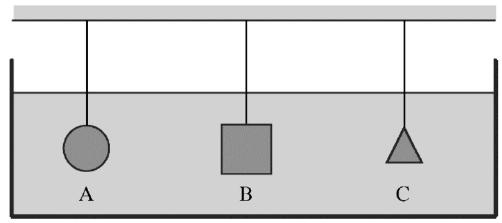
AP Physics B Problems - Fluids

Work the following problems on your own paper using standard problem solving format.

1. 2009 - 5

Three objects of identical mass attached to strings are suspended in a large tank of liquid, as shown to the right.



(a) Must all three strings have the same tension?

____ Yes ____ No

Justify your answer.

Object A has a volume of 1.0×10^{-5} m^3 and a density of 1300 kg/m^3. The tension in the string to which object A is attached is 0.0098 N.

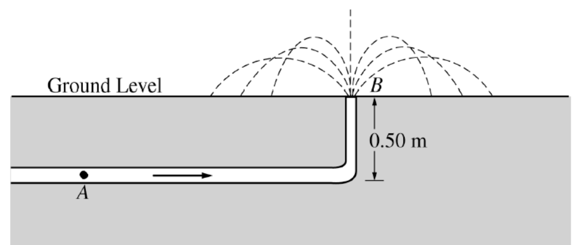
(b) Calculate the buoyant force on object A.

(c) Calculate the density of the liquid.

(d) Some of the liquid is now drained from the tank until only half of the volume of object A is submerged. Would the tension in the string to which object A is attached increase, decrease, or remain the same?

____ Increase ____ Decrease ____ Remain the same

Justify your answer.



2. 2009b - 3

An underground pipe carries water of density 1000 kg/m^3 to a fountain at ground level, as shown above. At point A, 0.50 m below ground level, the pipe has a cross-sectional area of 1.0×10^{-4} m^2. At ground level, the pipe has a cross-sectional area of 0.50×10^{-4} m^2. The water leaves the pipe at point B at a speed of 8.2 m/s.

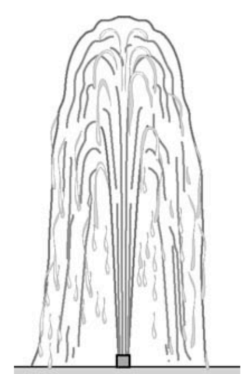
(a) Calculate the speed of the water in the pipe at point A.

(b) Calculate the absolute water pressure in the pipe at point A.

(c) Calculate the maximum height above the ground that the water reaches upon leaving the pipe vertically at ground level, assuming air resistance is negligible.

(d) Calculate the horizontal distance from the pipe that is reached by water exiting the pipe at 60° from the level ground, assuming air resistance is negligible.

3. 2008b - 4



A fountain with an opening of radius 0.015 m shoots a stream of water vertically from ground level at 6.0 m/s .

The density of water is 1000 kg/m^3 .

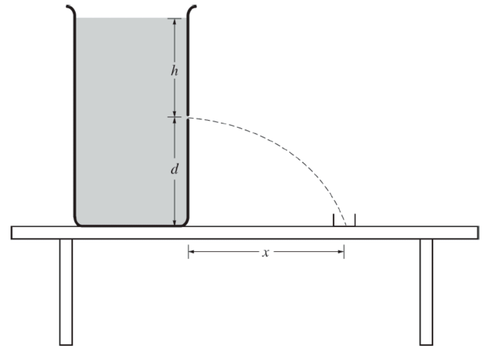
(a) Calculate the volume rate of flow of water.

(b) The fountain is fed by a pipe that at one point has a radius of 0.025 m and is 2.5 m below the fountain's opening. Calculate the absolute pressure in the pipe at this point.

(c) The fountain owner wants to launch the water 4.0 m into the air with the same volume flow rate. A nozzle can be attached to change the size of the opening. Calculate the radius needed on this new nozzle.

