Static Fluids

If it was easy to learn, we wouldn’t offer a course on it, would we?

This past summer and continuing into the school year, I've had an internship with Power Partners Inc. designing transformers. Basically, I'm helping the company cut costs in the design of transformers by trouble shooting problems. It has been awesome.

But as I meant to do a long time ago, here is my review of you as a teacher and of the 3 physics classes I took with you at BSC. I will begin by saying that from Day 1, I never doubted that you were right nor did I think your methods were pointless. But I do wish that I had capitalized in the 3 semesters of physics I had with you. I feel like I really underutilized your information. However, for as little effort I put into your classes, I still think that you gave me some invaluable information. And not just physics knowledge, but also, a knowledge of more efficient learning.

After 2 years now of pure engineering classes, I have really learned your lesson "**DON'T MEMORIZE**". It's possibly the worst thing you can ever do as an engineering major. Not only does memorizing not help you for the big tests, but undergraduate work in engineering (in a way) only aids your problem solving process for a real world job. Memorizing doesn't do anything.

An extension of this lesson, is your idea of **understanding the big picture, rather than the details**. Hopefully after 17 years of school I will finally grasp this concept. I can't describe how much class time I have wasted trying to copy down pointless details, rather than spending time to understand the larger idea. In my internship I have found that engineers are distinguished from everyone else in the factory by their ability to grasp the full concept.

Another thing you introduced to me was the reverse classroom. Because of you, I have started to "learn" the material on my own time and do problems in class. Granted the reverse classroom has been structured for some of my courses, but you were the one to first give me the idea.

The last thing I've taken to heart from you, is that "**people read ENGLISH not numbers**". It's very frustrating to review notes and forget my methods of solving problems. I save myself time in the long run writing notes in the margins of whatever I'm working on so when I return I remember my process way quicker. In my internship, this has been especially true. For every excel spreadsheet I create, I try writing many notes to remind myself of problems to avoid, caution signs, and lengthy explanations of certain data taken. It helps me pickup from where I left off, but also helps my co-workers if they have to view my work. So for every time I groaned at explaining my work in PH 201 Mathematical Tools, I tip a hat to you every time my boss says, "wow Brian you really labeled and explained your work nicely".

Anyway, I guess this email is just a really long thank you letter. You will always be one my best college professors. If your students are reading this on a projector, tell them I said you're awesome and stay enrolled in PH 121, haha.

Deep under the surface of the ocean, the force exerted by water on the window of a submarine is directed

1. downward
2. upward
3. horizontal
4. perpendicular to the window

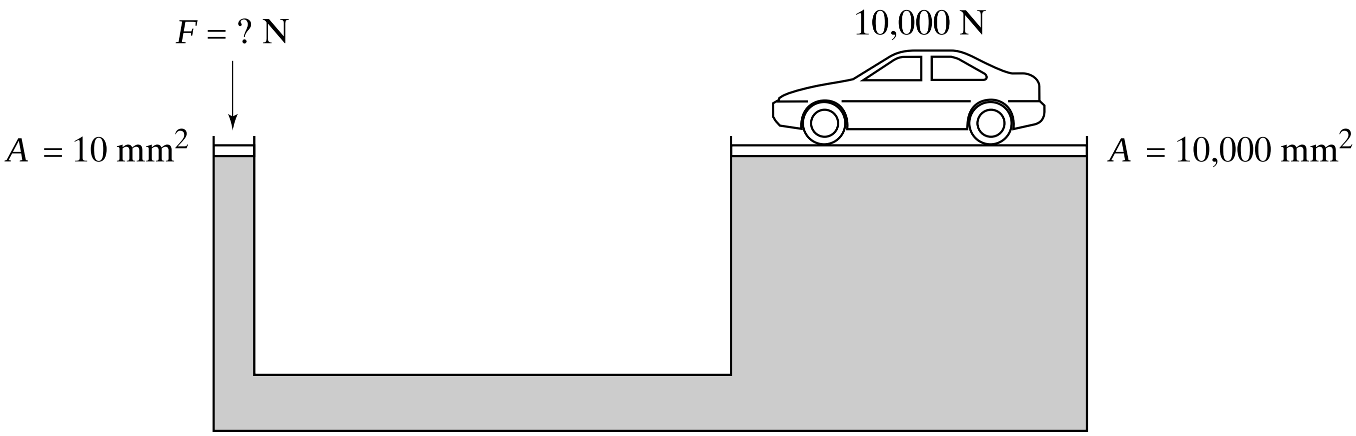
ANS: **4**—The force is perpendicular to the window.

