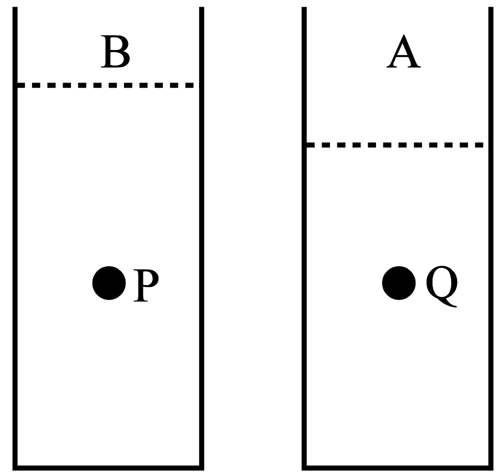
First Name:____________________ Last Name:________________________________

Two otherwise identical beakers are filled with unknown liquids (labeled A and B). Each beaker is open to the atmosphere and the pressure at the bottom of each beaker is the same.



1. You measure the force exerted by each liquid on the bottom of each beaker. Which force is larger or are they the same? Explain your reasoning.

2. Which liquid is more dense or do they have the same density? Explain your reasoning.

3. Which point (P or Q) has a higher pressure or are both pressures the same? Each point is the same distance above the bottom of the beaker. Explain your reasoning.

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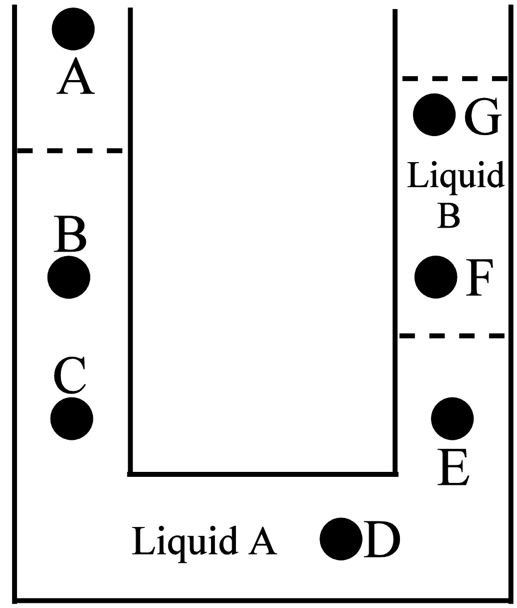
Two different static liquids are in a container as shown. Both sides of the container are open to the atmosphere. You are going to be analyzing the pressure at the seven labeled points. *Don't assume that these are the same liquids as in Questions #1-3.*



4. Is the pressure at point C larger, smaller or the same size as the pressure at point E? Each point is exactly the same distance above the bottom of the container. Explain your reasoning.

5. Which liquid is more dense? How do you know? Explain.

6. Is the pressure at point B larger, smaller or the same size as the pressure at point F? Each point is exactly the same distance above the bottom of the container. Explain your reasoning.

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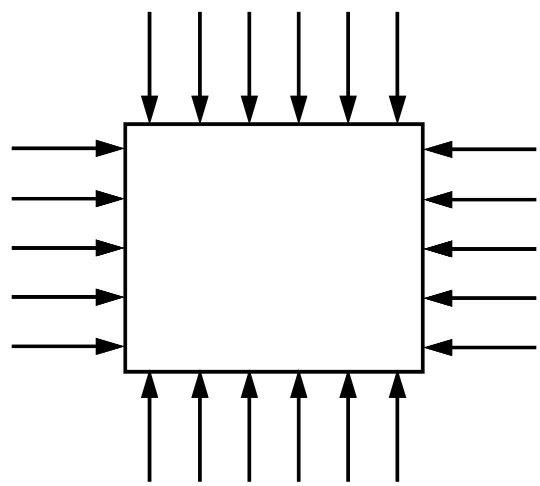
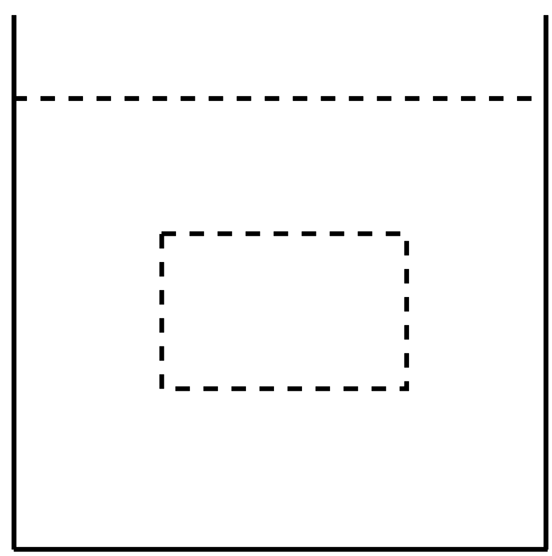
7. Rank, from largest to smallest, the magnitude of the pressure at each point. Explain any additional reasoning beyond what is already explained in Questions #4-5.