4. 2007 - 4

The large container shown in the cross section to the right is filled with a liquid of density 1.1×10^3 kg/m^3. A small hole of area 2.5×10^{-6} m^2 is opened in the side of the container a distance h below the liquid surface, which allows a stream of liquid to flow through the hole and into a beaker placed to the right of the container. At the same time, liquid is also added to the container at an appropriate rate so that h remains constant. The amount of liquid collected in the beaker in 2.0 minutes is 7.2×10^{-4} m^3.



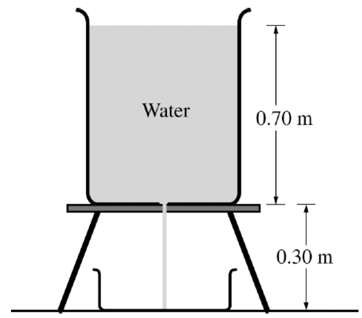
(a) Calculate the volume rate of flow of liquid from the hole in m^3/s.
(b) Calculate the speed of the liquid as it exits from the hole.
(c) Calculate the height h of liquid needed above the hole to cause the speed your determined in part (b).
(d) Suppose that there is now less liquid in the container so the the height h is reduced to h/2. In relation to the beaker, where will the liquid hit the table top

____ Left of the beaker ____ In the beaker ____ Right of the beaker

Justify your answer.

5. 2007b - 4

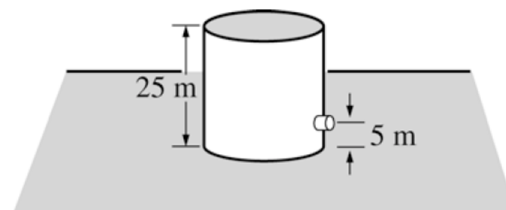
A cylindrical tank containing water of density 1000 kg/m^3 is filled to a height of 0.70 m and placed on a stand as shown in the cross section to the right. A hole of radius 0.0010 m in the bottom of the tank is opened. Water then flows through the hole and through an opening in the stand and is collected in a tray 0.30 m below the hole. At the same time, water is added to the tank at an appropriate rate so that the water level in the tank remains constant.



(a) Calculate the speed at which the water flows out from the hole.
(b) Calculate the volume rate at which water flows out from the hole.
(c) Calculate the volume of water collected in the tray in t = 2.0 minutes.
(d) Calculate the time it takes for a given droplet of water to fall 0.25 m from the hole.

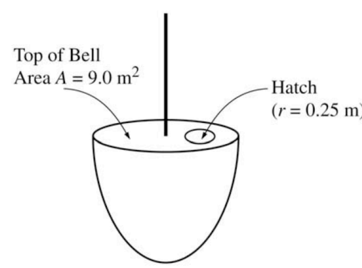
6. 2005b - 5

A large tank, 25 m in height and open at the top, is completely filled with saltwater (density = 1025 kg/m^3). A small drain plug with a cross-sectional area of 4.0×10^{-5} m^2 is located 5.0 m from the bottom of the tank. The plug breaks loose from the tank, and water flows from the drain.



(a) Calculate the force exerted by the water on the plug before the plug breaks free.
(b) Calculate the speed of the water as it leaves the hole in the side of the tank.
(c) Calculate the volume flow rate of the water from the hole.

7. 2004b - 2



The experimental diving bell shown to the right is lowered from rest at the ocean's surface and reacher a maximum depth of 80 m. Initially it accelerates downward at a rate of 0.10 m/s^2 until it reaches a speed of 2.0 m/s, which then remains constant. During the descent, the pressure inside the bell remains constant at 1 atmosphere. The top of the bell has a cross-sectional area A = 9.0 m^2. The density of seawater is 1025 kg/m^3.

(a) Calculate the total time it takes the bell to reach the maximum depth of 80 m.
(b) Calculate the weight of the water on the top of the bell when it is at the maximum depth.
(c) Calculate the absolute pressure on the top of the bell at the maximum depths

On the top of the bell there is a circular hatch of radius r = 0.25 m

(d) Calculate the minimum force necessary to lift open the hatch of the bell at the maximum depth.
(e) What could you do to reduce the force necessary to open the hatch at this depth? Justify your answer.

