6.91 Problems

for Section 6.1,

6-1: Answer these questions for a solid, a liquid, and a gas. Can its shape be changed easily? its volume? Do your answers change if "easily" is omitted?

for Section 6.2,

6-2: Describe the "meaning" of each of these math operations. Hint: think "visually" and then translate your picture-ideas into words.

$$\frac{81 \text{ g of Al}}{30 \text{ cm}^3 \text{ of Al}} = \frac{2.7 \text{ g of Al}}{1.0 \text{ cm}^3 \text{ of Al}}$$

$$30 \text{ cm}^3 \text{ of Al } \frac{2.7 \text{ g of Al}}{1.0 \text{ cm}^3 \text{ of Al}} = 81 \text{ g of Al}$$

$$\frac{81 \text{ g of Al}}{2.7 \text{ g of Al} / 1.0 \text{ cm}^3 \text{ of Al}} = 30 \text{ cm}^3 \text{ of Al}$$

6-3: [[== draw picture of cubes]]

6-4: A bottle's mass is 40 g when it is empty, 120 g when filled with water, and 112 g when filled with an unknown liquid. Is the liquid's density less than or greater than that of water? What is its density?

6-5: You mix 500 cm^3 of water with 200 cm^3 alcohol (specific gravity = .79). What is the mixture's density?

6-6: Would you rather sleep on a bed of 100 nails, or 100,000 nails? Why?
In these situations (peeling a potato, driving a nail into a board, pushing a car), what is more important, force or pressure?

6-7: On a day when the air pressure is .987 atmosphere, how much force pushes down on the top of a 1.20 m x 1.20 m table? How much force pushes upward on the table's bottom surface? What net force acts on the table?
What would happen if you were on the moon and your space suit got punctured?

6-8: A brick made of pure gold (density = 19.3 x 10^3 kg/m^3) is 9.2 cm x 5.8 cm x 19.4 cm. Standing on its narrow end, what downward pressure does it exert against the floor?
At the April 1, 1983 gold price of $384 per ounce, how much more valuable is this than a common concrete brick (of the same size) that costs 25¢? Hint: 16 ounces = 1 pound, and 453.6 grams = 1 pound <u>if</u> g = 9.807 m/s^2.

for Section 6.3,

6-9: **a)** A 15 kg block hangs from a 3.0 m long steel wire with .010 m diameter. What is the stress and strain, and how much does the wire strectch? **b)** What happens if you try to stretch this wire by .3%?
Hint: Use information from Problem 6-B.

6-10: To lessen the chance that a part will break, engineers can build in a *safety factor*. For example, to get a safety factor of "10" we would design the system (the wire material and diameter, mass that hangs from it,...) so the wire can, in theory, safely handle a stress up to 10 times the maximum stress it will actually experience.
To stay within a safety factor of 5, what is the maximum mass that can be hung from the wire in Problem 6-#? Will your answer change if the mass is not static, but is being accelerated?

6-11: Use "atomic theory" to explain why an object resists stretching or compression.
Hint: Why is an object's normal size "normal"?

6-12: How much pressure must be applied to increase the density of sea water (with a bulk modulus of 2 x 10^9 N/m^2) by .1%?

6-13: A 100 kg four-legged animal has leg bones (compressional modulus = 2 x 10^{10} N/m) with 5 cm diameter. How large an animal could the legs support?
What would happen if the animal was 100 times larger, with every part of it "perfectly scaled up"?
==[should I cut? do a shear-problem instead?]

for Section 6.1,

6-14: Compare the pressures at the •'s.

6-15: Atmospheric pressure (at point e) is 1.01 atm. What is the pressure at •?

6-16: How far must a diver descend into fresh water (1000 kg/m^3) for water pressure to increase by 1 atm? How far would she have to dive into ocean water (1025 kg/m^3)?
If air pressure is 1.00 atm, what pressure is exerted on a diver 31.02 m (102 feet) below the surface of a fresh-water lake? What is the gauge pressure at this depth?
If air pressure is 1.00 atm, and a diver 25.0 m below the surface feels a pressure of 3.48 atm. Is she in Minnesota or Hawaii?

