AP Physics

Fluids

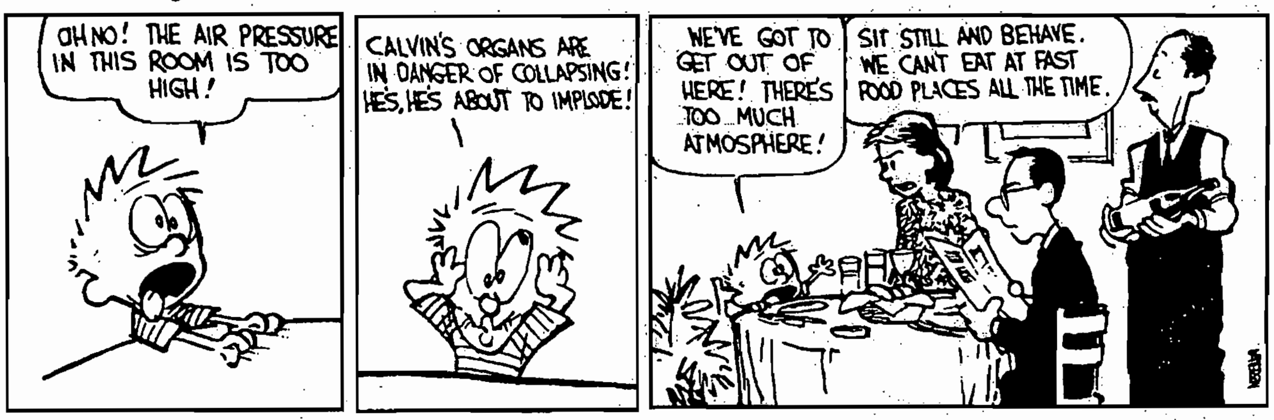
Upon completion of Chapter 10 you should be able to:

1. Calculate the density or specific gravity of a substance.
2. Distinguish between the gauge and total pressure.
3. Calculate pressure given force and area.
4. Solve problems relating pressure to depth and density of a fluid.
5. Solve problems involving Pascal's principle.
6. Apply Archimedes' Principle.
7. Deduce effects in a fluid flowing through a system by using Bernoulli's theorem.
8. Deduce the speed or flow rate of a fluid flowing though a tube or exiting a vessel.

Chapter 9

Topic	Reading	Homework	Extra HW
Density, Specific Gravity, Pressure, Barometer, Manometer	Sections 9.2, 9.4, 9.5	CQ: 5 P: 4, 6, 20, 21, 22, 23, 26	P: 24, 25, 82
Pascal's Principle Buoyancy and Archimedes' Principle	Sections 9.4, 9.6 Examples 9.7-9.9	CQ: 10 P: 27, 28, 29, 32, 35, 38, 42	P: 40, 41, 87
Bouyant Force Lab		Finish Lab	
Fluids in Motion Bernoulli's Equation	Sections 9.7, 9.8 Examples 9.11-9.14	CQ: 6, 11 P: 44, 49, 52, 53, 55, 57	P: 85
Review		Study for Test	
TEST			

AP Physics – Buoyant About Life Lab



If a man will begin with certainties, he shall end in doubts; but if he will be content to begin in doubts, he shall end in certainties. -- Francis Bacon

Come up with a lab that will confirm the buoyant force equation.

May the buoyant force be with you.

Fluids

Fluids are relatively easier to deal with. We need to learn or understand 3 guiding definitions 2 of which you are already familiar with:

Mass Density $\rho = \frac{mass}{Volume} \quad \frac{kg}{m^3}, \frac{gm}{cm^3}$

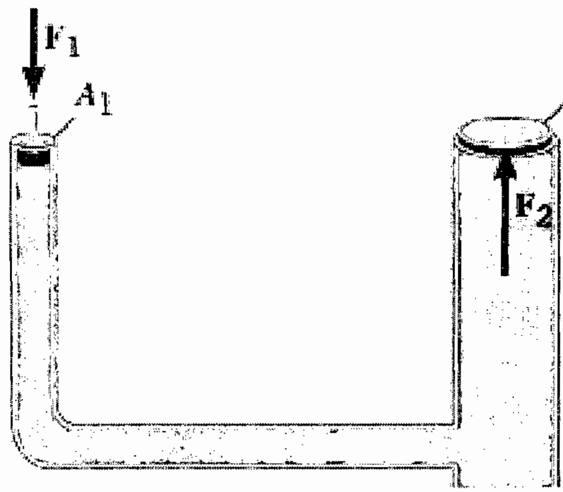
Pressure $P = \frac{Force}{Area} \quad \frac{Nt}{m^2}, pascal, bar$

