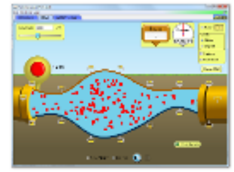
Bernoulli's Continuity of Fluid Pressure PhET Lab *(TWO DAYS)*

Introduction:

We've all put our thumbs over a hose to get that extra *oomph* out of a garden hose. Why does the water speed up? Why do some towns have water towers, giant tanks of water suspended high above the town? Why does your face turn red when you do a handstand? This simulation will help you answer these and other important questions about fluids and pressure.



Fluid Pressure and Flow

Critical to the understanding of fluids and pressure is the idea that **liquids are incompressible**, that is, that you can't get them to squish and compress like a gas. In other words, when liquids move, **the same amount goes in as comes out**. This principle was an important part of Daniel Bernoulli's work into *fluid dynamics*, how a fluid changes (or doesn't change) as it moves. The individual parts of the formulas related to the *continuity* of fluid flow can be summarized in what many of us call ***Bernoulli's Equations***:

$$P_1 + \tfrac{1}{2}\rho v_1^{\,2} + \rho g h_1 = P_2 + \tfrac{1}{2}\rho v_2^{\,2} + \rho g h_2 \qquad A_1 v_1 = A_2 v_2$$

Please take some time to define the each of the variables present in the above equations:

P ____ units of: ________________

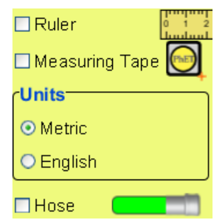
ρ (rho) ____ units of: ________________

v ____ units of: ___________

g ____ units of: ___________

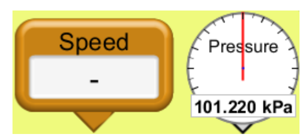
h ____ units of: ___________

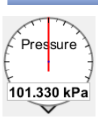
A ____ units of: ___________



Procedure: *PHET Simulations → Play With Sims → Physics → Fluid Pressure and Flow*

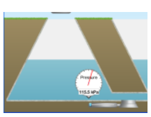
- Take some time and play with the simulation. Answer the questions below as you play. Learn how to use the toolkit on the left; these tools will be very useful in this simulation.





As the sensor is moved **deeper** into the liquid, how does the pressure change? ____________________________
____

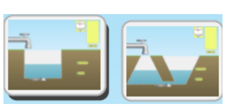
As **more liquid** is added, how does the pressure near the **bottom of the tank** change? ____________________



Why does the pressure change as the sensor is moved up and down in the air above the liquid? __________
____

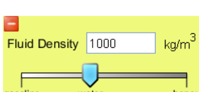
How does the pressure in the water change when the atmosphere is removed? ____________________

Why is this? ____

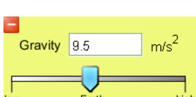


Does the **shape** of the tank play a role in the pressure under the surface? ____________________

Why do you suppose this is? ____



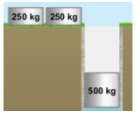
How does the **density** of the fluid relate to the pressure it exerts? ____________________
____



How does increasing **gravity** change the pressure in the fluid?______________________________

Why do you think this is? ____

At normal Earth gravity (9.8 m/s^2), how does pressure (in Pascals, Pa) change for each meter of water depth? ___________Pa
To what **depth** would you have to swim to experience another "atmosphere" (+101000 Pa)? ____________m



Why does adding a **floating mass** appear to change the pressure of the liquid? ____________________________

What is the floating mass changing? ____

What effect does changing the density of the liquid have on the **buoyant force** applied on the floating mass?

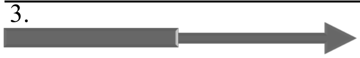
____

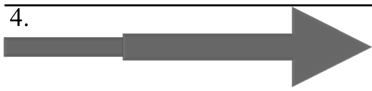
Flow

Imagine the following as pipes carrying water. How would the speed and pressure of the water **in the center of the pipe** change as it moves from left to right? **Speed?** **Pressure?**

1. 

2. 