6-17: **a)** A refrigerator is at the bottom of a swimming pool, 3.0 m below the surface. Air is trapped inside it at 1 atm. To open the door (.6 m x 1.5 m), how much force do you have to exert against it?
b) If your car drives into a river and ends up 3.0 m under water. ==? will it float? door is an average depth of 3.0 m under water, you cannot (as the shown by the calculations in Part a) open

6-18: What is the difference in air pressure between the bottom & top of the Sears Tower in Chicago, the world's tallest building at 443 m? Air density (1.29 kg/m^3) is approximately constant over this small range of Δh.

6-19: To lift an elephant slowly by pushing on one of the pistons below, where should you put the elephant?

Which piston should you put a mouse on, if you want to send it flying up into the air?

6-20: In each "lift" below, the left & right piston diameters are 60 cm & 6.0 cm.

In the first picture, what force must be exerted to lift a 1200 kg car?

In the second picture, what mass can be lifted if the maximum air pressure (P_{gauge}) is 1000 kPa? { High-pressure air is pumped into the chamber above the small piston. } What if 1000 kPa is the absolute (not gauge) pressure?

6-21: **a)** Is a rock easier to lift when it is underwater, or out of the water? Does the rock's mass change? **b)** A block weighs 70 N in air and 45 N under water; what buoyant force acts on it? **c)** Three 2 cm cubes, of aluminum (2700 kg/m^3), lead (11300 kg/m^3), and gold (19300 kg/m^3) are put into mercury (13600 kg/m^3) that is 3 cm deep. List these in order of height: tops of Al-cube, lead-cube, gold-cube, and mercury-surface. **d)** The specific gravities of liquid in fresh and dead batteries are approximately 1.30 and 1.10, respectively. Will a "hydrometer" tube float higher in a fresh or dead battery? **e)** 5 kg of water and a 2 kg wood block (800 kg/m^3) are in a 1 kg container that is on a scale; what is the scale's reading? **f)** A container is full of liquid to the rim. A 2 kg block is placed in the liquid and its "overflow" is caught in another container. What is the mass of the overflow if the block floats? if it sinks?

6-22: What is the reading on the scale? Hint: Draw 3 F-diagrams, for each block & the scale.

6-23: Use principles from the beginning of Section 6.4 to derive Archimedes' principle.
Hint: Draw a submerged cube, draw arrows to show the P that acts on each face of the cube, then calculate the net water-pressure force that acts on the cube.

6-24: A block of wood floats in ocean water (1025 kg/m^3) with 30% of its height above the surface. What is the wood's density?

6-25: A block weighs 70 N in air and 45 N under water. What is its density?

6-26: What minimum mass of aluminum (2700 kg/m^3) will sink a 10.0 kg wood block (780 kg/m^3) in water, if it is placed on top of the block? if it is attached beneath the block?

6-27: **a)** A scale ( ) is balanced in air, with 5 kg of aluminum and lead on the left and right sides. What happens if the scale is submerged in water? **b)** If both are weighed in air, does a pound of feathers have more mass than a pound of gold? { 1 pound = 4.45 N. } **c)** Does a floating boat sink lower into fresh water or salt water? **d)** Will a balloon filled with helium keep ascending forever? Why? **e)** A glass containing an ice cube is filled to the rim with water. When the ice melts, does the glass overflow? **f)** You are in a boat floating on a lake, and you throw a large rock into the lake. Does the water level rise or fall?

6-28: When a cube (2.0 cm on each side) floats in glycerine (1260 kg/m^3) .3 cm is above the surface. Would this cube float in water?

6-29: Section 20.3 describes how the great scientist Archimedes discovered the key to a famous problem: was the king's crown made of pure gold (19.3 g/cm^3) or had some less costly silver (10.5 g/cm^3) been mixed in?

Describe three ways to discover whether the crown is made of pure gold, by using the following equipment: the crown, a scale that measures the mass of an object, a balance scale ( ), a large bucket, a graduated cylinder to measure liquid volume, plus plenty of water and small pieces of gold.

