

Physics 110
Spring 2006
Fluid Mechanics

1. Pressure in a fluid varies linearly with depth.
 - a. What is the absolute pressure at a depth of 1000m in the ocean if the density of seawater is 1024 kg/m^3 ?
 - b. At this depth what force must the frame around a circular submarine porthole having a diameter of 30cm exert to counterbalance the force exerted by the water?
2. A light balloon can be filled with either 400m^3 of helium ($\rho_{\text{He}} = 0.179 \text{ kg/m}^3$) or 400m^3 of hydrogen ($\rho_{\text{H}} = 0.0899 \text{ kg/m}^3$) and floated to carry a payload.
 - a. If the balloon is nearly in equilibrium (meaning all accelerations are zero), what mass of a payload could a balloon filled with helium support at 0°C ?
 - b. If the balloon is nearly in equilibrium (meaning all accelerations are zero), what mass of a payload could a balloon filled with hydrogen support at 0°C ?

3. The U.S. Navy has the largest warships in the world, aircraft carriers of the *Nimitz* class (for example, the *USS Ronald Regan* shown on the right.) Suppose that 50, 29,000kg airplanes take off from the flight deck and the ship bobs up to float 11cm higher in the water, in an area where $g = 9.78\text{m/s}^2$. What is the horizontal area enclosed by the waterline of the ship? Compare this to the deck of an aircraft which has an area $18,000 \text{ m}^2$.



www.aerospaceweb.org/question/history/q0226.shtml

4. A Boeing 777 has a mass of $2.43 \times 10^5 \text{ kg}$ and each wing has an area of 189m^2 . During level flight, the pressure on the lower wing surface is $700 \times 10^4 \text{ Pa}$.
 - a. What is the pressure on one of the upper wings?
 - b. What is the upward acceleration of the aircraft if the pressure on the lower surface were to increase to $702 \times 10^4 \text{ Pa}$? (This increase in pressure is due to the aircraft increasing its forward velocity and assumes that P_{upper} remains constant.)



www.boeing.com

5. A helium filled balloon is tied to a 2.0m long string where the mass of the string is 0.05kg. The balloon is spherical with radius of 0.40m. When released the balloon lifts a length of string h and then remains in equilibrium. What length of the string is lifted if the balloon has a mass of 0.250kg?

6. A uniform disk with a mass of 10kg and a radius of 0.250m spins at 300 rpm on a low-friction axle. The disk must be brought to rest in 1.0min by a brake pad that makes contact with the disk at an average distance of 0.220m from the axis. The coefficient of friction between the brake pad and the disk is 0.5. A piston in a cylinder with a diameter of 5.0cm presses the brake pad against the disk. What is the pressure of the brake fluid in the cylinder?
7. Suppose that the pressure in the cerebrospinal fluid (CSF) is measured as shown below, using a spinal tap with the patient sitting erect. The pressure due to the weight of the CSF (given that its density is 1050 kg/m^3) in the spinal column increases the pressure?
- What is the pressure measured in Pascal and in centimeters of water if the pressure around the brain is 10mm Hg and the tap is at a point 60cm lower than the brain?
 - What is the pressure measured in Pascal and in centimeters of water if the person is lying down?
8. The total flow rate of the adult circulatory system is about $10^{-4} \text{ m}^3/\text{s}$. This is the flow that passes through either the right or left side of the heart. The aorta, which carries the blood from the left side of the heart, has a diameter of 2.5cm. What is the flow velocity of the aorta?
9. Suppose that the aorta has a radius of about 1.25cm and that the typical blood velocity is around 30 cm/s and that it has an average density of 1060 kg/m^3 .
- What is the average blood velocity in the major arteries if the total cross sectional area of the major arteries is 20cm^2 ?
 - What is the total flow rate?
 - On the assumption that all the blood in the circulatory system goes through the capillaries, what is the total cross sectional area of the capillaries if the average velocity of the blood in the capillaries is 0.03cm/s ?
 - If a typical capillary has a cross sectional area of $3 \times 10^{-11} \text{ m}^2$, about how many capillaries are there in the human body?
 - What are the kinetic energy per unit volume for blood in the aorta, the major arteries, and the capillaries?
 - If a capillary has an average length of 0.75mm what is the average time that a red blood cell remains in a capillary?
10. Estimate the amount by which the blood pressure P_2 in the anterior tibial artery at the top of the foot exceeds the blood pressure P_1 in the aorta at the heart when the body is reclining horizontally and when standing erect. Assume that the distance between the aorta and the artery in the top of the foot is 1.35m and express your answer in Pascal and in mmHg, were $1 \text{ mmHg} = 133.3 \text{ Pa}$.