8. 2003 – 6

A diver descends from a salvage ship to the ocean floor at a depth of 35 m below the surface. The density of ocean water is 1.025×10^3 kg/m^3.

(a) Calculate the gauge pressure on the diver on the ocean floor.

(b) Calculate the absolute pressure on the diver on the ocean floor.

The diver finds a rectangular aluminum plate having dimensions 1.0 m × 2.0 m × 0.03 m. A hoisting cable is lowered from the ship and the diver connects it to the plate. The denisty of aluminum is 2.7×10^3 kg/m^3. Ignore the effects of viscosity

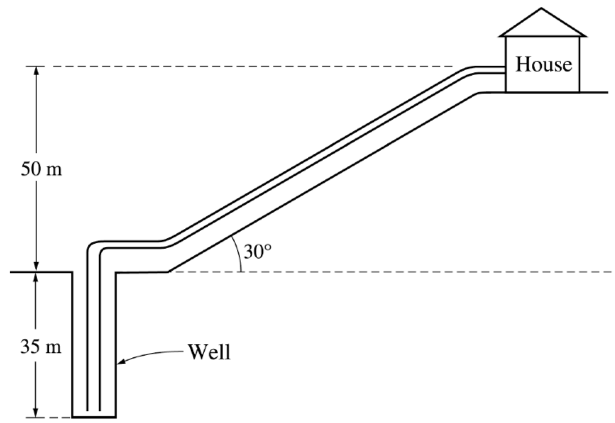
(c) Calculate the tension in the cable if it lifts the plate upward at a slow, constant velocity.

(d) Will the tension in the hoisting cable increase, decrease, or remain the same if the plate accelerates upward at 0.05 m/s^2?

____ increase ____ decrease ____ remain the same

Explain your reasoning.

9. 2003b – 6



A pump, submerged at the bottom of a well that is 35 m deep, is used to pump water uphill to a house that is 50 m above the top of the well, as shown to the right. The density of water is 1000 kg/m^3. All pressures are gauge pressures. Neglect the effects of friction, turbulence, and viscosity.

(a) Residents of the house use 0.35 m^3 of water per day. The day's pumping is completed in 2 hours during the day.

i. Calculate the minimum work required to pump the water used per day.

ii. Calculate the minimum power rating of the pump.

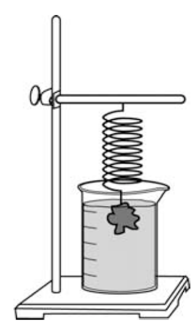
(b) The average pressure the pump actually produces is 9.20×10^5 N/m^2. Within the well the water flows at 0.50 m/s and the pipe has a diameter of 3.0 cm. At the house the pipe diameter is 1.25 cm.

i. Calculate the flow velocity when a faucet in the house is open.

ii. Explain how you would calculate the minimum pressure at the faucet.

10. 2002 – 7

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.

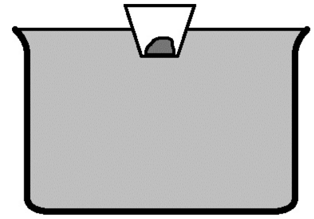
(b) The spring-object system is now arranged so that the object (but none of the spring) is immersed in the unknown fluid as shown to the right. Describe any changes that are observed in the spring-object system and explain why they occur.

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

(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.

Symbol	Physical Quantity

11. 2010 – 2



A large pan is filled to the top with oil of density ρ_O. A plastic cup of mass m_C, containing a sample of known mass m_S, is placed in the oil so that the cup and sample float, as shown above. The oil that overflows from the pan is collected, and its volume is measured. The procedure is repeated with a variety of samples of different mass, and the pan is refilled each time.