6-30: A 50 cm cube of iron (7.86 g/cm^3) sits in water, on a scale that reads 882.5 kg. How much of the cube is above the surface?

6-31: The weight of an aluminum object decreases by 46.6% when it is submerged in a liquid. What is the liquid's density?

6-32: The mass of a large helium balloon (including basket, riders,...) is 750 kg. If it is to ascend into the air, what is its volume?

$\rho_{air} = 1.29$ kg/m^3, $\rho_{helium} = .179$ kg/m^3

for Section 6.5,

6-33: If an aorta (the main vessel carrying blood away from the heart) has a radius of .9 cm and flow rate of 35 cm/s, what volume of blood passes through it during one day?

At a place where the aorta narrows to a .7 cm radius, what is the blood speed? { Hint: Substitute-and-solve, or use ratio logic. }

6-34: Will the canvas top of a convertible bulge upward or downward when the car is moving at a fast speed? Does air move faster over the top or bottom of an airplane wing?

If you hold two pieces of paper vertically, parallel, an inch apart ( ) and blow air between them, what will happen? { Predict the results, then "check" by doing the experiment. }

6-35: What is the net "lift force" on a 40 m^2 wings if air (1.1 kg/m^3 at the flying altitude) moves above and below the wing at 290 m/s and 250 m/s, respectively. { Ignore Δh between the bottom and top of the wing. } What airplane mass could be supported by this "lift"?

6-36: A baseball moves ↑ and, viewed from above, spins counter-clockwise. What direction will it curve? Why?

Will a tennis ball travel further if it has "overspin" ( ), "underspin" ( ), or no spin ( )? Why?

6.92 Solutions

6-1: Change of shape is easy for a liquid or gas, possible (but difficult) for a solid. Volume change is easy for gas, possible but difficult for solid or liquid.

6-2: To understand "2.7 g of Al / 1.0 cm^3 of Al", visualize a small cube of Aluminum that is 1.0 cm on each side (so its volume is 1.0 cm^3). This 1.0 cm^3 cube of Al has a mass of 2.7 grams.

Each 1.0 cm^3 chunk of Al has a mass of 2.7 g, so 30 of these chunks (in 30 cm^3) have a mass that is 30 times this large: it contains 81 g of Al.

The final division asks: How many 1.0 cm^3 chunks of Al (each with 2.7 g of Al) are there in an object that contains 81 g of Al? answer is==more?

6-3:

6-4: The same full-bottle volume contains $120-40 =$ 80 g of water, but only $112-40 = 72$ g of the liquid. The liquid has less mass-per-volume (the bottle's volume) by a factor of 72/80 = .90; this is its specific gravity, and its density is .90 g/cm^3 or 900 kg/m^3.

6-5: The mixture contains (500 cm^3)(1.00 g/cm^3) g of water, and (200 cm^3)(.79 g/cm^3) g of alcohol. If the volumes "add" (this is approximately true, but not exactly) the final volume is (500 cm^3) + (200 cm^3). Mixture density ≡ [mixture-mass] / [mixture-volume] = [(500 g) + (158 g)] / [700 cm^3] = .94 g/cm^3.

Ratio logic: water contributes 5/7 of the volume, so the mixture's density is closer to that of water (1.00) than alcohol (.79). Water and alcohol densities differ by .21, and the mixture's density is 5/7 of the way toward the water-density: .79 + (5/7)(.21) = .94.

6-6: On either bed, your body pushes down on the nails with a force of "mg" and they push upward (as described by Newton's Third Law) with "mg". But with 100,000 nails the pressure is less (by a factor of 1/1000) so your body is less likely to be "punctured".

If the same force is applied with each knife, a sharp knife (with small contact-area) exerts more pressure than a dull knife (large contact-area) and thus peels the potato more easily. Similarly, high pressure (that can be caused by a large F or small A in F/A) is needed to drive a nail into a board.