Flow $Q = Area \cdot velocity \quad \frac{m^3}{s}$

The pressure of a fluid at any depth is simply equal to the weight of the liquid above that point. ***It doesn't matter how wide the channel is. Only the depth and density.***

$$P = \rho g h$$

The first principal is Pascal's law which states that pressure in any closed chamber is felt everywhere the same. This presumes that what ever you have done to change the pressure has stopped and the system is static or unchanging. (I want to distinguish this from the dynamic system we will be talking about later.)



If I push on piston A_1 with a force F_1 then I create a new pressure P felt everywhere through out the system. The force on the other piston is simply this pressure times the area that the pressure acts on.

$$\frac{F_1}{A_1} = P = \frac{F_2}{A_2}$$

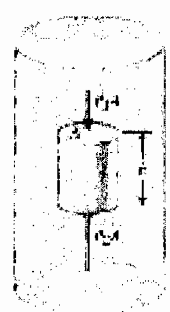
$$F_2 = A_2 \frac{F_1}{A_1}$$

The next rule is Archemedes' Principal. This is simply a statement that the bouyant force is equal to the weight of the displaced fluid. Keep in mind that we need to account for the relative changes in density between two materials.

$$F_B = P_2 A - P_1 A$$

$$P(y) = \rho g y$$

$$F_B = \rho g V$$

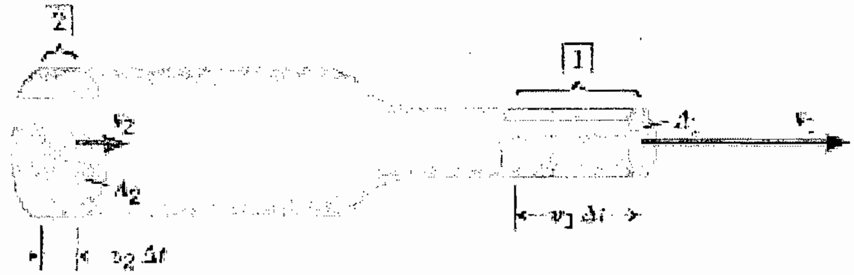


The shape doesn't matter, it is simply the weight of the displaced fluid.
A sphere with a radius of 0.3 m would have a volume of $\frac{4}{3}\pi(0.3m)^3 = 0.1m^3$
This implies that it would displace $\rho_{H_2O} V_{sphere} = 113\ kg$ *of water which weighs* 1100 Nt.
Assuming that the weight of the ball is negligable then this is, in fact, the Bouyant force.

Fluids

The last two ideas refer to systems that are changing. This is fluid *dynamics* as opposed to statics indicated above.

The first is the Continuity relation:



$$mass\ flow\ rate = \rho Q = \rho A v$$

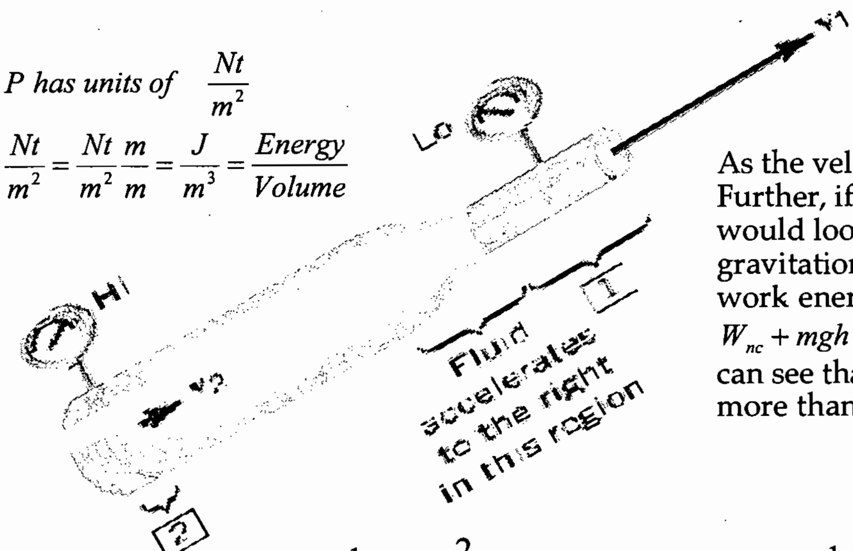
$$continuity: \quad \rho Q_1 = \rho Q_2$$

