through a hole. Initially the rope is at rest.

- (a) Find a general differential equation for  $y(t)$ , the length of rope through the hole.
- (b) Solve the differential equation with appropriate initial conditions for  $y(t)$ , the length of rope through the hole.

**Problem 3: K&K 3.16**

Water shoots out of a fire hydrant having nozzle diameter  $D$  with nozzle speed  $V_0$ . What is the reaction force on the hydrant?

**Problem 4: K&K 3.18**

A raindrop of initial mass  $m_0$  starts falling from rest under the influence of gravity. Assume that the raindrop gains mass from the cloud at a rate proportional to the momentum of the raindrop,  $dm/dt = kmv$ , where  $m$  is the instantaneous mass of the raindrop,  $v$  is the instantaneous velocity of the raindrop, and  $k$  is a constant. You may neglect air resistance.

- (a) Derive a differential equation for the velocity of the raindrop.
- (b) Show that the speed of the drop eventually becomes effectively constant and give an expression for the terminal speed.

- (c) Assume the air resistance is proportional to the square of the velocity. How would air resistance effect the terminal speed?

### Problem 5: K&K 3.20

A rocket ascends from rest in a uniform gravitational field by ejecting exhaust with constant speed  $u$  relative to the rocket. Assume that the rate at which mass is expelled is given by  $dm/dt = \gamma m$ , where  $m$  is the instantaneous mass of the rocket and  $\gamma$  is a constant. The rocket is retarded by air resistance with a force  $F = bmv$  proportional to the instantaneous momentum of the rocket where  $b$  is a constant. Find the velocity of the rocket as a function of time.