Selected Answers – Fluids Assignment

1. a. 150 kg
   b. The entire Sun, including its core, is plasma – mainly hydrogen. In the plasma state the hydrogen is ionized – stripped of electrons. Therefore you could describe the Sun as a big ball of mainly protons and electrons, not bound to one another. In 1 liter of the core there must be about 8.98×10^{28} protons and 8.98×10^{28} electrons separated by distances on the order of 0.1 angstrom. This is similar to the spacing found in a single atom of monatomic hydrogen gas (not ionized). In H_2 gas at room temperature the molecules are separated by distances on the order of 30 angstroms. Compare either distance to the size of the proton itself, which is roughly a fermi or 0.00001 angstrom.
2. Greater atomic number means there are more and more nucleons, *i.e.* protons and neutrons, in the nucleus. So as atomic number increases the mass of the nucleus increases. However the spacing between nucleons does not change much, so the volume of the nucleus also increases and density of the nucleus is relatively constant. At the same time the electron cloud mass is a tiny fraction of the overall mass so mainly its volume controls the overall volume of the atom. The size of the electron cloud increases with more orbital shells, going down the periodic table but decreases going rightward because of greater attraction to the more positively charged nucleus. General trend of increased density overall suggests the increase in volume is generally not as great as the increase in mass.
3. a. 0.077 m^3 (or 77 L)
   b. 0.43 m (or 16 in) cube; or approx. same volume as a beach ball with diameter 20 inches!
4. a. 0.895 g/mL (895 kg/m^3)
   b. 0.882 g/mL (882 kg/m^3)
5. a. 3600 N
   b. 44 kN
   c. 12.8 kPa
6. a. 0.65 g
   b. Downward motion of the diaphragm increases the volume of the lungs, atmospheric pressure pushes air into the lungs to fill this space.
7. a. 2.50×10^6 kg, 24.5 MN
   b. 127 MN
   c. 151 MN
   d. 121 kPa
8. a. The atmosphere pushes the suction cup against the wall with force $P_0A = P_0\pi R^2$; the normal force of the wall on the cup is equal and opposite. Because of the normal force there is a certain amount of friction preventing the cup from sliding down the wall.
   b. $m = \dfrac{\mu P_0 \pi R^2}{g}$
   c. 12 kg
   d. If any amount of air remains under the cup it will exert an outward force on the cup and decrease the normal force. With less normal force the maximum friction and therefore maximum supportable weight will be less.
9. a. 36 kN
   b. 120 kN
   c. $4\underline{0}$ kN (about 9000 pounds of force!)
10. a. 15 mm
    b. 1.3 mm
    c. Change in volume shows conservation of matter:
    slave = $1.3*\pi*9^2 = 340\ mm^3$; master = $2.0*\pi*7.3^2 = 340\ mm^3$
    Work is force times distance; the force at the wheel cylinder is 1.5 times greater but the distance is 1.5 times smaller so the work is the same. Or, $W = Fd = PAd = PV$; since pressure is same and change in volume is same the work is the same!
11. a. 8.0 km, 5.3×10^{18} kg
    b. The actual atmosphere has a density that decreases at greater altitudes. The gravitational field weakens significantly over an elevation of 50 km (to 9.65 m/s^2) whereas the equation $P = \rho g h$ assumes g to be constant. Nonetheless, the estimate of the mass is decent because it is ultimately the weight of the air that "generates" the pressure at the surface.
12. a. –16 kPa
    b. 0.62 N outward
13. a. 10.4 cm^2
    b. The patch is pushed down by air pressure and up by normal force from the road. Complicating the picture, there are also internal forces in the rubber such that the sidewalls of the tire exert force on the tread (which this solution will ignore). Also ignored is the consequence of tread pattern – this solution assumes a slick, smooth rubber tire surface.
    c. 2.6 cm
    d. At half the pressure the area would be doubled. Assuming the width of the patch has little change it would now be twice as long (5.2 cm). This leads to greater rolling resistance and more force required to pedal.
14. a. $1\underline{0}0$ kPa
    b. Since this is nearly one atmosphere, ascend about 50 km (see problem 11).
    c. Change in pressure of the seawater causes change in pressure at surface of person, but also by Pascal's principle throughout all parts of human body. This reduction in pressure can cause nitrogen to go from a dissolved state to a gaseous bubble.
15. a. 6.2 cm
    b. 14 cm (which leaves only a few centimeters before water comes in over the sides!)
    c. 540 N, up
16. a. $a = \left(\dfrac{\rho_2}{\rho_1} - 1\right)g$
    b. As object starts to move, drag (friction) with the water will act in the opposite direction, decreasing the acceleration.
    c. A solid aluminum object submerged in mercury would accelerate upward at 4g! (Any sinking object would always have an acceleration less than 1g.)
17. a. 109 N
    b. 0.0111 m^3; 0.277 m
    c. 2.57 m/s

18. a. 4.4 m/s^2 up
    b. 16 g
19. 0.764 N upward – this force is only about 0.1% of the force of gravity, which is about a 1 part in 1000 discrepancy. Using only 3 significant digits is an approximate uncertainty in the range 0.1% to 1%, so buoyancy would be "lost in the noise" of random error and scattering of typical quantities used.
20. a. 0.36 kg/s
    b. 55 s
21. a. 3.8 cm/s
    b. 0.038 cm/s
    c. – 1100 Pa
22. a. 2.5 cm/s
    b. –0.38 Pa
    c. 8.9 μW
23. a. 0.36 m/s
    b. 0.18 L/s
    c. Assuming density is constant (true for incompressible fluid) the flow rate must be constant so that matter and mass are conserved. Water cannot simply magically appear nor disappear inside the pipe, so mass per time and volume per time in larger section must equal mass per time and volume per time in the smaller section.
24. a. 78.4 kPa
    b. 1.4 L/s
    c. The pressure in the pipes is directly proportional to the height of the water in the elevated tank. As illustrated by this example, the "pressure head" generates pressure sufficient to keep the pipes pressurized and full of water ready to use. And, the greater the pressure head, the greater the flow rate – an adequate pressure is required to get an adequate flow of water.
25. a. 2.26 m/s
    b. 248 kPa
    c. Other taps that are open would change the continuity situation. The solution given here assumes the flow into the building equals the flow out of the one faucet. If multiple faucets are in use the inflow would be equal to the sum of all of the outflows. That would change the values in the solution.
26. a. $d = d_0 \sqrt[4]{\frac{v_0^2}{v_0^2 + 2gh}}$
    b. The density of the stream doesn't matter – essentially for the same reason that mass doesn't matter in freefall. The narrowing of the stream is a consequence of the increase in speed, and the acceleration of gravity is independent of mass. A denser fluid would be heavier but its acceleration would be the same.
    c. Without viscosity one can assume the speed of the falling water is uniform at any particular elevation or cross section. This simplifies the analysis of the continuity of the flow rate. A more realistic model would allow for the speed at the center of the stream to be different than the speed at the edge of the stream.
27. a. 44 mL/s
    b. 13 kPa
    c. 0.57 W
    d. The actual pump needs to have greater power. Viscosity is similar to friction and results in the generation of heat and sound. The power of the pump would have to "make up for" these losses of energy. The value calculated assumes no energy is "wasted".
28. 370 kN upward
29. a. –690 Pa
    b. 72 m/s