F=ma, so a large applied force will accelerate a car quickly. But to avoid denting the car, pressure should be low. If one car pushes another (this can produce a large force) it is important to "match the bumpers" properly, thus maximizing the area-of-contact and minimizing the applied pressure.

6-7: In SI units, P = (.987 atm)(101300 Pa/atm) = 100,000 Pa. The table's area is (1.20 m)(1.20 m) = 1.44 m^2. F = PA = (10^5 Pa)(1.44 m^2) = 144,000 N.

On earth, a huge air-pressure force pushes your skin inward (the same way it pushes a table top) but it is balanced by an equally large "internal force" that is exerted outward against the skin by the pressure from your own cells. On the moon, P_{air} is ≈ 0. If your space suit (which had been exerting a pressure of ≈ 1 atm) punctures and the external air pressure drops to ≈ 0, your internal pressure-and-force is no longer balanced, and you will "explode".

6-8: Use links: $\rho V = \underline{m}$, $\underline{m} g = \underline{F}$, $\underline{F} = PA$.

$$V_{brick} = (.092\text{ m})(.058\text{ m})(.194\text{ m}) = .001035\text{ m}^3,$$
$$m_{brick} = (19300\text{ kg/m}^3)(.001035\text{ m}^3) = 19.98\text{ kg},$$
$$F_{gravity} = (19.98\text{ kg})(.9807\text{ m/s}^2) = 19.59\text{ Newton},$$
$$A_{narrow\ end} = (.092\text{ m})(.058\text{ m}) = .005336\text{ m}^2,$$
$$P = (19.59\text{ N})/(.005336\text{ m}^2) = 3670\text{ Pa}.$$

Use conversion factors to find the value of the brick:

$$19.98\text{ kg}\ \frac{1000\text{ g}}{1\text{ kg}}\ \frac{1\text{ lb}}{453.6\text{ g}}\ \frac{16\text{ oz}}{1\text{ lb}}\ \frac{\$384}{1\text{ oz}} = \$270{,}600$$

To answer "How much more valuable...", you can subtract (\$270600 –\$.25 = \$270599.75 *), or divide (\$270600 / \$.25 = 1,082,400 times more valuable).

* If significant figures are done correctly, there is actually "no difference".

6-9: **a)** Write a 4-sided equation, substitute, solve:

$$\text{Stress} \equiv \frac{F}{A} = Y \frac{\Delta L}{L_o} \equiv \text{Strain}$$

$$\text{Stress} = \frac{15\,(9.8)}{\pi\,(.0005)^2} = (2000 \times 10^8)\frac{\Delta L}{2.5} = \text{Strain}$$

$$\text{Stress} = 1.9 \times 10^8\text{ Pa} = \text{Strain},$$
$$2.3 \times 10^{-3}\text{ m} = \Delta L\text{ (amount of stretch)},$$
$$\%\text{ stretch} = 100\,(2.3 \times 10^{-3})/(2.5) = .092\ \%$$

b) Translate the %-description into an equation. If the wire-length increase is .3% of the original length, then $\mathbf{\Delta L}$ (wire-length increase) **=** (is) **.003** (.3%) $\mathbf{L_o}$ (of the original length): $\mathbf{\Delta L = .003\ L_o}$.

We can calculate Stress = Strain = Y ΔL / L_o = $(2000 \times 10^8)(.003\ L_o)/(L_o) = 6 \times 10^8$ N/m. This exceeds the steel's ultimate tensile strength of 5×10^8 Pa, so the wire will break.

6-10: We can state our self-imposed safety factor limitation as "the stress (which can be expressed as F/A or $Y\Delta L/L_o$) must be less than 1/5 of the material's ultimate strength". Since this problem asks about the maximum force (not the maximum stretch $\Delta L/L$) we will use "stress = F/A", not "stress = Y $\Delta L/L_o$":

$$\text{Stress} = \frac{1}{5}\ \text{(ultimate strength)}$$

$$\frac{m\,(9.8)}{\pi\,(.0005)^2} = \frac{1}{5}\ (5 \times 10^8)$$

$$m = 8.0\ \text{kg}$$

In theory, the 15 kg mass in Problem 6-# won't make the wire break, because the wire could (with no safety factor) carry 40 kg, 5 times the 8.0 kg limit. But 15 kg is "too close for comfort" if we judge by a standard that says "the safety factor should be 5".