(a) On the dot below that represents the cup-sample system, draw and label the forces (not components) that act on the system when it is floating on the surface of the oil.

(b) Derive an expression for the overflow volume V_O (the volume of oil that overflows due to the floating system) in terms of ρ_O, m_S, m_C, and fundamental constants. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

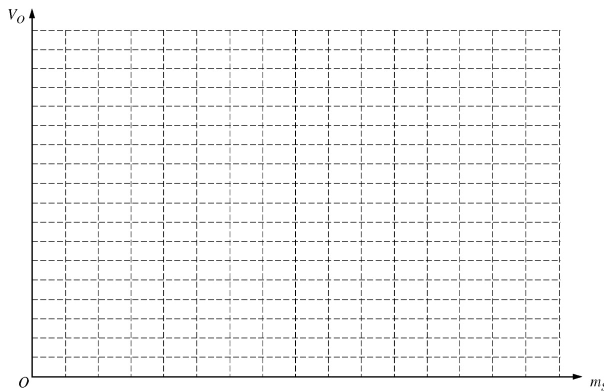
Assume that the following data are obtained for the overflow volume V_O for several sample masses m_S.

Sample mass m_S (kg)	0.020	0.030	0.040	0.050	0.060	0.070
Overflow volume V_O (m^3)	29×10^{-6}	38×10^{-6}	54×10^{-6}	62×10^{-6}	76×10^{-6}	84×10^{-6}

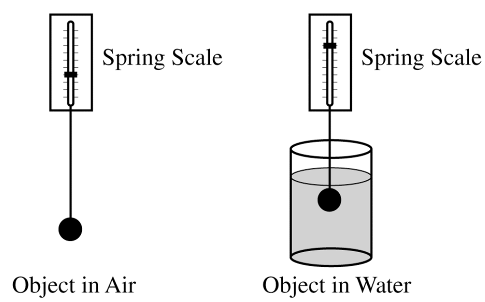
(c) Graph the data on the axes below, plotting the overflow volume as a function of sample mass. Place numbers and units on both axes. Draw a straight line that best represents the data.

(d) Use the slope of the best-fit line to calculate the density of the oil.

(e) What is the physical significance of the intercept of your line with the vertical axis?



12. 2010b – 6



An object is suspended from a spring scale first in air, then in water, as shown in the figure above. The spring scale reading in air is 17.8 N, and the spring scale reading when the object is completely submerged in water is 16.2 N. The density of water is 1000 kg/m^3 .

(a) Calculate the buoyant force on the object when it is in the water.

(b) Calculate the volume of the object.

(c) Calculate the density of the object.

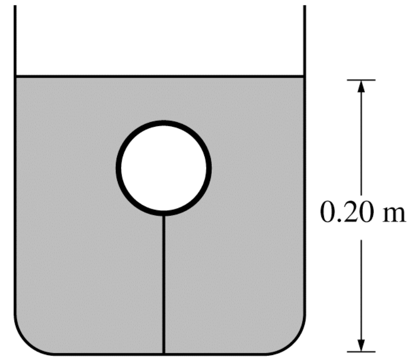
(d) How would the absolute pressure at the bottom of the water change if the object was removed?

___ It would increase. ___ It would decrease ___ It would remain the same.

Justify your answer.

13. 2011 – 4

A beaker weighing 2.0 N is filled with 5.0×10^{-3} m^3 of water. A rubber ball weighing 3.0 N is held entirely underwater by a massless string attached to the bottom of the beaker, as represented in the figure above. The tension in the string is 4.0 N. The water fills the beaker to a depth of 0.20 m. Water has a density of 1000 kg/m^3 . The effects of atmospheric pressure may be neglected.



Note: Figure not drawn to scale.

(a) Calculate the weight of the entire apparatus.

(b) On the dot below that represents the ball, draw and label the forces (not components) that act on the ball.

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(c) Calculate the buoyant force exerted on the ball by the water. If you need to draw anything other than what you have shown in part (b) to assist in your solution, use the space below. Do NOT add anything to the figure in part (b).

