Physics 31A 2nd Midterm (200 Points MAX)
Spring 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) The human thing 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 jut 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) A bug having a mass of 0.20 g falls into a spider's web, setting it into vibration with a dominant frequency of 18 Hz. Find the corresponding elastic spring constant.
2. (a) An essentially weightless helical spring hangs vertically. When a mass *m* is suspended from it, it elongates an amount ΔL. When let loose, it oscillates with a measured period of *T*. Show how you might use this arrangement to determine *g*.
   (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 $PE_e = \dfrac{\frac{1}{2} A L_0 \sigma_R^2}{Y}$ in getting to that stress level.
3. (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) A large-diameter open cylindrical storage tank stands on a high platform. It has a small horizontal spigot at its very bottom, a height *Y* above the ground and a depth *h* below the surface of the water. Use Bernoulli's Equation to follow a tube of flow from point-1 at the surface, to point-2 just outside the spigot, to point-3 at the point of impact with the ground. Write expressions for v_2 and for v_3 (the speeds at the spigot and at the point of impact with the ground) in terms of *g*, *h*, and *Y*. Did you expect these results?
4. (a) Determine the mass of helium needed to provide enough buoyancy (in dry air at 0°C) to lift a balloon and its load having a net mass of 454 kg. The load has a negligible volume.
   (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) 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 its bottom end that remains where it was without slipping. The rod makes an angle θ with the vertical as it descends. Show that $w = \sqrt{(3g/L)(1-\cos\theta)}$.
   (b) A long pencil is balanced straight up on its point on a horizontal surface. Without slipping, the pencil topples over. Show that the speed at which the eraser end strikes the surface is $v = \sqrt{3gL}$.
6. (a) 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.
   (b) Compute the moment-of-inertia of a thin uniform hoop of mass M and radius R about an axis through its center perpendicular to the plane in which it is located.
7. (a) A bullet fired from a standard 9-mm Luger pistol has a mass of 8.0 g and a muzzle speed of 352 m/s (i.e., 1155 ft/s). If the mass of the gun is 0.90 kg, what is its recoil speed when fired horizontally? Studies of handgun recoils for ordinary low-speed bullets confirm that the escaping gases can be ignored.
   (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.
8. (a) What is the change in potential energy of a 100-kg meteorite if it free-falls from an altitude of 1000 km down to the surface of the Earth? Take the mass of the planet to be 6.0×10^{24} kg and the diameter to be 1.28×10^7 m.
   (b) The express elevator in the Sears Tower in Chicago averages a speed of 9.144 m/s (i.e., 1800 ft/min) in its climb to the 103rd floor, 408.4 m (i.e., 1340 ft) above ground. Assuming a load of 1.0×10^3 kg, what average power must the lifting motor supply?