There are 6 problems on this exam. They are ***not*** equally weighted. The majority of the points will be in earned in problem #1. For all problems where g is needed, please use **_ g = 10 m/s^2 _**. Beware, there are several red herrings scattered throughout the exam. Enjoy finding them ☺. Be cautious though – some values are given so that you can do quick conversions… Finally, nearly all of the answers are "nice" round numbers with the exception of problem #3. If you end up with a string of four or five answers which don't round nicely, double-check your calculations.

Please write your solutions neatly on unlined white 8.5 x 11 paper. **_ Box _** all answers so that I can find them easily.

1. A 1200 kg "Top Fuel Drag Racer" has fat, smooth tires called *slicks* on the back with a radius of 0.5 m each (the front tires are small and will ***not*** be discussed anywhere in this problem). The rear tires are kept at a low pressure of 7 psi (pounds per square inch), or about 48 kPa. **(a)** What is the necessary surface area **A** in square centimeters (cm^2) of tire that must be in contact with the road in order to support half of the vehicle's weight per tire? (We assume that all of the vehicle's weight is transferred to the rear during acceleration.) **(b)** The tire's contact area is rectangular, with the width twice the length. How wide w is each tire in centimeters?

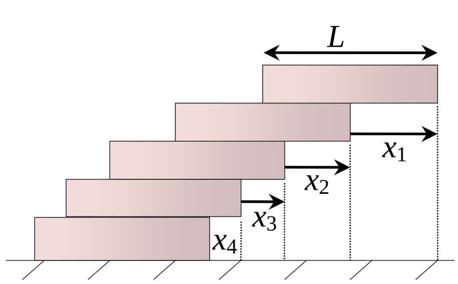
(c) "Top Fuel" racetracks are ¼ mile long (= 400 m). The driver revs the engine, releases the clutch and shoots down the raceway. Her engine is powerful enough that it accelerates the car to a top speed of 360 mph. Please express this speed v_{max} in m/s. **(d)** What is her acceleration a_0 (in MKS units)? **(e)** How long a time t_f does it take for her dragster to reach the finish line? **(f)** If the entire weight of the car rests on the rear wheels during the race, what is the minimum coefficient of friction μ_s between the tires and the track necessary in order to maintain that acceleration? **(g)** How much power P_{max} is being delivered by the engine at the end of the race? Note that this value is **not** constant throughout the race, being zero at the beginning and greatest at the end. **(h)** What is the car's final linear kinetic energy K_L?

(i) If the dragster's rear wheels are treated as solid disks with a mass of 40 kg, what is the moment of inertia I_0 of each one? **(j)** What is the angular velocity ω_f of each tire at the end of the race? **(k)** Through what angle θ_f does each tire turn during the race (give your answer in both radians **and** revolutions)? **(*l*)** Assuming the tires don't slip because of *friction*, how much torque τ_f is provided by the engine to the tires near the end of the race? **(m)** When the car is resting at the starting line, the low pressure in each back tire makes it sink 10 cm closer to the ground than when the car is at full speed, because at high rpm's the rotation of the tire makes them swell outwards. As a result of this, the torque necessary to accelerate the car is reduced at the beginning of the race. What is the actual starting value of the torque τ_0, assuming that the vehicle acceleration is the same as in part (d) above? **(n)** What is the total rotational kinetic energy K_r of the two rear tires at the end of the race? **(o)** Does K_r contribute significantly to the total kinetic energy K_T of the vehicle at the end of the race?

(p) The reason that one uses the ***entire*** weight to calculate part (f) above is that the engine torque is able to lift the front end of the vehicle completely off the ground. How far forward from the rear axle is the car's center of mass x_{CM}, if we assume the maximum torque from part (*l*) above just barely counteracts gravity and lifts the front of the car? [We *don't* want the vehicle to flip over backwards!] **(q)** Using that value, estimate the length of the car L, assuming that its total length is five times the center of mass distance from the rear axle.

