CSUC
Department of Physics
301A Mechanics
Problem Set 3, due: Monday, October 15, 2018

I. READING

Read Chapter 3 in your class text completely as well as the class notes on **"Systems of Particles"** .

II. PROBLEMS

A. From the Class Text: *Difficulty Index 1.0*

Please complete for submission the following text problems from *chapter 3*:

(1.) Page 99 problem *3-1*

(2.) Page 100 problem *3-11*

(3.) Page 101 problem *3-12*

(4.) Page 101 problem *3-13*

(5.) Page 101 problem *3-14*

(6.) Page 101 problem *3-18* $\rightarrow$ problem *3-17* $\rightarrow$ problem *3-16*
Comment carefully on where the Earth-Moon and Sun-Earth centers of mass actually fall. Provide a scaled sketch for each and express your final numerical answers first as fractions of the inter-body distance and then also as fractions of the Earth radius (3.17) or Sun radius (3.16) .

(7.) Page 102 problem *3-21*

(8.) Page 102 problem *3-22*

(9.) Page 103 problem *3-32*

B. From the Class Lectures and Notes:

(10.) *Difficulty Index 2.0* Now generalize problem *3-1* by assuming that the cannon is aimed at an angle ϕ above the horizontal. Since the cannon is on a frictionless track it will still recoil . . . but **not** at the previous velocity! In addition, the projectile will **not** start off with the angle to the ground with which the cannon barrel is inclined! It will, in fact, start out at some "shifted" new angle ψ .

a) Please find this *new* angle ψ.

b) If the total released energy is E_o, What *fraction* of this goes into the projectile ?

c) What angle ϕ now maximizes the range ? Show that your answer reduces to the known elementary answer when the cannon mass is very much larger than the projectile mass.

(11.) *Fast Ionizing Particles* A high-speed proton of electric charge e is modeled as moving with constant speed v_o past an electron of mass m and charge $-e$ initially at rest. The electron is a distance a from the straight-line path of the proton and we assume it '*scarcely moves*' while the proton comes and goes. Use the standard Coulomb force law to:

a) Find the components (along and perpendicular to the proton trajectory) of the net impulse delivered to the electron.

b) Using these results find the (approximate) final kinetic energy of the electron.

c) We now return to the beginning of the problem for an argument of self-consistency. Show that the assumed 'approximate stationarity' of the electron was, in fact, accurate only if $(\frac{e^2}{4\pi\epsilon_o a}) \ll \frac{1}{2}mv^2$ happens to be true.

(12.) Real Rockets Built Under ... Budgetary Constraints! *Difficulty Index 2.0*

Now generalize problem *3-12* by assuming that a rocket is to be built capable of accelerating a 100-kg payload to a velocity of 6000 m/s in free flight in empty space. Assume that the fuel used can reach an exhaust velocity of 1500m/s and that structural requirements imply that an empty rocket (without fuel or payload) will weigh 10 percent as much as the fuel it can carry.

a) Show, first, that it is impossible to build a single stage rocket that will do the job.

b) Now show that a *two stage* rocket ***can*** achieve our goal if the empty first stage superstructure is detached after exhausting its fuel just before the second stage is then fired.

c) Finally, you are to find the *optimum* choice of masses for the two stages so that the total take-off weight is now at a **minimum**.