Physics 224A **Problem Set 1** March 2007

Due Wednesday, April 4, 2007, by 5 pm

Questions for grading:

1. A large beaker is filled to the brim with pure water at its maximum density of 1.00 kg/l. The following objects are put gently into the water and then released:

a) A cube of wood of density 250 kg/m^3 (0.25 kg/l), and dimension 1.0 cm by 1.0 cm by 1.0 cm;

b) A rod made of wood of density 850 kg/m^3, with length 4 cm and square cross section 5 mm by 5 mm;

c) An ice cube of volume 2.0 cm^3;

d) A rock of density 3400 kg/m^3, with volume 2.0 cm^3;

e) Two cubic centimeters of lead.

In each case, what is the volume of water that spills out of the beaker?

2. An SUV with mass 2400 kg is placed on a hydraulic lift whose platform has mass 100 kg. The platform is supported by a cylinder of diameter 500 mm. To raise the lift by 1.50 m, oil is pumped into the cylinder by a pump whose piston has diameter 30 mm.

(a) What is the gauge pressure of the oil that is supporting the piston in the large diameter cylinder?

(b) How far does the small piston have to move in order to raise the SUV by 1.5 m?

(c) What force must be applied to the small piston to do this?

(d) Should we have taken account of the increasing pressure of the oil as the big piston head moves up? How important is this effect?

3. (a) A balloon is spherical in shape with radius 8.0 m, is rigid, so that it maintains its shape and volume, and is filled with helium at atmospheric pressure. The structure of the balloon and the basket attached to it have a total mass of 1200 kg. What load can it lift in the basket?

(b) What additional load could it lift if molecular hydrogen (H_2) were used instead of helium?

4. A balloon for high altitude observations is made of flexible material which does not stretch readily. It is initially empty, and is then partly filled with hydrogen gas at ground level, to, let us say, 10% of its maximum capacity, and it has a light load of measuring instruments and a tracking radio. When it is released from the ground it rises, and continues to rise to high altitudes, until the pressure is so low that the balloon is completely filled by the hydrogen.

(a) When the balloon is partly filled, how does the pressure inside the balloon compare with the atmospheric pressure outside?

(b) While the balloon is partly filled, how does its lifting force depend on altitude?

(c) At what altitude, roughly, will the gas fill the balloon, if the initial lifting force produced by the hydrogen at ground level is 25% more than the weight of the load (including the fabric of the balloon, and the container for the instruments)? Assume that the atmosphere remains at a constant temperature.

(d) Will the balloon continue to rise after the gas fills it completely?

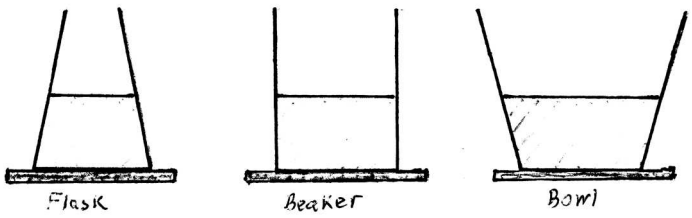

Figure 1: Three vessels, each with the same base area, and each filled to the same level with water

Other questions, for practice, and for discussion:

5. The figure shows three vessels made of thin glass, each filled to the same level with water. The flask on the left narrows at the top, the beaker in the center has vertical sides, and the bowl on the right is wider at the top. Each of them is standing on the solid platform of a spring balance.

(a) On each of the bases the water in contact with it exerts a downward force. On which base is the force exerted by the water the greatest, or are they all the same?

(b) On each of the bases the platform in contact with it exerts a upward force. On which base is the force exerted by the platform the greatest, or are they all the same?

(c) In equilibrium, the total force has to be zero. What additional forces on the bases of the vessels have to be taken into account to make sense of the answers to parts (a) and (b)?

6. When a beam balance is used to make an accurate comparison of the masses of brass weights of density 8300 kg/m^3 with the mass of an aqueous solution of density 1100 kg/m^3, what is the proportional correction that has to be made to the measured mass of the solution in order to allow for the buoyancy in air? Does the measured mass have to be corrected upwards or downwards to get the real mass of the solution?

7. In 1654 Otto von Guericke demonstrated his vacuum pump by constructing two hemispheres which could be joined together with an airtight seal between them, and then the spherical space inside pumped down to low pressure. He hired two teams of horses to attempt to pull them apart.

(a) If the radius of the sphere is R and the pressures outside and inside the sphere are p_o, p_i, with $p_o > p_i$, show that the force needed to pull them apart with a straight pull is $\pi R^2(p_o - p_i)$.

(b) With $R = 0.9$ m, $p_o = 1.0 \times 10^5$ pa and $p_i = 1.0 \times 10^4$ pa, what force would this represent?