(d) Calculate the pressure due to the liquid (the gauge pressure) at the bottom of the beaker.

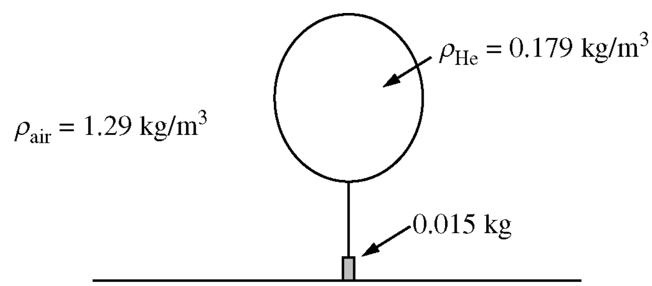
(e) The string is cut, and the ball rises to the surface and floats. Indicate whether the water level is higher, lower, or the same after equilibrium is reached.

____ Higher ____ Lower ____ The same

Justify your answer.

14. 2011b – 4

A helium-filled balloon is attached by a string of negligible mass to a small 0.015 kg object that is just heavy enough to keep the balloon from rising. The total mass of the balloon, including the helium, is 0.0050 kg. The density of air is ρ_{air} = 1.29 kg/m , and the density of helium is ρ_{He} = 0.179 kg/m . The buoyant force on the 0.015 kg object is small enough to be negligible.



(a) On the dot below that represents the balloon, draw and label the forces (not components) that act on the balloon.

•

(b) Calculate the buoyant force on the balloon. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

(c) Calculate the volume of the balloon.

(d) A child holds the string midway between the balloon and the 0.015 kg object. The child gets into a car, brings the balloon and the 0.015 kg object into the car, and holds the string so that neither the balloon nor the 0.015 kg object touches any surface. The car then begins to move forward, accelerating in a straight line.

What behavior does the 0.015 kg object exhibit when the car accelerates?

_____ It swings toward the front of the car.

_____ It swings toward the back of the car.

_____ It swings toward the right side of the car.

_____ It swings toward the left side of the car.

_____ It remains vertical below the child’s hand.

Explain your reasoning.

Answers to AP Physics B Fluids questions

1. a. No, justification b. 0.12 N c. 1200 kg/m^3 d. increases, justification
2. a. 4.1 m/s b. 1.3×10^5 N/m^2 c. 3.4 m d. 5.9 m
3. a. 4.2×10^{-3} m^3/s b. 1.4×10^5 N/m^2 c. 1.2×10^{-2} m
4. a. 6.0×10^{-6} m^3/s b. 2.4 m/s c. 0.29 m d. left of the beaker, explanation
5. a. 3.7 m/s b. 1.2×10^{-5} m^3/s c. 1.4×10^{-3} m^3 d. 0.062 s
6. a. 12 N b. 20 m/s c. 8.0×10^{-4} m^3/s
7. a. 50 s b. 7.2×10^6 N c. 9.0×10^5 N/m^2 d. 1.6×10^5 N e. student response
8. a. 3.5×10^5 N/m^2 b. 4.5×10^5 N/m^2 c. 1.0×10^3 N d. increase, explanation
9. a. i. 290,000 J ii. 40 W b. i. 2.88 m/s ii. explanation
10. student responses
11. a. force diagram b. $\dfrac{m_c + m_s}{\rho_O}$ c. graph with correct plotting, units, scaling, best-fit line that does <u>not</u> go through the origin. d. 8.8×10^2 kg/m^3 e. explanation that y-intercept represents the volume of oil displaced by the empty cup.
12. a. 1.6 N b. 1.6×10^{-4} kg/m^3 c. 1.1×10^4 kg/m^3 d. decrease, explanation
13. a. 54 N b. force diagram c. 7.0 N d. 1960 Pa e. Lower, justification
14. a. force diagram b. 0.196 N c. 0.0155 m^3 d. toward back of car, explanation