Largest Smallest

8. Imagine that you had a rectangular box surrounded by a fluid which exerted equal forces everywhere. You could draw a free body diagram with qualitatively correct vector lengths as is shown on the right. Clearly, this is a two-dimensional representation of what is really three-dimensional.



In most situations, however, the forces (or pressures) will not be the same everywhere. Draw a free body diagram with qualitatively correct vector lengths for the volume of liquid indicated using the dashed lines in the figure below right. Draw this diagram on the rectangle directly below.



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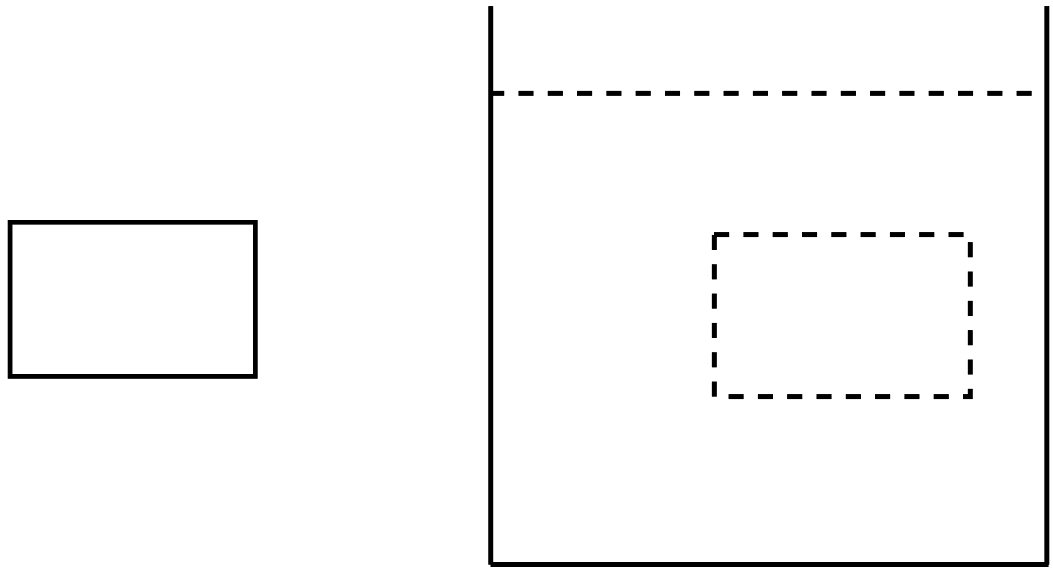
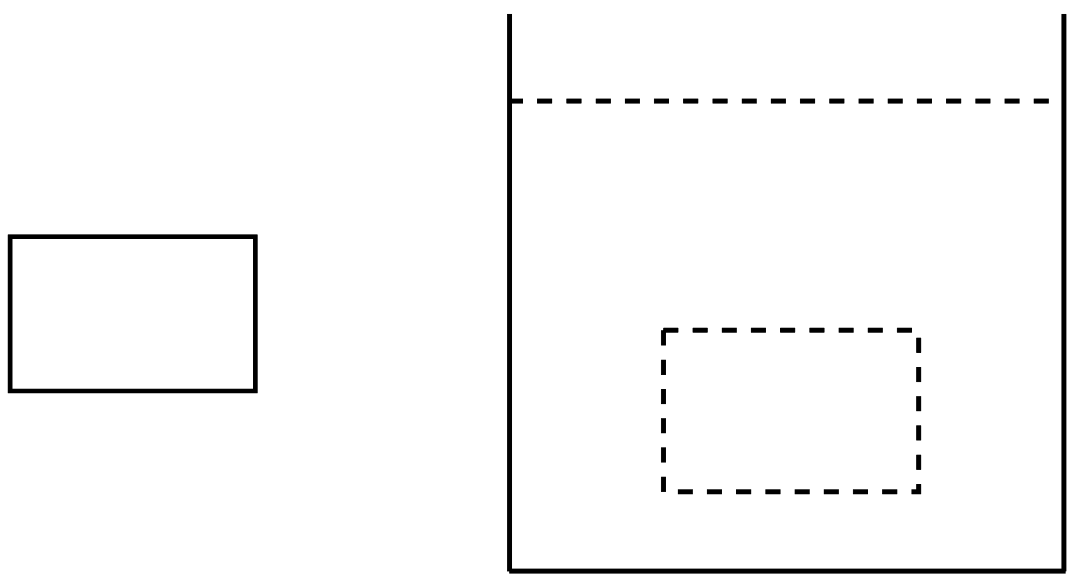
9. How would your free body diagram in Question #8 change if the volume of water you focus on is slighly further right in the beaker (but at the same depth). If the diagram is unchanged, explain why. If it is different, explain why and make a new diagram.