The force on a surface due to fluid pressure is always directed perpendicular to the surface. In fact, since the fluid is all outside the submarine, the force will be directed *inward*, normal to each window.

Your dog stands on a bathroom scale. For some reason, you try to lift the scale with the dog on it. A quick calculation shows that the downward force of the atmosphere on a bathroom scale is about 6 kN (which is roughly 1500 pounds). What is the magnitude of the minimum force you must exert to support the scale with the dog on it?

1. The weight of the dog
2. The weight of the scale
3. The atmospheric force of 6kN
4. The sum of all of the above
5. Just 1 & 2
6. Other

A container is filled with oil and fitted on both ends with pistons. The area of the left piston is 10 mm^2; that of the right piston 10 000 mm^2. What force must be exerted on the left piston to keep the 10 000 N car on the right at the same height?

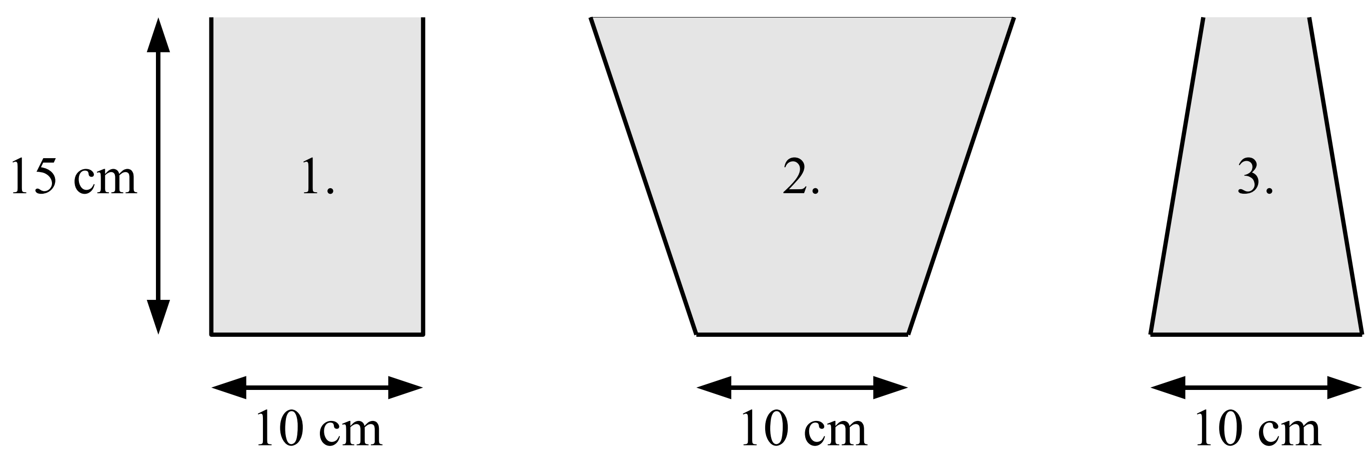


1. 10 N
2. 100 N
3. 10 000 N
4. 10^6 N
5. 10^8 N
6. insufficient information

ANS: **1**—A force of 10 N is required to hold the car.