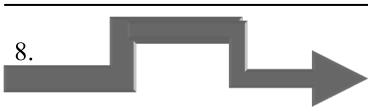
3. 

4. 

5. 

6. 

7. 

8. 

How does **flow rate** (volume per second) change as a pipe becomes smaller (as in #3)? ______________________________

How does the **flow rate** (volume per second) change as a pipe rises (as in #2)? ____________________________________

Explain your answers to the two questions above. ____

If one trillion water molecules are added to one end of a filled garden hose, what happens at the other end of the garden hose?

____

As fluid **density** increases, the fluid speed (*increases / decrease / remains the same*) and the pressure (*increases / decreases remains the same*). Explain your answers. ____

Imagine two identical houses, one at the top of a hill and one at the bottom of a valley. In which one would you rather take a shower? ___________________ Why? ____

Shower pipes in newer houses have smaller diameters than those in older houses. Why do you suppose this is? ____________

____

Using the formulas on the front page, calculate this: water flows horizontally through a garden hose with an inner diameter of .012 m at a speed of 7.8 m/s. It exits out a small nozzle with a diameter of only 0.0085 m. How fast it is travelling out of the nozzle? _____________________ m/s

Kinematics formulas you may use:

$$d = \bar{v}t \qquad v = \bar{a}t \qquad d = \tfrac{1}{2}at^2 \qquad d = v_o t + \tfrac{1}{2}at^2 \qquad v_f^{\,2} = v_i^{\,2} + 2ad$$

Water Tower

In this simulation, water is allowed to flow out of a hole at the bottom of a tall water tower. Play with the simulation and use the tools provided before answering the questions below. When allowing fluid out, assume tank is **FILLED**.

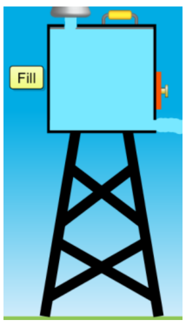
Does the speed of the flow of the water (out of the tank) depend upon the height of the tank? _______________

Why do you suppose this is? ____

Does the speed of the flow depend upon the fluid density? ____

What does flow speed depend upon? ____

Explain this relationship (in your own words). ____



What happens to the stream of fluid after it leaves the tank? ____________________________________

Describe the path of the fluid steam. ____

Does it remind you of anything you have seen before (in physics, not in the bathroom)? _________________

What does it remind you of? ____

How far (horizontally) will a steam of water travel if it exists the water tower at 14 m/s 10m above the ground? ____

How far do you suppose a baseball will travel if thrown horizontally 14 m/s from the top of a 10m-high ladder? ___________

Turn on the **hose** and leave it aimed directly upward. Adjust the other pieces of the simulation. What do you notice about the height of the little fountain created?

____

When you have your blood pressure monitored, the nurse places the cuff on your arm, just below the shoulder. Why do you suppose this is? ____

What organ is s/he really measuring? ____

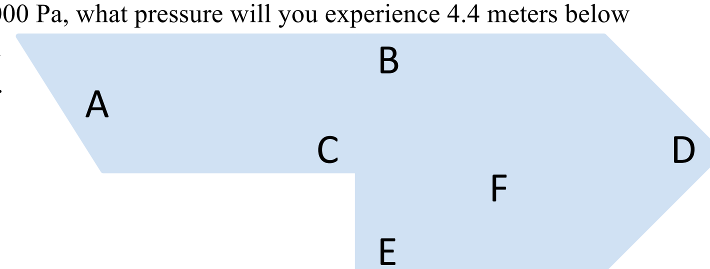
The height difference between the top of the tower and the leaking hole is 10 m. Using the Bernoulli's big ol' continuity formula, to what depth would the tower need to be filled to produce a stream leaving the hole at 8.0 m/s? _______________

As the stream falls it gains speed. Why is this? ____

<u>**Conclusion Questions and** Calculations</u> *(please attach scratch paper with your calculations when appropriate)*