10. How would your free body diagram in Question #8 change if the volume of water you focus on is slighly lower in the beaker (but at the same horizontal location). If the diagram is unchanged, explain why. If it is different, explain why and make a new diagram.



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11. If you add up all the force vectors acting on that section of fluid in the last three questions, you will get what we refer to as the buoyant force that the surrounding fluid exerts on that specific section of fluid. If your compare that buoyant force in questions #8-10, are they all the same size? Are they all different sizes? Or are two the same while the third one is different? Explain.

12. Assume that the beaker in Question #8 is a perfect cube with each side having a length L. Additionally, assume that the beaker is completely full. Determine the force that the liquid exerts on one side of the beaker. You may use ρ for the density of the liquid. Hint: you will need to integrate the pressure over the area to calculate the force. In other words, $F = \int\int p dA$ where the pressure in the integral will be a function of the depth and where $dA = dxdy$.

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Comments about this Tutorial:

This has been used in both algebra-based and calculus-based physics courses. For the algebra-based courses, question 11 should be removed.

Clearly the objective here is to help students understand how the pressure varies in a liquid and how you can use that pressure to calculate forces.

Questions #1-3 and 8-10 were used as part of a 50 minute activity in an algebra-based physics class. Some of the students finished those questions in 15 minutes but others took closer to 30 minutes.

Comments about individual questions:

Question #1: No surprisingly, many thought that the force in picture B was larger since the volume was larger. Some of them also didn't understand what the A in $P = \frac{F}{A}$ meant. It was mixed up with height and volume.

Question #3: A fair number of students sort of got the idea here but their explanations weren't really correct. A common mistake was to say, "Point P is further from the Liquid B surface than Point Q is from the Liquid A surface." A smaller number of students did use words like, "Point P is proportionally closer to the bottom."

Question #7: This ranking task has been used in class many times in the past. Normally, students get all the ranking correct except for the obvious confusion comparing points B and F. However, their explanations of their ranking are usually somewhat vague.

Question #8-10: I can believe that these questions are something most faculty never talk about but I find it useful for them to see how the pressures (or forces) vary with location. You could obviously skip these if you don't want to use them.

Question #8: Perhaps 5-10% of the students were drawing the arrows outward instead of inward. And sometimes they didn't even realize they did it. Generally, at each table one of the students was able to do this so they all eventually got correct diagrams. The one thing to be careful of is for the pressure on the sides near the top to be about the same size as the pressure on the top. Similarly, the pressure on the sides near the bottom should be about the same size as the pressure on the bottom.

Question #9: The majority of the students draw this incorrectly. The most common mistake is for students to have the pressure larger on the left side than on the right side since there is more material on the left side. But some fraction of students had the reverse – I am not entirely sure why. It worked pretty well to just say to them, "if someone showed you this free-body diagram and you had no idea what it was, what would you think is happening to the object?" In almost all cases, the students recognized that there would have been an acceleration.

Question #10: They did pretty well on this.

Question #12: This is clearly too difficult for most classes but is available if someone wants to use it. I would think about using it in an honors class.

Changes made Summer 2017:

Paragraph before Question #4: The last sentence was added.

Question #4: Note that I haven't told them if the two columns have the same area. They look like they do of course but that doesn't influence any of the arguments. You probably will get students talking about the areas. You may need to get students to talk about the mass in a column of unit area instead of talking about the mass in the column which is there.

Question 6: This is new. Most students think that liquid B is less dense either because it was in Question #2 or because it is on top of liquid A. I point out that the higher density liquid could be on top. That would be an unstable equilibrium but an equilibrium nonetheless. I need them to come up with a different reason for why B is less dense.

Thinking about adding a question between #2 and #3: Imagine that the beaker with liquid A had twice the cross-sectional area, how much more or less of liquid A would you need for there still to be the same pressure at the bottom? Explain.

Changes made Fall 2017:

Questions #9 and #10: The diagrams were added since some students were misinterpreting the phrasing of the question.

Question #11: This is new and hasn't been used yet.

Tutorial source(s):

All Questions written by Drew Milsom.

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