The two pistons are at the same height in the fluid, so they have the same fluid pressure applied to them. The fluid pressure is the force on the fluid from each piston divided by that piston's cross-sectional area, so $P = F_1/A_1 = F_2/A_2$. The piston on the left is 1000 times smaller than the one on the right, so the force on the left piston will be 1000 times smaller than the force on the right piston (weight) of the car. Therefore, you need to push the left piston with 10N of force.

The three flasks pictured below have identical bases and heights but varied shapes. All bottles are completely filled with water. In which is the total weight of water greatest?

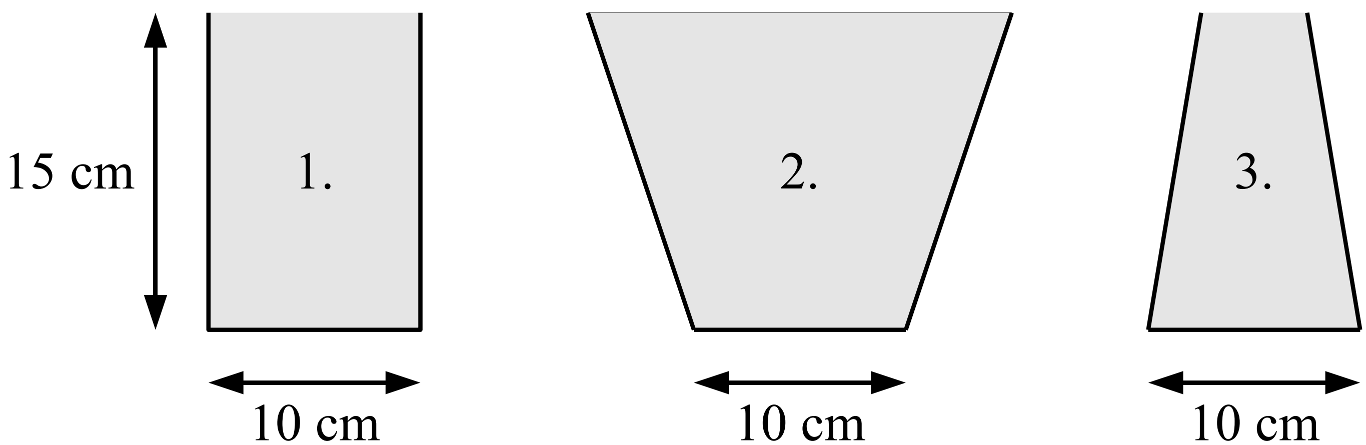


4. They are all the same
5. Need more information

ANS: **2**—The middle flask holds the greatest weight of water.

This is rather straightforward. Because the middle glass is wider (all are equally deep), it holds more water.

The three flasks pictured below have identical bases and heights but varied shapes. All bottles are completely filled with water. In which is the water pressure at the bottom the greatest?



4. They are all the same
5. Need more information

ANS: **4**—The water pressure is the same at the bottom of all three flasks.

The short explanation is that pressure depends only on the depth in the fluid, not the width of the container. The longer explanation involves analyzing forces. In #1, only the base of the glass pushes up on the fluid, with a force equal to the weight of the water in the glass.

In #2, the base and the sides all exert at least some component of force upward on the fluid. In fact, it can be shown that the base exerts a force equal to the weight of the fluid directly above it (the sides exert upward forces equal to the weight of the fluid directly above them). Therefore, the bases of #1 and #2 have the same pressure on them.

Case #3 is a little trickier because the sides actually exert forces on the fluid that have a *downward* component. It can be shown that these downward forces are equal to the weight of the water that would have been above those lines if they weren't there, i.e. if the glass looked like #1. Therefore, all three bases have the same downward force and thus the same pressure on them due to the fluid.