As explained in Problem 3-A, using force diagrams and F=ma, for a given mass the F supplied by wire-tension increases if acceleration is in the ↑ direction, and the "safe" mass limit would be less than 8.0 kg. But F will decrease (and the mass that is considered "safe" will ↑) if acceleration points ↓.

Contrary to what you might expect, constant-speed upward movement produces the same stress as "no movement", because both situations have a=0.

6-11: All objects are made of tiny atoms that exert attractive and repulsive forces on each other*. When an object is unstressed and is at its normal size, it has an average atom-to-atom separation that "optimizes" the combination of attractive and repulsive forces.

* *Electrostatic forces* and *chemical potential energy* are discussed in Chapter 10. For this solution the only idea you'll need is that electrical forces (both attractive and repulsive) increase if atoms are closer to each other. This makes sense, doesn't it?

When an object is "stretched" its atoms move a little further apart and the attractive forces decrease. This new situation is not as good as it was, and the object tries to "pull" itself back to its original optimal size.

When an object is compressed, the repulsive atomic forces increase. This is bad, and the object tries to "push" itself back to its unstressed optimal size.

6-12: Pressure doesn't change mass, so if density ($\equiv$ mass/volume) is to increase by .1%, volume must decrease by .1%. As described in Solution 6-##, a .1% V-decrease means that $\Delta V = .001 V_o$.

$$P = B\ (\Delta V / V_o)$$

$$P = (2 \times 10^9\ \text{Pa})\ (.001 V_o / V_o)$$

$$P = 2 \times 10^6\ \text{Pa}$$

6-13: If the animal is standing still the equation is: $m(9.8)/(\pi\ .025^2) = (2 \times 10^9)($

6-14: The vertical distance from • to the top of the fluid is equal in each container except #3. If each fluid has the same density, all of the •'s have the same pressure except for #3 whose pressure is lower.

6-15: Use these four principles from Section 6.4: a) equal P at same fluid-level, b) equal P at boundary, c) $P_{btm} = P_{top} + \rho gh$, d) equal P in all directions.

In SI units, P_e = (1.01 atm)(101300 Pa/atm) = 102300 Pa. $P_d = P_e$ (boundary), $P_c = P_d + \rho gh$ = 102300 + (1000)(9.8)(.45), $P_b = P_e$ (at same level in fluid), $P_a = P_b$ (boundary), and $P_\bullet \approx P_a$ because air density is so low that the ρgh is negligible. P at • is (102300 + 4400) Pa = 106700 Pa = 1.05 atm.

If $P_\bullet$ exceeds P_e by 1 atm, 1 atm = 101300 Pa = (1000)(9.8) h, and h = 10.34 m.

6-16: P-increase = 101300 = (1000)(9.8)h, so h = 10.34 m = 33.92 feet. Sea water's density is higher, so a Δh of only 10.09 m (smaller than 10.34 m by a factor of 1000/1025) will produce a ΔP of 1 atm.

P = (101300) + (1000)(9.8)(31.02) = 405300 Pa = 4.00 atm. An alternate method: P increases by 1 atm for every 10.34 m the diver descends, so 31.02/10.34 = 3.00 "extra" atm (above the $P_{surface}$ of 1.00 atm). The "gauge" pressure is 3.00 atm, and the "absolute" pressure is 4.00 atm.

In fresh water, P = 1.00 + 25.0/10.34 = 3.42 atm. In sea water, P = 1.00 + 25.0/10.09 = 3.48 atm. She is in sea water, probably in the warm Pacific Ocean off the shores of Hawaii.

6-17: At 3.0 m below the surface, P = (101300) + (1000)(9.8)(3.0) = 130700 Pa. This P pushes in on the door, to prevent it from opening, with F = PA = (130700 Pa)(.6 m)(1.5 m) = 117600 N. There is also an air-pressure force pushing out, trying to open the door: F = (101300)(.9 m^2) = 91170 N.

