CSUC Physics 204A sections 5 and 6
Final Exam

Please complete the following problems on the blank sheets provided using one side only. Show all your work clearly and don't dwell too long on any one problem. Rather, complete first those that you understand better and return to any remaining problems at the end. Each problem is worth 10 points. Be sure to work from fundamental equations only and indicate your derivations. When you are done please sign each sheet and number them, then please stack them in order, staple them together, and place them in the box provided. **No calculators and no notes of any kind are to be used. Please complete all your reasoning symbolicallyand state your solution as an algebraic expression.**

I. KINEMATICS

1) Suppose that the acceleration of a particle is given by: $\vec{a} = \hat{i}\, 7.2\,\mathbf{t} + \hat{j}\, 15\cos(3\mathbf{t})$
find the particle's velocity and position as functions of time.

2) Given any two vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ we may combine them in the dot and cross products.
a) Give careful geometric definitions of these two operations.
b) Give careful component definitions of these two operations.
c) Give an example for each where it is used to define an important physical quantity.

3) A child in danger of drowning in a river is being carried downstream by a current that flows uniformly with a speed of 2.5 km/h. The child is .6 km from shore and .8 km upstream of a boat landing when a rescue boat leaves the landing to rescue the child. The boat is able to proceed at a maximum speed of 20 km/h with respect to the water.
(a) At what angle with respect to the shore should the axis of the boat be set ?
(b) At what angle with respect to the shore will the resultant *velocity* of the boat be ?
(c) How long will it take to reach the child ?

II. BASIC DYNAMICS

4) State Newton's laws clearly (in words and/or symbols) and in order.

5) Non physicists often misuse the term *force*. **a)** Please criticize in detail the following sentence which was overheard recently at a little-league baseball game: "A baseball is harder to catch than a tennis ball going the same speed because it has more force". **b)** Explain carefully in words why heavy objects which, after all, ***do*** experience a larger gravitational force than light objects, nonetheless fall no faster.

6) Two blocks m_1 and m_2 are connected by an ideal string that runs over an ideal frictionless peg at the top vertex of a smooth wedge as shown.
a) Draw a free-body diagram for each mass,
b) Find the acceleration of each mass and then,
c) find the string tension.
d) find the force exerted on the peg.

7) A rope of length **R** has one end tied to a fixed point and the other end tied to a pail full of water. The pail of water of mass **M** is brought into vertical circular motion. The rope can sustain a tension of $\mathbf{T_o}$ and no more before breaking.
a) What is the minimum speed of the pail at the top of the circle if no water is to spill out? What is the tension in the rope at that point?
b) If the pail is in uniform circular motion, what is the minimum speed at which the rope will break and at what point in the circle will it break?

III. ENERGY

8) How do you know if a given force is conservative? Carefully explain how you would go about defining a potential function for a given conservative force (be sure to explain briefly the significance of the choice of reference point).

9) Show in detail how the statement of conservation of mechanical energy derives from the work energy theorem and the definition of a potential function.

IV. MOMENTUM / CENTER OF MASS / COLLISIONS

10) A hunting rifle of mass 4kg fires a bullet of mass 0.012kg with a muzzle velocity of 600 m/s.
(a) What is the recoil velocity of the rifle as the bullet leaves the barrel ?
(b) If the rifle is stopped by the hunter's shoulder in a distance of 2.5 cm, what is the average force on the hunter's shoulder ?
(c) In this case, then, how much time is required to stop the rifle?
(d) What is the average power delivered to the shoulder?

11) A wedge of mass M is in the shape of a right triangle and has sides of length .3,.4, and .5 meters. The wedge rests upon a frictionless floor on the side of length .4 meter. If a small block of mass m is now allowed to slide down the hypotenuse from the upper vertex to the floor (where it stops), what will be the net resulting horizontal displacements of the wedge and the block?

12) A moving electron of mass m_e and initial speed v_1 collides head on with an initially stationary Hydrogen atom of mass m_p. If the collision is elastic and 1-dimensional and if $m_p / m_e = 1840$:
(a) What is the center of mass velocity?
(b) What does this collision look like from the center of mass reference frame? Draw *two* pictures (*before* and *after*) to depict the collision from this frame.
(c) When viewed *entirely* from the *center of mass* frame, what fraction of the electron's initial kinetic energy is transferred to the Hydrogen atom ?
(d) Viewed from the original LAB frame, what final velocity does the Hydrogen atom recoil with?

V. ROTATION

13) Suppose that we hang an arbitrary physical pendulum from a fixed frictionless axis and set it swinging. **a)** Define the moment of inertia formally **b)** State the fundamental dynamical equation of rotational motion. **c)** Now apply the equation to this problem carefully inserting all the specifics as far as you know them. **d)** In the limit of small displacements show that the motion becomes simple harmonic and identify the period of the motion.

14) A child of mass m runs at speed v up to a flat circular merry-go-round of mass M and radius R and jumps aboard. If the child wishes to bring about a maximum resultant angular velocity, where and in what manner should she jump aboard? What will be the resultant angular velocity?

15) A ladder of mass M and length L leans up against a building. The building has a smooth wall and supplies no frictional force to the ladder so that only the frictional force of the ground on the ladder keeps its foot from slipping out. What will be the minimum necessary coefficient of static friction such that the ladder will stand at a given angle with the ground ?

VII. A PROBLEM

16) A block with mass M rests on a frictionless horizontal surface and is attached to a wall by a spring of spring constant k. A blob of putty of mass m and horizontal speed v collides with and sticks to the block. Find the maximum compression of the spring.