Imagine holding two bricks under water. Brick A is just beneath the surface of the water, while brick B is at a greater depth. The force needed to hold brick B in place is

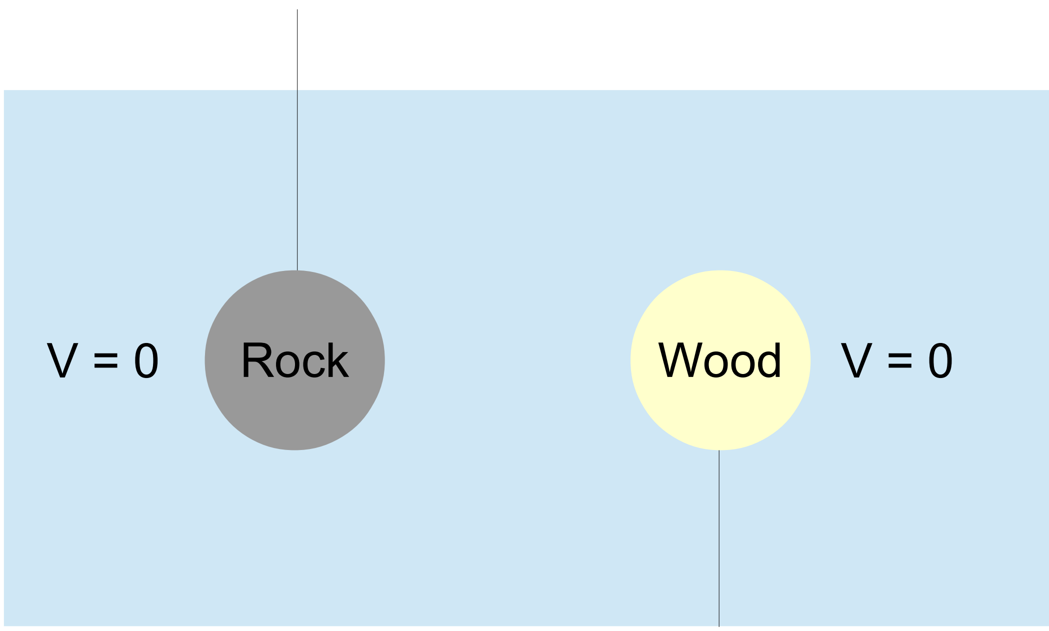
1. larger
2. the same as
3. smaller

than the force required to hold brick A in place.

ANS: **2**—The same force is required to hold both bricks in place.

Fluid pressure increases with depth, but buoyant force, which is due to the difference in fluid pressure on the top and bottom of the brick, will not. The force required to hold the brick up is its weight minus the buoyant force on the brick. This result is true as long as the density of the fluid is constant, a very good assumption for water and oil, but a very poor assumption for gases.

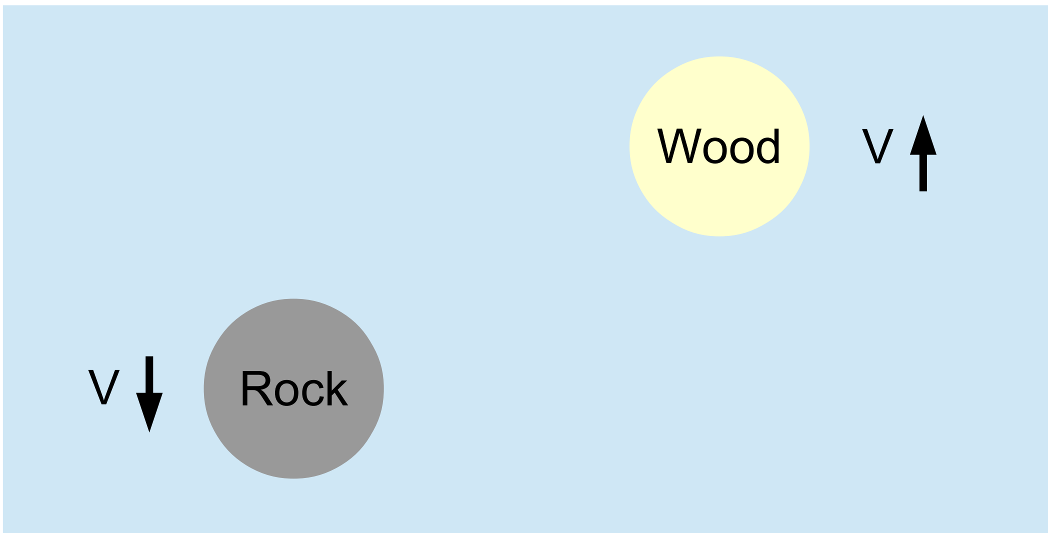
Two spheres of identical volume are completely immersed under water. The first is made of heavy stone and hangs suspended from above a string. The second is made of lightweight wood and is tethered from below by a string.