To open the door, you must pull outward with 26430 N (2950 pounds, almost 3 tons), enough force to overcome the "117600 N – 91170 N" difference between the pressure-forces.

{If the door faces sideways the P_{water} force against it would be even larger, because part of the door would be further than 3.0 m below the surface.}

6-18: $\Delta P = \rho g h = (1.29)(9.80)(443 \text{ m}) = 5600 \text{ Pa} = .055 \text{ atm}$. Air pressure is less at the top.

6-19: Put an elephant on the large piston, and lift it slowly by applying relatively small force on the small piston. Or put a mouse on the small piston, and lift it quickly by pushing the large piston (with a relatively large force) at medium speed. Do you see the force-versus-speed "tradeoff"?

A summary: small piston (small force, fast), large piston (large force, slow).

6-20: Substitute into $(F/A)_{left} = (F/A)_{right}$, solve.

For the left-side lift,

$$(F/A)_{left} = (F/A)_{right} \qquad (F/A)_{left} = (P)_{right}$$

$$\frac{1200(9.8)}{\pi(.30)^2} = \frac{F_{right}}{\pi(.03)^2} \qquad \frac{M(9.8)}{\pi(.30)^2} = 1000 \times 10^3$$

$$118 \text{ N} = F_{right} \qquad M = 28900 \text{ kg}$$

Gauge pressure is used for P_{right} because 1 atm pushes down on the left-side piston, so only pressure in excess of 1 atm pushing up on the left-side piston (after being transmitted from the right-side air chamber through the piston and fluid) produces a net upward force on the left-side piston. Notice that the area of the right-side piston doesn't matter.

If $P_{absolute} = 1$ atm, $P_{right} = P_{gauge} = (1000 \text{ kPa}) - (101 \text{ kPa}) = 899$ k Pa), and $M = 26000$ kg.

6-21: **a)** The rock's mass & weight don't change, but upward buoyant force helps you lift an underwater rock. **b)** 25 N. **c)** Gold, mercury, lead, aluminum. Compare the densities; gold sinks (100% is under the surface, lead floats (83% is under), aluminum floats (20% is under). **d)** It floats higher in a high-density fresh battery. **e)** 8 kg, or 78.4 N [buoyant force doesn't "eliminate" mass or weight. **f)** If it floats, the weight of displaced water (this is the "overflow", since water was at the rim initially) equals the weight of the floating object: 2 kg. If the object sinks, there isn't enough information to answer the question.

6-22: Draw three F-diagrams, solve three F=ma's.

For Al: $+7.3 - 19.6 + N = 0$, $N = 12.3$ Newtons. For wood: $+24.5 - 19.6 - T = 0$, $T = 4.9$ Newtons. The scale reading is $+N - T = +12.3 - 4.9 = 7.4$ *N,* or a mass of $7.4/9.8 = .76$ kg.

6-23: If each edge of the cube has length "a", the P on the cube-bottom is larger than P on the cube-top: $P_{bottom} = P_{top} + \rho g a$. Pressure difference is shown by the difference in arrow sizes:

The sideways pressures cancel each other, but the upward and downward forces produce a net *buoyant force:* $F_B = +F_{upward} - F_{downward} = +P_{btm} A - P_{top} A = +(P_{top} + \rho_{fluid}\, g\, a)(a^2) - P_{top}(a^2) = +\rho_{fluid}\, g\, a^3 = \rho_{fluid}\, X\, V_{object}\, g = \rho_{fluid}\, V_{displ\text{-}fluid}\, g = w_{displ\text{-}fluid}$.

P increases with depth, so the ↑ P-force is larger than the ↓ P-force. This difference in ↑ and ↓ water-pressure forces is called the "buoyant" force.

