Preparation Notes for Chapter 15 (Fluids; 4-5 classes)

Note: I have marked with ** the sections I feel to be essential. Although I have marked the problems as essential, that may be a matter of instructor's taste; the problems perhaps need not be carried through all the way to the end. I have not identified where the student presentations are to come in; consult your separate list for that; they are fairly well tied to the topics, I think.

Pressure

Reading 15.1-15.4; Problems 19, 63

(1) Key introductory concepts: Un-ionized states of matter; continuity between fluid and gas in some circumstances (both held together by weak cohesive forces and walls of container). Compressibility: why in gas and liquid; why so different in solid. Concepts of volume and density. What are the characteristics of fluids?
(2) ** Introduce concept of pressure; reinforce connection with force (P=F/A; pascal Pa=N/m^2); pressure is a scalar (proportional to magnitude of force); Fluids can't pull or shear (twist), can only push: forces and pressures act only perpendicular to surfaces; for a small area dA, and a force dF, P=dF/dA; may need to integrate over area to find total pressure
(3) ** (whole class discussion i.e. ask for volunteers without group discussion first) Familiar experiences of pressure changes: ears popping driving down "the mountain"; ears hurting while skin-diving; changes while in a plane; someone steps on you in high heels
(4) ** Variation of pressure with depth: "equation of hydrostatic equilibrium"; consider a volume of fluid with base area A and height h; force of gravity is ρAhg; pressure at surface is P_oA; if fluid is not to move, force at bottom must be $PA = P_oA + \rho Ahg$ or $P = P_o + \rho hg$
(5) ** Pascal's law ; change in P applied to a fluid is transmitted undiminished throught the fluid and to the walls; (concept of the speed of sound i.e. pressure changes get transmitted at the speed of sound); Connection with hydraulics i.e. small force on small area can produce big force over big area and lift a heavy object (like a car); $F_1/A_1 = F_2/A_2$; Connection of Pascal's law with Work; $A_1d_1 = A_2d_2; F_1d_1 = F_2d_2$
(6) ** Pressure Measurements: absolute pressure and "gauge pressure"; $P_o = 1.013 \times 10^5$ Pa; gauge pressure is $P - P_o$; - barometer closed tube so P(top)=0; $P_o = \rho gh$
(7) (possible discussion topic, either for groups or the whole class) Why not use water in barometer? (density is 13.6×10^3 versus 1×10^3)
(8) Problem 15.63 (Superman)

Buoyant forces and Archimedes's Principle

Reading 15.4; Problems 49, 55

(1) Introduction: buoyant objects (boats, rubber duckies, people); connection with resultant of pressure forces i.e. discussion of volume of liquid in deriving variation of pressure with depth

(2) ** Archimedes's Principle: the magnitude of the buoyant force always equals the weight of the fluid displaced by the object; totally submerged object $F_B = \rho_f V_o g$; partially submerged object $F_B = mg$ i.e. the object floats; so $\rho_f V_f g = \rho_o V_o g$ and $\rho_o/\rho_f = V_f/V_o$
(3) ** Group discussion: Effect of Arctic icecap melting on sea-level (none except for Greenland's ice) versus effect of Antarctic's icecap melting on sea-level (substantial)
(4) ** Problem 15.49: A helium-filled balloon is tied to a 2.00 m long 0.0500 kg uniform string. The balloon is spherical witha radius of 0.400 m. When released, the balloon lifts a length h of string and then remains in equilibrium. Determine the value of h. The envelope of the balloon has a mass of 0.250 kg. ($\rho_{He} = 0.179$ kg/m^3)

Fluid Dynamics
Reading 15.5-15.7; Problems 67, 69

(1) ** Flow Characteristics: types of flows; laminar (smooth path, v(x,y,z) but not t); turbulent (eddies, whirlpools); ask for examples from class. Viscosity: degree of internal friction; layers move relative to each other; ask for examples from class
(2) ** Streamlines and the Equation of Continuity: Describe in terms of conservation of mass; "Tube of flow" concept: particles stick to streamlines; mass can't come in or out, otherwise the streamlines will cross; Example of "water/air tornado" in bath tub or sink; Equation of continuity; conservation of mass gives $\rho A_1 \Delta x_1 = \rho A_1 v_1 \Delta t = \rho A_2 v_2 \Delta t$; so $A_1 v_1 = A_2 v_2$
(3) Group discussion: Why does stream of water get narrower as it comes out of the faucet? Or, why does water squirt out of hose faster when you cover up part of the whole with your thumb? Or both together, with pictures to stimulate discussion
(4) ** Bernoulli's Equation: $P_1 + \frac{1}{2}\rho v_1^2 + mgy_1 = P_2 + \frac{1}{2}\rho v_2^2 + mgy_2$; don't derive this, they can read the text
(5)more discussion; describe importance of pressure difference i.e. a hose lying filled with water; water doesn't shoot out unless pressure difference; $(P_1 - P_2)Ad = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$. Garden hose example; cover area with thumb and speed goes up. Water towers and mgh connection; open to atmospheric pressure at both ends; $mgy_2 - mgy_1 = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$; $v = \sqrt{2gh}$, Torricelli's law
(6) ** Problem 15.69: A U-tube open at both ends is partially filled with water. Oil having a density of 750 kg/m^3 is then poured into the right arm and forms a column L=5.00 cm in height. (a) Determine the difference h in the heights of the two liquid surfaces. (b) The right arm is shielded from any air motion while air is blown across the top of the left arm until the surfaces of the two liquids are at the same height. Determine the speed of the air being blown across the left arm. (Take the density of air as 1.29 kg/m^3.)

Suggested Presentation Topics

Viscosity of three household fluids

Pressure difference between the "mountain" and Mac

Measurement errors due to container shape in displacement measurements (and/or thermometers and barometers)

Volume of people's heads

Pressure patterns of people's feet (calibrate it!)

Pressure differences in a bathtub

Time taken to drain a coffee filter for a conical and cylindrical coffee filter holder.

Pressure and SCUBA Diving

Snowshoes and Skis (or how to move through deep snow)

Why can a canoe go places a motorboat can't?

Why some people are floaters and others are sinkers (when they swim)