On which is the buoyancy force larger?

1. The stone sphere
2. The wood sphere
3. The two buoyancy forces are identical
4. It depends on their actual masses

The two strings are now cut, so the stone sphere descends and the wood sphere rises.



While moving but before they reach the surface or the bottom, on which is the buoyancy force larger?

1. The stone sphere
2. The wood sphere
3. The two buoyancy forces are identical
4. It depends on their actual speeds

Two cups are filled to the same level with water. One of the two cups has ice cubes floating in it. Which weighs more?

1. The cup without ice cubes.
2. The cup with ice cubes.
3. The two weigh the same.

ANS: **3**—The two cups weigh the same.

Because the cups have water up to the same level, the cup with the ice cubes in it will have less water in it than the cup with no ice in it. The extra volume that brings the water level up is the portion of the ice cubes' volume that is submerged, i.e. the volume of the displaced water. The weight of this "missing" water is the buoyant force on the ice, equal to the weight of the floating ice. Therefore, we have one cup with weight W, and the other cup with weight $W - W_{\text{missing water}} + W_{\text{ice}} = W$.

Two cups are filled to the same level with water. One of the two cups has ice cubes floating in it. When the ice cubes melt, in which cup is the level of the water higher?

1. The cup without ice cubes.
2. The cup with ice cubes.
3. The two are equally full.

ANS: **3**—The two cups are equally full.

Because the ice floats, the missing water in the ice cup weighs the same as the ice in the cup. As the ice melts, it turns back into water of the same weight, which means the volume of the melted ice is the same as the volume of the missing water.

Put more simply, you have two cups of water that we have previously established weigh the same, so they must have the same volume (mass does not appear or disappear as ice melts).

Warmup Question

The density of water is $1\,\mathrm{g/cm^3}$, by definition of the gram. With careful attention to units, show that descending 10 meters under water increases pressure by approximately one atmosphere, $10^5\,\mathrm{Pa}$. Show your work.

ANS: The pressure of water a depth h in a fluid is $P = \rho g h$ greater than the pressure at the top. The density of water is $1\,\mathrm{g/cm^3} = 1000\,\mathrm{kg/m^3}$, and $g \approx 10\,\mathrm{N/kg}$, so the increased pressure at a depth of $10\,\mathrm{m}$ will be

$$P = (1000\,\mathrm{kg/m^3})(10\,\mathrm{N/kg})(10\,\mathrm{m}) = 10^5\,\mathrm{N/m^2} = 10^5\,\mathrm{Pa}\,.$$

Warmup Question

How is it that ships made of metal float?

1. The metal used is a special alloy that is lighter than water
2. Most of their volume is air
3. Their motion gives an upward thrust, just like an airplane's wings
4. Trick question: metal ships can't float, they're actually made of fiberglass and only look metallic

ANS: **2**—Most of the volume is air.

Whether or not something floats is determined by its density compared to the fluid in which it is immersed. A ship’s hull may be made out of metal, but most of the ship’s volume is comprised of air. The overall density of the ship, its mass divided by its volume, is less than the density of water.