6-24: If 30% is above the surface, 70% is under, so $X = .70$. Draw a F-diagram, write F=ma, solve: $-V_{obj}\,\rho_{obj}\, g + \rho_{liquid}\, X\, V_{obj}\, g = 0$, $\boldsymbol{\rho_{liquid}\, X = \rho_{obj}}$ if (and only if) the object floats. $\rho_{wood} = 717 \text{ kg/m}^3$

Optional: You can use this equation in rearranged form, $\boldsymbol{X = \rho_{object} / \rho_{fluid}}$, to calculate X for the blocks of aluminum and lead in Problem 6-##c.

6-25: In the air, $w_{obj} = 70 = \rho_{obj}\, V_{obj}\,(9.8)$, and $V_{obj} = 7.14/\rho_{obj}$. {We could also solve for m_{object}, but trial-and-error (I tried several approaches before finding one that worked) shows that $\rho V g$ is more "algebraically productive".} In water, the F=ma is:

$$+45 - w_{obj} + \rho_{liquid}\; X \quad V_{obj} \quad (9.8) = 0$$
$$+45 - 70 + (9800)(1.00)(7.14/\rho_{obj})(9.8) = 0$$
$$69972/\rho_{obj} = 25$$
$$2800 \text{ kg/m}^3 = \rho_{obj}$$

6-26: Draw F-diagrams, write F=ma, substitute and solve. If Al is on top, F_B acts only on the wood. But if Al is underneath, F_B acts on the wood and Al. The wood sinks: $X_{wood} = 1.00$. $V = m/\rho$. And because the minimum mass of Al is used, $a = 0$.

If Al is on top,
$$-M_{Al}\, g + 10g + 1000(1)(10/780)g = 0,$$
cancel the g's, solve for $M_{Al} = 10 + 12.8 = 22.8$ kg.

If Al is underneath,
$$-Mg + 10g + 1000(1)(10/780)g + 1000(1)(M/2700) = 0,$$
cancel the g's, $22.8 = .63\, M$, $36.2 \text{ kg} = M_{Al}$.

6-27: **a)** Al is less dense than lead, so 5 kg of Al has more volume and (when it is submerged) feels more upward buoyant force than 5 kg of lead, so the left side of the scale rises. **b)** Surprise! Feathers are less dense so they feel more F_B due to displacement of air, so to get the same weight-force (1 pound) you must put a larger mass of feathers on the scale. **c)** It must sink lower into lower-density fresh water, to displace enough fluid to equal its weight. **d)** As the balloon rises, air-density decreases and so does F_B, until F_B no longer exceeds the weight of balloon-plus-helium, and the balloon stops rising. **e)** The water remains "at the rim". If the ice cube's mass is 25 g, it diplaces 25 g of water. When this ice melts it becomes 25 g of water, exactly filling in the space it formerly "displaced". **f)** If a rock (2500 kg/m^3) is $.010 \text{ m}^3$ and

25 kg, it displaces .010 m^3 when it enters the lake, causing the lake to rise. But there is 25 kg less mass in boat+you+rock, so 25 kg (and .025 m^3) less water is displaced, lowering the lake. Because .025 m^3 is larger than .010 m^3, the lake level becomes lower.

6-28: $X = (2.0 - .3)/2.0 = .85$. Using the logic (and derived formula) from Problem 6-##, $\rho_{object} = X\ \rho_{fluid} = .85(1260) = 1070\ kg/m^3$. The object is more dense than water, so it won't float in water

6-29: Measure the crown's mass (using the scale) and volume (by comparing water volume without the crown and with it, or by weighing the water that over-flows from a full container when the crown is placed into it), calculate the crown's mass/volume density: is it 19.3 g/cm^3? If it contains some silver, the crown's density will be less than 19.3 g/cm^3.

Or you could pile enough gold pieces on the 's right side to balance the crown on the left side, as in the first picture below. Then 1) immerse the balance in water [top row below], or 2) measure the volume of the gold pieces and the crown [bottom row below].