All this says is that if a tube gets smaller then the velocity of a fluid has to increase inversely proportional to area of the tube it flows through. Smaller diameter tube means faster flow because more stuff has to go through in a unit time. If you have watched a stream that narrows you have witnessed this phenomenon. Next time squeeze the end of a hoe and note how the velocity of the spray increases.

The final equation is the grand mother of them all. Bernoulli's equation which is, really, nothing more than the conservation of energy in a new cloak.

P has units of $\frac{Nt}{m^2}$

$$\frac{Nt}{m^2} = \frac{Nt}{m^2}\frac{m}{m} = \frac{J}{m^3} = \frac{Energy}{Volume}$$



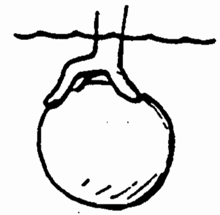
As the velocity increases the pressure drops. Further, if the tube were to travel up a hill we would loose pressure because of the change in gravitational potential. By examining the simple work energy relation $W_{nc} + mgh + \frac{1}{2}mv^2 = E$ and divide by the volume we can see that the "internal" energy density is nothing more than the pressure.

$$P_1 + \tfrac{1}{2}\rho v_1^{\,2} + \rho g y_1 = P_2 + \tfrac{1}{2}\rho v_2^{\,2} + \rho g y_2$$

So, if you know the change in the diameter of a pipe and the "head" or distance it rises or falls, you can calculate the change in pressure. Just writeout what you know and solve for what you don't.

FLUIDS REVIEW

1 1. About how much force would you have to exert to hold a one-cubic foot beach ball under the water?
a) 32 lb b) 64 lb c) 128 lb

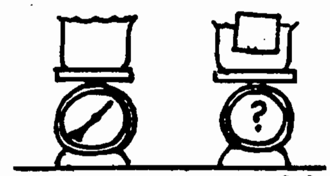


2 2. A cubic-foot block of solid balsa wood floats on water while a solid cubic-foot block of iron lies submerged in water. The buoyant force is greatest on the
a) wood b) iron c) . . . is the same on each

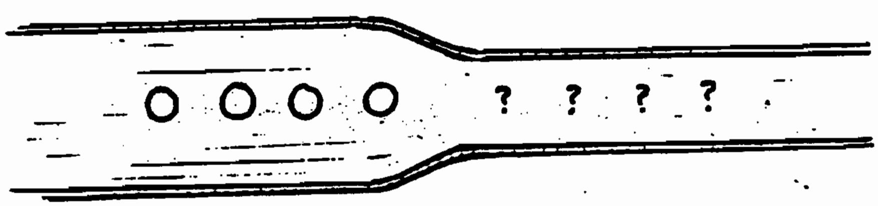
3 3. A boat loaded with scrap iron floats in a swimming pool. If the iron is thrown overboard into the pool, the water level at the side of the pool will
a) rise b) fall c) remain unchanged

4 4. If a ship in a closed canal lock springs a leak and sinks, the water level at the side of the canal lock will
a) rise b) fall c) remain unchanged

5 7. A pair of identical containers are filled to the brim with water. One has a piece of wood floating in it, so its total weight is
a) greater b) less c) the same as the other container



6 11. Little air bubbles are carried along in water that is flowing through a pipe of varying cross sections. As the bubbles flow through a narrow section of the pipe, the size of the bubbles will
a) increase b) decrease c) remain unchanged



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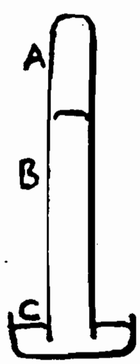


If a barometer tube were made of very thin glass, the pressures that normally act on it would be most likely to break it at
a) A b) B c) C d) no particular location

8 What is the net upward force on an airplane wing of area 20 m^2 if the speed of flow is 300 m/s across the top of the wing and 280 m/s across the bottom?

