AP Physics – Fluids Wrap-up

Here are the equations that you get to play around with:

$$p = p_0 + \rho g h$$

This is the equation for the pressure of something as a function of depth in a fluid. You would use it to figure out the pressure acting at a depth of 25.0 m in a lake for example.

$$F_{Buoy} = \rho V g$$

This is the equation for the buoyant force. It is also an equation that calculates the weight of an object as a function of its density, volume, and the acceleration of gravity.

$$A_1 v_1 = A_2 v_2$$

This equation represents flow rate, which is the cross sectional area, A, multiplied by the velocity of the fluid, v. This is set up for two locations in a flow system. The flow rate for a fluid that is incompressible must stay constant, so this equation allows you to calculate the linear speed of the fluid as a function of the cross sectional area of the system.

$$p + \rho gy + \frac{1}{2}\rho v^2 = const.$$

This is a Bernoulli's equation. This allows you to calculate pressure, linear speed, etc.... For a system at different places within the system.

Here is the stuff you need to be able to do.

A. Fluid Mechanics

- 1. Hydrostatic pressure
 - a) You should understand that a fluid exerts pressure in all directions.

This is basic. For example, atmospheric pressure goes in all directions about an object – under it, over it, on the sides, etc.... Good old Pascal's Principle.

b) You should understand that a fluid at rest exerts pressure perpendicular to any surface that it contacts.

This is also an application of Pascal's principle. The pressure is everywhere throughout the liquid. The direction of the force acting on a surface is always perpendicular to the surface.

c) You should understand and be able to use the relationship between pressure and depth in a liquid, $\Delta p = \rho g \Delta h.$

The actual equation that is provided you is $p = p_0 + \rho gh$ where p_0 would be some initial pressure. We did a bunch of these problems. Gauge pressure is based on the idea that the atmospheric pressure is zero pressure. Absolute pressure uses a perfect vacuum – zero Pascals – as its zero pressure. So gauge pressure differs from absolute pressure by one atmosphere. The pressure at a certain depth would be given by $p = p_0 + \rho gh$. For an absolute pressure you would set p_0 equal to the atmospheric pressure. For a gage pressure you would drop the p_0 term.

- 2. Buoyancy
 - a) You should understand that the difference in the pressure on the upper and lower surfaces of an object immersed in a liquid results in an upward force on the object.

We went through this when the teacher derived the buoyancy equation for you. Because the pressure depends on depth, the pressure increases with the depth. So if the top of a regular object is 10 m below the surface and the bottom of it is 15 m below – five meters deeper, the force, which is pressure times area, must be greater. Thus there is a larger force pushing up on the bottom of the body than the pressure pushing down on the top of the body. The net force is upward and is given the name of 'buoyant' force.

b) You should understand and be able to apply Archimedes' principle; the buoyant force on a submersed object is equal to the weight of the liquid it displaces.

Well, the statement gives you Archimedes' principle and tells you to understand it. So do that.

- 3. Fluid flow continuity
 - a) You should understand that for laminar flow, the flow rate of a liquid through its cross section is the same at any point along its path.

So okay, do that too.

b) You understand and be able to apply the equation of continuity, $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$.

Actually the equation that you are given is: $A_1v_1 = A_2v_2$ the density part isn't in the equation. This is because in the type of problem that you'll be doing, the density won't change and will remain constant. Because of that, it cancels out of the equation. The teacher is not at all sure why statement b) above had a different form of the equation. Probably some miscommunication at the College Board. Anyway, we did a bunch of problems where you got to use the equation. It is all pie.

- 4. Bernoulli's equation
 - a) You should understand that the pressure of a flowing liquid is low where the velocity is high, and vice versa.

Simple principle, simple stuff. Hey you can do it!

b) You should understand and be able to apply Bernoulli's equation, $p + \rho gy + \frac{1}{2}\rho v^2 = const.$

The teacher is not sure what sort of questions you can expect. He provided you with several of them, but is only guessing. So it goes.

Well. That's it for what you need to know.

From 2002:

- In the laboratory, you are given a cylindrical beaker containing a fluid and you are asked to determine the density ρ of the fluid. You are to use a spring of negligible mass and unknown spring constant k attached to a stand. An irregularly shaped object of known mass m and density D ($D >> \rho$) hangs from the spring. You may also choose from among the following items to complete the task.
 - A metric ruler
 - A stopwatch
 - String
 - (a) Explain how you could experimentally determine the spring constant *k*.



The mass of the weight is known, suspend the mass from the spring in air, measure the displacement of the spring and calculate k from the equation $F_s = -kx$ where F_s is the mg, the weight of the thing.

(b) The spring-object system is now arranged so that the object (but not the spring) is immersed in the unknown fluid, as shown above. Describe any changes that are observed in the spring-object system and explain why they occur.

The mass will have less weight in the fluid because of the buoyant force. It will decrease by the amount of the force which is $F_{buoy} = \rho Vg$

(c) Explain how you could experimentally determine the density of the fluid.

Knowing k we can calculate the apparent weight of the object in the fluid. The difference between its weight in the air and in the fluid will equal the buoyant force.

The volume of the object could be calculated using the equation for density: $\rho = \frac{m}{V}$ The volume of fluid displaced will be the same as the volume of the object.

Knowing the buoyant force, we can use the buoyant force to calculate the density of the fluid.

$$F_{buoy} = \rho Vg \quad \rho = \frac{F_{Buoy}}{Vg}$$

Symbol	Physical quantity
F_s	This is the force that stretches the spring. In air, it will be the weight of the object.
k	The spring constant
x	The spring displacement
F_{g}	The weight of the object
т	The mass of the object
8	The acceleration of gravity
F _{buoy}	The buoyant force
ρ	The density of the fluid
V	Volume of fluid displaced by the object
g	Acceleration of gravity

(d) Show explicitly, using equations, how you will use your measurements to calculate the fluid density ρ . Start by identifying any symbols you use in your equations.

Measure the displacement of the spring by the object in air. Calculate the weight of the object using $F_g = mg$. Using this weight, calculate the spring constant from $F_s = -kx$. Calculate the volume of the object using the equation for density. This will be the same as the volume of the fluid displaced.

Note the spring displacement. From this calculate the weight of the object in the fluid using the buoyant force equation. The difference in the two forces is the buoyant force. Using the volume displaced, the buoyant force, and the acceleration of gravity calculate the density of the fluid. (Using the buoyant force equation.)

So there it is. You're all set fluid mechanics-wise.

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