(r) At the end of the race the driver decelerates the car rapidly using a 20 m long parachute. Unfortunately, before she is completely stopped she collides at right angles with a service truck improperly crossing the track. The racecar's speed is 20 m/s North at that moment, and the truck's speed is 10 m/s East. What is the relative velocity (vector) $\vec{\mathbf{v}}_{C-T}$ of the racecar with respect to the truck just before the collision? **(s)** They collide and stick. The truck has a mass of 1800 kg. What is the total linear momentum (vector) $\vec{\mathbf{P}}_T$ of the two cars before they collide? **(t)** What is the speed v_f of the resulting pile of metal immediately after the collision. **(u)** How much total kinetic energy K_0 did the two vehicles have just before the collision and **(v)** how much energy ΔK was lost during the collision?

2. Five identical uniform-density bricks, each of length L are placed on top of one another in such a way that part of each extends beyond the one beneath by the maximum amount without falling off. **(a)** Use *Center-of-Mass* calculations to calculate the largest equilibrium extensions (x_1, x_2, x_3 and x_4) for each brick. [***Note:*** $x_1 = L/2$, the center of mass of one brick by itself, and $x_2 = L/4$, the midpoint between the two central ends of the top two bricks. A set of bricks balance if their CM is directly above the corner of the next block below.] **(b)** Is there a pattern to the values of x_1, x_2, etc? **(c)** The maximum extension for five blocks is given by $x_1 + x_2 + x_3 + x_4$. Evaluate $x_1 + x_2 + x_3 + x_4$ for L = 10 cm. Compare this value with L itself.



3. The first Foucault Pendulum was constructed in 1851 at the Pantheon in Paris and consists of a 28 kg iron ball hanging from a thin cable that is 67 m long (measured to the center of the ball). (a) If the density of iron is $\rho = 7.87$ g/cm^3, what is the radius r of the ball. (b) What is the moment of inertia I_{cm} of the ball about its center of mass, (c) the moment of inertia I_0 of the ball assuming it is a point mass at the end of the cable (i.e. a simple pendulum), and (d) the actual total moment of inertia I_T of the ball swinging at the end of the cable? Compare I_T and I_0. (e) What is the period of oscillation T for this pendulum? (f) Foucault Pendulums precess, such that the plane of motion slowly rotates throughout the day. The period of precession is 12 hours divided by the sine of the latitude (T_F = 12 hours at the North Pole and $T_F = \infty$ at the equator = no precession). If Paris is at 49°N, what is the expected precession time T_F of the Foucault Pendulum at the Pantheon? (g) There is a Foucault Pendulum located right here in San Diego at the Natural History Museum in Balboa Park and its precession time is 22 hours. What is our latitude? You may presume that our pendulum is otherwise identical to the Parisian pendulum. (h) The museum curators here like to place domino tiles in a circle, and the pointed tip on the bottom of the ball slowly knocks them over one-by-one. If the domino circle is 5 m across and each domino is placed Δs = 3 cm apart, approximately how long t_0 does the pendulum take between knocking over successive tiles, and (i) how many oscillations N_0 does the pendulum swing in that time? (j) The pointed tip of the ball is 2 cm above the floor when it crosses the center. How high h above the floor is the tip when it knocks over each domino? Note that this is the shortest that the dominos can stand if they are to be successfully knocked over. (k) We learned that for linear systems the maximum speed occurs at the middle of the swing, and has a value $v_{max} = 2\pi A/T$, where T is the period. The equivalent expression for a pendulum replaces A with θ_{max} and v_{max} becomes ω_{max}. What is the minimum value of ω_{max} assuming that the pendulum just barely knocks over the dominos? (l) Use that value of ω_{max} to find the minimum kinetic energy K_{min} of the iron ball. (m) Finally, express the oscillatory motion of the pendulum with an equation for $\theta(t)$. [***Note:*** Neglect the mass of the cable in all calculations.]

4. Five teenagers agree to play a game of *Crack-the-Whip* using ice skates on the local frozen pond. They line up side-by-side and accelerate to a speed of v_0 = 12 m/s with their arms linked together so they are spaced exactly l = 0.75 m apart. Assume that they all have the same mass m = 50 kg, and the same height of h = 1.25 m. (a) What is the linear momentum p_0 of each child? (b) What is their total angular momentum L_T with respect to the first skater's position? [***Note:*** the angular momentum of each child (L_1 through L_5) is unique and must be calculated separately, and then all of them added together. Assume that the first child is at a position of zero, and the fifth child is located at r_5 = 3.0 m.] (c) Now, the first child digs in with his skates and locks them to the ice, abruptly stopping. Assume that all of his energy and his linear momentum are instantly dissipated, but the remaining four kids' angular momenta are conserved in the resulting "*collision*" and the line of kids starts rotating around the anchored child. What is the moment of inertia I_T of the rotating group of kids, treating each child as a point mass? Remember, each child is a different distance from the first child who acts as the pivot point for the group. (d) Assuming conservation of angular momentum, what is the final angular velocity ω_f of the group? (e) Using that result, what is the linear speed v_5 of the last child? Please express this value in units of m/s, km/hr and mi/hr. How is v_5 related to v_0?