9. A sample of an unknown material weighs 300 N in air and 200 N when immersed in alcohol of specific gravity 0.70. What are (a) the volume and (b) the density of the material?

10. Piston 1 in Figure 9.37 has a diameter of 0.25 in.; piston 2 has a diameter of 1.5 in. In the absence of friction, determine the force, F, necessary to support the 500-lb weight.

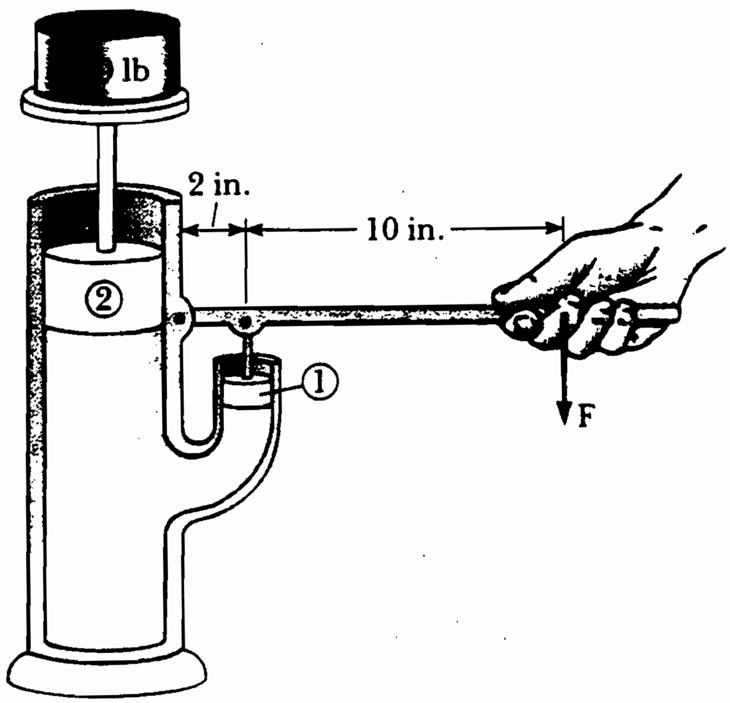


FIGURE 9.37 (Problem 10)

11. The inside diameters of the larger portions of the horizontal pipe in Figure 9.47 are 2.5 cm. Water flows to the right at a rate of 1.8×10^{-4} m^3/s. Determine the inside diameter of the constriction.

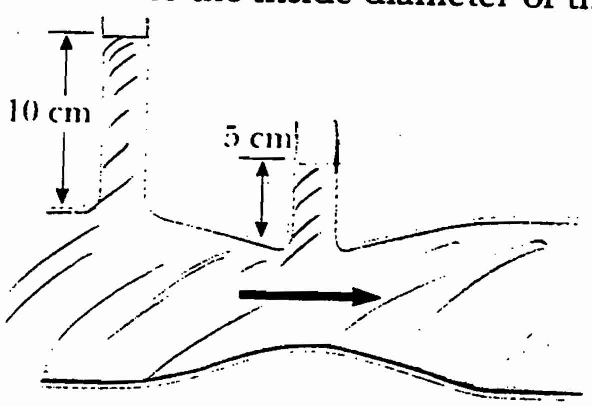


FIGURE 9.47 (Problem 11)

1) B Force = weight of water displaced

$= (\rho g) V = \left(9800\frac{N}{m^3}\right)(1 ft^3)$ use conversion key on TI-86 if you have one.

$1 ft^3 = .0283\ m^3$

$F = 62.38\ lb$

$1 N = .2248\ lb$

2) B Buoyant force = weight of water displaced. all of the iron displaces water but only part of the balsa wood displaces water.

