

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 γ 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.