Physics 31A 2nd Midterm (200 Points MAX)
Winter 2005

Show your works with diagrams, explanations, and clear writings. No credit will be given for answers without diagrams, explanations, and clear writings.

1. (a) A bicycle handbrake works by squeezing the metal rim of the wheel between two rubber pads. Suppose that the maximum inward force on each brake pad is 50 N and the metal-rubber kinetic coefficient of friction is 0.70. Taking the rim-to-axle distance as 30 cm, determine the maximum torque produced by a set of brakes about the axis of rotation.
   (b) Imagine an extremely thin cylindrical shell of radius *R* and length *L* made of a uniformly dense material. If its total mass is M, determine its moment-of-inertia about its central symmetry axis.
2. (a) A 2000-kg car is traveling east at 20.0 m/s when it's rammed in the rear by a 1000-kg car that was traveling at 30.0 m/s just before impact. The two cars tangle together and move off together at a speed that we now wish to determine – please do so.
   (b) A 100-kg rocket held in place on the launchpad fires its engines. Once it is released, the rocket experiences a net upward force given by the expression $\vec{F}(t) = [40.0kN - (2.00kN/s)t - mg]\hat{k}$, for about 20.0 s. Assuming the mass is constant, find the change in momentum during the first 10.0 s.
3. (a) Find the lowest velocity $\vec{V}_{esc}$ (escape velocity) with which we could fire a projectile straight up and never have it fall back to the planet earth from which it was launched.
   (b) A 70-kg passenger riding in a typical automobile is involved in a 17.9-m/s (i.e., 40 mi/h) head-on collision with a concrete barrier. Taking the stopping time as 100 ms, compute the average force exerted by the seat belt and shoulder strap on the person.
4. (a) If the period of a simple pendulum is *T*, what will its new period be if its length is increased by 50%?
   (b) An object of volume *V* floats in water with a volume V_u up above the surface. (i) Write an expression for its average density in terms of the density of water. (ii) Apply this solution to find the average density of a loaded barge with 20% of its volume above the waterline.
5. (a) The human thigh bone, the femur, at its narrowest point resembles a hollow cylinder with an outer radius of roughly 1.1 cm and an inner radius of just about half of that. Taking the compressive strength of the bone to be 170 MPa, how much force will be required to rupture it?
   (b) If a uniform rod of cross-sectional area *A* and length L_0 can sustain a maximum stress of σ_R without rupture, show that it stores an amount of elastic energy given by $PE_e = \dfrac{\frac{1}{2}AL_0\sigma_R^2}{Y}$ in getting to that stress level.
6. (a) A Texas pipeline carrying natural gas ($\rho = 0.90$ kg/m^3) with a mass-rate of flow of 1.0 kg/s is 35 cm in diameter. Determine the average speed at which the gas is moving along.
   (b) Gasoline (with a density of 0.68 kg/m^3) is flowing in a pipeline having a 0.50-m diameter. Taking the fluid to be ideal, what pressure change results when the pipe descends 4.0 m down an embankment?
7. (a) A hollow cylinder, or hoop, of mass *m* rolls down an inclined plane from a height *h*. If it begins at rest, show that its final speed is given by $v = \sqrt{gh}$.
   (b) A long, uniform rod of length *L* is balanced vertically on one end, which rests on a rough horizontal floor. After a moment the rod begins to fall, rotating around it bottom end that remains where it was without slipping. The rod makes an angel θ with the vertical as it descends. Show that $w = \sqrt{(3g/L)(1-\cos\theta)}$.