3) B Floating boat displaces water equivalent to mass. when submerged, water displaced is equivalent to volume.

4) B Same as above.

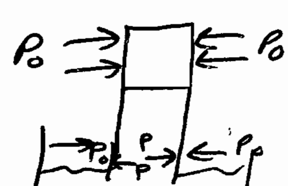
5) C Weight of water displaced equals the weight of the wood.

6) A Speed of flow increases in narrow section, and pressure decreases so bubbles will expand.

7) A ~~Pressure is greater deeper in a fluid.~~

VACUUM AT TOP, NOTHING PUSHING OUT AGAINST P_0

GREATEST ΔP



8) $\Delta \rho g h = 0$ so $\Delta \frac{1}{2}\rho v^2 = \Delta P$ (Bernoulli's Eq.)

$$\frac{1}{2}\, 1.29 \frac{kg}{m^3}\left((300\,m/s)^2 - (280\,m/s)^2\right) = \Delta P$$

$$7480 \frac{N}{m^2} = \Delta P$$

$$F_{net} = \Delta P \cdot A = 7480 \frac{N}{m^2} \times 20\,m^2$$
$$= 149{,}600\,N$$

$$\boxed{F = 150{,}000\,N}$$

9) Buoyant force = weight of displaced fluid

$$100\,N = \rho g V = sp.gravity \times \rho_{water}\, g\, V$$
$$100\,N = 700\frac{kg}{m^3} \times 9.8\frac{N}{kg}\, V$$
$$V = .0146\,m^3$$

$$\rho = \frac{m}{V} = \frac{F_G/g}{V}$$

$$\boxed{\rho = \frac{300/9.8}{.0146} = 2100\frac{kg}{m^3}}$$

10) $\Delta P_2 = \Delta P_1$

$$\frac{F_2}{A_2} = \frac{F_1}{A_1};\quad \frac{500\,lb}{\frac{\pi}{4}(1.5\,in)^2} = \frac{F_1}{\frac{\pi}{4}(.25\,in)^2};\quad F_1 = 13.9\,lb$$

$$\tau_1 = \tau_{Hand};\quad 13.9\,lb \times 2\,in = F_{Hand} \times 12\,in$$

$$\boxed{F_{Hand} = 2.3\,lb}$$

11) $\frac{\Delta Volume}{t}_{Left} = \frac{\Delta Volume}{t}_{Right}$

$$A v_{Left} = A v_{Right} = 1.8 \times 10^{-4}\, m^3/s$$

$$\frac{\pi}{4}(.025)^2 \cdot v_{Left} = 1.8 \times 10^{-4}\, m^3/s$$

$$v_{..} = .367\,m/s$$

$$\Delta P = \rho g \Delta h = \Delta \frac{1}{2}\rho v^2$$

$$9.8 \times .05 = \frac{1}{2}\left(v_{Right}^2 - .367^2\right)$$

$$v_{Right} = 1.06\,m/s$$

$$A_L v_L = A_R v_R;\quad \frac{\pi}{4}(.025)^2 \times .367 = \frac{\pi}{4} d^2 \times 1.06\,m/s$$

Fluids

A force of 250 N is applied to a hydraulic jack piston that is 0.01 m in diameter. If the piston which supports the load has a diameter of 0.10 m, approximately how much mass can be lifted by the Ignore any difference in height between the pistons. *Ans: 2550 kg*

A balloon inflated with helium gas (density = 0.2 kg/m3) has a volume of 6 × 10—3 m3. If the density of air is 1.3 kg/m3, what is the buoyant force exerted on the balloon? *Ans: 0.08 N*

An object weighs 15 N in air and 13 N when submerged in water. Determine the density of the object. *Ans: 7.5×10^3 kg/m3*

The density of the liquid flowing through the horizontal pipe in the drawing is 1500 kg/m3. The speed of the fluid at point A is 5.5 m/s while at point B it is 8.0 m/s. What is the difference in pressure, P_B — P_A, between points B and A? *Ans: —2.5×10^4 Pa*