5. A painter with a mass M_p = 80 kg (with paint, brushes, etc.) wants to paint the upper portion of a building, and has a 5 m long ladder weighing W_L = 200 N to reach the highest parts. Unfortunately, because of an obstruction at the base of the wall, the closest he can place the base of the ladder to the wall is 3 m! The coefficient of friction against the ground is μ_g = 3/4 (new rubber pads on concrete), and the coefficient of friction against the wall is μ_w = 1/3 (rubber on aluminum siding). (a) Draw a detailed sketch of the ladder and painter, labeling each of the 6 forces in the problem. (b) Set up the 5 equations, 5 unknowns for static equilibrium here (4 forces plus the unknown position of the painter on the ladder). (c) Now, determine how high can he climb without slipping? [**Warnings and hints:** Do not directly use the masses of any object in the problem − use only their weights. Plug in all numerical values from the start, keeping all fractions as rational numbers – do not do the problem algebraically. If you've done the problem correctly, the answer will work out nicely with rational numbers. There is a lot of algebra, so take your time and do it neatly. Use lots of paper.]

6. As you know, I bicycle to work every day when I am able. My bike is well tuned so there is negligible rolling friction. (a) There is a hill on Black Mountain Road which has a 7.2% grade, or an angle of 4.1289°. This may seem small but in fact is very steep for both cars and bicyclists. If my mass including bike and school supplies is 100 kg, what is the net force of gravity F_g on me parallel to the road which I must work against? (b) When I pedal up it, I am barely able to maintain a maximum speed of v_{up} = 1.5 m/s. What is my average sustained power P_{max} output while climbing the hill? (c) On the way to work, if I glide down that same hill without pedaling I reach a maximum speed of v_{down} = 12 m/s before wind drag prevents me from going any faster. What is the drag force D_{down} on me at that speed? (d) If friction due to drag is of the form $D = -bv^2$, what is the value of b for myself? (e) My normal cruising speed on level ground is v_0 = 6 m/s. What is the value of D_0 on me at that speed? (f) How much power P_0 do I expend traveling at v_0? Note that P_0 is significantly less than P_{max}. (g) I ride to work early in the morning when there is no appreciable wind and the trip takes me 48 minutes traveling at speed v_0. Estimate the distance d I ride to work. (h) I find that when I come home I face into a steady wind, and the trip takes me 64 minutes. Estimate the speed of the wind assuming I exert a power P_0 all the way home. [***Note:*** this is a relative motion problem!] (i) I recently measured the wind speed and found that it was only v_{wind} = 1 m/s, less than I expected in part (h). How long should it take for me to get home with this actual wind speed? (j) The wind interference isn't enough to account for my longer ride time going home. The only explanation that I've been able to come up with to explain the extra few minutes of ride time is that my home in Mira Mesa is at a higher elevation than Mesa College. Using power and energy considerations, estimate the difference in elevation Δy between my home and work.

FINAL EXAM COVER SHEET

Names: ______________________ **People we contacted:**

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This is a Take-Home exam, intended for Physics 195, Summer 2010.

There are six problems which require complete solutions, with everyone in your group contributing as I instructed you in class. Your group may have up to 4 students in it. Please include this cover sheet with all of your names clearly printed, plus the names of any other classmates that you may have contacted by phone.

The exam must be turned in by 8:45 AM on Monday, Aug 16. Every person in your group must be present to receive credit for the exam.

I expect you to be working on the exam on Thursday, so do ***not*** come to the lab. I apologize for the inconvenience. I won't be able to read my email over the weekend more than a couple of times. You may ask me questions via email, but I can't guarantee that I will answer it in a timely manner.

Well, work hard, work fair, and work early. Do **not** put off doing the exam until the last minute. You will definitely not finish it in time…