Choose the picture (1, 2 or 3) in each row that will occur if the crown is made of pure gold, and if it is a mix of silver-and-gold. {Answers are after 6-##.}

6-30: Draw a F-diagram for the cube, write F=ma:

$$+N \;-\; V_{obj}\ \ \rho_{obj}\ \ g \;+\; \rho_{fluid}\, X\, V_{displ\text{-}fl}\ g \;=\; 0$$
$$+882 \;-\; (.50^3)(7860) \;+\; 1000\, X\ (.50^3) \;=\; 0$$

$X = .804$, .804(50 cm) of the block is under water and the rest, .196(50 cm) = 10 cm, is above water.

6-31: If the object's weight in air is Mg, its weight in the liquid is (1–.466)Mg. Draw an F-diagram for the submerged block, and write F=ma:

$$+.534\,Mg - Mg + \rho_{fluid}\,(M/2700)(1)\,g = 0,$$
cancel the M's & g's, solve for $\rho_{fluid} = 1260\ kg/m^3$.

(6-29): If the crown is pure gold, the #2 pictures occur. If it has lower density because silver is mixed in, the crown has a larger volume than the equal-mass block of gold, so it displaces more water and has a larger buoyant force, as in the #3 pictures.

6-32: If the balloon is barely able to "lift off", with $a = 0$, $-w_{balloon} \;-\; w_{helium} \;+\; F_B \;=\; 0$

$$-750g - .179\ V_{helm}\, g + 1.29(1) V_{helm}\, g = 0$$

The volume of helium could be 675 m^3 or larger.

6-33: If we treat the aorta as if it was a cylinder, flow rate $= A v = \pi\,(.9\ cm)^2\,(35\ cm/s) = 89\ cm^3/s$, or $\pi(.009\ m)^2\,(.35\ m/s) = 8.9 \times 10^{-5}\ m^3/s$.

In one day the blood volume flowing thru the aorta is (24 hours)(3600 s/hr)(89 cm^3/s) = 7,700,000 cm^3.

The flow rate is constant, so where the aorta narrows:

$$\begin{aligned} Q_1 &= Q_2 \\ A_1\, v_1 &= A_2\, v_2 \\ \pi\,(.9\ cm)^2\,(35\ cm/s) &= \pi\,(.7\ cm)^2\, v_2 \\ 58\ cm/s &= v_2 \end{aligned}$$

Ratio logic. Av is constant, so if A decreases by a factor of $(.7/.9)^2$, v "compensates" by increasing by a factor of $(.9/.7)^2$: $v_2 = (35\ cm/s)(.9/.7)^2 = 58\ cm/s$.

6-34: When the car is moving, air speed is fast above the canvas top, and slow (≈0) inside the car. Above the top where velocity is high, the air pressure [and force] is low, so the canvas bulges upward.

To get "lift" that makes an airplane fly, P-and-PA-and-F must be larger on the bottom side of the wing, so air must flow slower underneath the wing: low v means high P. This is shown above.

When you blow between the pages, v_{air} increases, P_{air} decreases, and the pages move together. Try it!

6-35: Use Bernoulli's equation without the ρgh's:

$$\begin{aligned} P_{above} + \tfrac{1}{2}\ \rho\ \ v_1^2 &= P_{below} + \tfrac{1}{2}\ \rho\ \ v_2^2 \\ P_{above} + \tfrac{1}{2}\,(1.1)(290)^2 &= P_{below} + \tfrac{1}{2}\,(1.1)(250)^2 \\ P_{above} + 46255 &= P_{below} + 34375 \\ 11880\ Pa &= P_{below} - P_{above} \end{aligned}$$

$F_{lift} = +F_{bottom} - F_{top} = P_{bottom}A_{bottom} - P_{top}A_{top}$. If $A_{bottom} = A_{top}$, $F_{lift} = (P_{bottom} - P_{top})\,A = (11880\ Pa)(20\ m^2) = 238000\ N$. This is enough to counteract an mg-force of 238000 N, for an airplane with a mass of $m = w/g = 238000/9.8 = 24000\ kg$, so two wings could support a 48,000 kg airplane.

6-36: If you've thrown or hit a "curve ball", you'll know that the ball curves leftward, .

Explaining why it curves requires careful analysis. A common error (==