Static Pressure at Depth

1. Does air produce a pressure? (*Yes, air is a fluid.* / *No. Air is not dense enough to exert pressure*)
2. As I swim deeper in a pool, the pressure on me (*increases* / *decreases*).
3. If I replaced all the water in my swimming pool with honey, the pressure at the bottom of the pool would (*increase* / *decrease*).
4. If the pressure at San Francisco's Pier 39 (sea level) is 101kPa, you would expect the pressure at Las Vegas' strip (620 m or 2030 ft above sea level) to be (*higher than 101kPa* / *the same 101kPA* / *lower than 101kPa*)
5. For every meter of depth in water (density = 1000 kg/m^3) what is the increase in pressure? ________________ Pa
6. If the pressure above the surface of a swimming pool is 101000 Pa, what pressure will you experience 4.4 meters below the surface? ____________________ Pa
7. Consider the diagram here of a weird sort of swimming pool.
   Pressure is greatest at __________
   Pressure is least at __________
   Two points where pressure is the same __________



Flowing Fluids (horizontally)

8. If 40 L of water enter a garden hose each minute, we would expect how much water to exit the hose each second? ________
9. When water flows *downhill* as in (Flow Arrow #1), we expect the pressure to (*increase / decrease / remain the same*).
10. As a hose's cross sectional area becomes smaller (hose being squished) we would expect the **pressure of the fluid** at the squish to (*increase / decrease / remain the same*).
11. As a hose's cross sectional area becomes smaller (hose being squished) we would expect the **speed of the fluid** at the squish to (*increase / decrease / remain the same*).
12. As a hose's cross sectional area becomes smaller (hose being squished) we would expect the **flow rate** (volume per second) at the squish to (*increase / decrease / remain the same).*
13. If we replace the water in our hypothetical hose with honey and using the same flow rate as before, we would expect the **pressure** to (*increase / decrease / remain the same).* (ignore friction/viscosity)
14. The speed of the more-dense honey, compared to the water in the same hose would be (*faster / slower / the same speed*).
15. Imagine water flowing in a stream with a diameter of 1.5m at a speed of 6.8 m/s. If a rock blocked half of the stream, how fast would the water flow around the rock?

    ____________________m/s
16. If the stream (back to its 1.5m diameter and 6.8 m/s speed) flowed downhill 18 meters, how fast would we expect it to flow?

    ____________________m/s

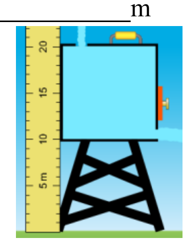
Flowing Fluids (as projectiles)

17. Are fluids (liquids and gasses) affected by gravity? (*Yes, even air gets pulled down by gravity / No. Air is not dense enough to be affected by gravity*)
18. Remembering your kinematics of projectiles…A baseball is thrown horizontally a 25 m/s from the top of a 5m-high tower. How far does it travel?

    ____________________m
19. If a stream of water exits a water tower horizontally with a speed of 25 m/s 5m above the ground, we would expect it to travel how far?

    ____________________m
20. Consider a water tower like the one pictured at the introduction of this lab. Imagine a 10-meter tall water tower develops a small hole at its base, 10 meters above the ground. If the water tower is open to the atmosphere at the top and at the hole, how fast (speed, not time) would the water leak out of the hole?

    ____________________m/s



21. Now, using what you've learned about kinematics, if the hole created a horizontal stream, how far from the base of the water tower would the water initially land?

    ____________________m
22. As the water leaked out over time, would the stream of water travel further from the base, closer to the base, or remain the same distance from the base? ________________________
23. Why is this? ____
24. How deep would the water have to be to create a stream leaking out at 12.0 m/s?

    ____________________m
25. Consider this: a 2L soda bottle can take about 5 atmospheres of pressure before it bursts. This is 505000Pa! If you attach a steel pipe (vertically) to the bottle and fill that bottle/pipe system with water (density = 1000 kg/m^3) there is a height where the pressure of the column of water will cause the bottle to rupture. What is that height?

    ____________________m
26. How high could a similar bottle hold a column of honey (density = 1420 kg/m^3)?

    ____________________m
27. If you tried this investigation using PVC pipe rated to fail at pressures exceeding 60 PSI, which would rupture first, the PVC pipe or the plastic 2L bottle? (look up pressure values) ____________________