Physics 2010 (Schroeder)
spring 2004

Name ______________________________

Problem Set 9

(due Monday, March 22)

1. You are driving north on Harrison Blvd. at a speed of 40 mph. The mass of your car is 1200 kg. What is its angular momentum with respect to an origin located at the intersection of Harrison and 36th Street? What is its angular momentum with respect to an origin located at 25th and Washington (1.2 miles west of Harrison)? What is its angular momentum with respect to an origin located at the center of our classroom (.6 miles east of Harrison)? Explain why none of your answers depend on your current location along Harrison Blvd. (unless you're way north or south, where the road bends).
2. After the sun runs out of nuclear fuel (about five billion years from now), it is predicted to collapse to a "white dwarf star", with a diameter roughly equal to that of the earth. Given that the sun currently rotates with a period of about 25 days, estimate its rotation period after the collapse. (Hint: For lack of a better assumption, take the sun to be a sphere of uniform density both before and after the collapse. You may wish to use the conservation laws worksheet.)
3. In a playground, there is a small merry-go-round with a mass of 180 kg and a radius of 1.2 m. Its radius of gyration is 91 cm; this is the radius at which you could put all its mass without changing its moment of inertia. A child of mass 44 kg runs at a speed of 3.0 m/s along a path tangent to the rim of the initially stationary merry-go-round, then jumps on. (a) Calculate the moment of inertia of the merry-go-round. (b) Calculate the child's angular momentum, while running, with respect to the merry-go-round's axis of rotation. (c) Calculate the angular speed of the merry-go-round after the child has jumped on. (Hint: Use the conservation laws worksheet.)
4. A certain rock has a mass of 240 g and a volume (measured by submerging it in water within a graduated cylinder) of 89 cm^3. Calculate its density in g/cm^3, in kg/liter, and in kg/m^3. Which of these is the official SI unit of density?
5. Imagine a large window measuring 2 m by 3 m. Inside the window, the pressure is held constant at 1 bar, while outside, during a storm, the pressure momentarily drops to 0.96 bar. What net force acts on the window?
6. Estimate the pressure you exert on the ground when standing (a) in normal shoes; (b) in ice skates; (c) in snowshoes. Please express your answers both in pascals and in bars (atmospheres).
7. For this exercise you need an inexpensive tire pressure gauge, which you should always carry with you anyway if you drive a car. If you don't have one, please borrow one. Then find a parked car (either your own or a friend's), and measure the tire pressure. Also measure the approximate area of each tire that is in contact with the road surface. Use this information to estimate the weight of the car, explaining your reasoning completely. You might as well work in English units (force in pounds and area in square inches). If possible, check your answer against the number printed in the owner's manual. Otherwise, record the make and model of the vehicle so you can check later whether your answer is reasonable.
8. Explain why it was ok to completely ignore the ambient atmospheric pressure in the previous problem.

9. Estimate the total weight of the air directly above your head.

10. Elemental carbon has two possible crystal structures, diamond and graphite. Graphite is more stable at low pressures (implying that diamonds are *not* forever, though they last thousands of years if they are not heated), while diamond is more stable at high pressures. To convert graphite into diamond requires a pressure of approximately 60,000 atmospheres. At what depth below earth's surface would you expect to find such a pressure, assuming that rock can be treated as a fluid (at great depths) and that the average rock has a density three times that of water?

11. If you swim in the Dead Sea, about 1/3 of your body will be above the water line. Assuming that your body has the same density as pure water (a good enough approximation), what is the density of the water in the Dead Sea? (Of course, you can experience the same effect, to a lesser extent, in the Great Salt Lake.)

12. To study earth's upper atmosphere, you wish to lift a 40 kg instrument to an altitude of 27 km, where the density of air is 0.035 kg/m^3. To lift this payload you will use a helium balloon whose unfilled weight is 15 kg. The density of the helium at the final altitude will be 0.005 kg/m^3. What should be the volume of the balloon at its final altitude? How much helium (in kg) should you use to fill the balloon?

Study Guide

Please refer to last week's study guide for angular momentum.

Density is the ratio of mass/volume for a substance. The SI unit of density is kg/m^3, but for common substances it is often easier to work in g/cm^3 (or kg/liter, which is the same thing). You should be able to convert between these units. You should know that the density of water is almost exactly 1 g/cm^3, and the density of air under normal conditions is about 1/1000 that of water (or about one kg/m^3).

Pressure is the force per unit area exerted perpendicular to a surface. The SI unit of pressure is the N/m^2, called a pascal (Pa). Atmospheric pressure at sea level is approximately 1 bar, which is defined as exactly 10^5 pascals. (At our elevation in Ogden the pressure is about 15% less.)

In a static fluid, the pressure exerted on the container or on a submerged object depends only on the depth, and is caused by the weight of the fluid above. If P_0 is the pressure at the top surface, and an object is submerged a distance h below this surface, then

$$P(h) = P_0 + \rho g h,$$

where ρ is the density of the fluid (assumed here to be uniform).

Because the pressure below a submerged object is always greater than the pressure above, there is net force exerted upward by the fluid. This net force is called the *buoyant force*. Since the buoyant force on a chunk of the fluid itself must precisely balance the weight of the chunk, and since the buoyant force on an object depends only on its size and shape, not on what it's made out of, we can conclude that the buoyant force on any submerged object is equal in magnitude to the weight of the fluid displaced (Archimedes' principle).