Physics 05-01 Fluids and Density Name: ______________________

Phases of Matter

Solid

- Atoms in ______________ contact so they can't move much
- Set ______________ and ______________
- Can't ______________

Liquid

- Atoms ______________ past each other
- Set ______________
- Takes ______________ of container
- Hard to ______________

Gas

- Atoms ______________ apart
- ______________ set ______________ or ______________
- ______________

Fluids

- ______________
- Both ______________ and ______________

Density

$$\rho = \frac{m}{V}$$

Where ρ = density, m = mass, V = Volume

Table 11.1 Densities of Various Substances

Substance	$\rho(10^3\ kg/m^3\ \text{or}\ g/mL)$	Substance	$\rho(10^3\ kg/m^3\ \text{or}\ g/mL)$	Substance	$\rho(10^3\ kg/m^3\ \text{or}\ g/mL)$
Solids		**Liquids**		**Gases**	
Aluminum	2.7	Water (4ºC)	1.000	Air	1.29×10^{-3}
Brass	8.44	Blood	1.05	Carbon dioxide	1.98×10^{-3}
Copper (average)	8.8	Sea water	1.025	Carbon monoxide	1.25×10^{-3}
Gold	19.32	Mercury	13.6	Hydrogen	0.090×10^{-3}
Iron or steel	7.8	Ethyl alcohol	0.79	Helium	0.18×10^{-3}
Lead	11.3	Petrol	0.68	Methane	0.72×10^{-3}
Polystyrene	0.10	Glycerin	1.26	Nitrogen	1.25×10^{-3}
Tungsten	19.30	Olive oil	0.92	Nitrous oxide	1.98×10^{-3}
Uranium	18.70			Oxygen	1.43×10^{-3}
Concrete	2.30–3.0			Steam $(100^o\ C)$	0.60×10^{-3}
Cork	0.24				
Glass, common (average)	2.6				
Granite	2.7				
Earth's crust	3.3				
Wood	0.3–0.9				
Ice (0°C)	0.917				
Bone	1.7–2.0				

Physics 05-01 Fluids and Density **Name: ________________________**

Things with _______________ density _______________ on things with _______________ density

- Solids _______________ dense
- Gases _______________ dense

You can use density to determine unknown material.

An ornate silver crown is thought to be fake. How could we determine if is silver without damaging the crown?

1. Find its mass using a balance. (It is 1.25 kg)
2. Find its volume by submerging in water and finding volume of displaces water. (It is 1.60×10^{-4} m^3)
3. Find the density

Silver's density is 10.5×10^3 kg/m^3

Homework

1. What physical characteristic distinguishes a fluid from a solid?
2. Which of the following substances are fluids at room temperature: air, mercury, water, glass?
3. How do gases differ from liquids?
4. A pile of empty aluminum cans has a volume of 1.0 m^3. The density of aluminum is 2700 kg/m^3. Explain why the mass of the pile is not $\rho_{Al}V = \left(2700 \frac{kg}{m^3}\right)(1.0\ m^3) = 2700\ kg$.
5. Gold is sold by the troy ounce (31.103 g). What is the volume of 1 troy ounce of pure gold? (OpenStax 11.1) **1.610 cm^3**
6. Mercury is commonly supplied in flasks containing 34.5 kg (about 76 lb). What is the volume in liters of this much mercury? (OpenStax 11.2) **2.54 L**
7. (a) What is the mass of a deep breath of air having a volume of 2.00 L? (b) Discuss the effect taking such a breath has on your body's volume and density. (OpenStax 11.3) **2.58 g**
8. A straightforward method of finding the density of an object is to measure its mass and then measure its volume by submerging it in a graduated cylinder. What is the density of a 240-g rock that displaces 89.0 cm^3 of water? (Note that the accuracy and practical applications of this technique are more limited than a variety of others that are based on Archimedes' principle.) (OpenStax 11.4) **2.70 g/cm^3**
9. Suppose you have a coffee mug with a circular cross section and vertical sides (uniform radius). What is its inside radius if it holds 375 g of coffee when filled to a depth of 7.50 cm? Assume coffee has the same density as water. (OpenStax 11.5) **3.99 cm**
10. (a) A rectangular gasoline tank can hold 50.0 kg of gasoline when full. What is the depth of the tank if it is 0.500-m wide by 0.900-m long? (b) Discuss whether this gas tank has a reasonable volume for a passenger car. (OpenStax 11.6) **0.163 m**
11. A trash compactor can reduce the volume of its contents to 0.350 their original value. Neglecting the mass of air expelled, by what factor is the density of the rubbish increased? (OpenStax 11.7) **2.86 times denser**
12. A pirate in a movie is carrying a chest (0.30 m × 0.30 m × 0.20 m) that is supposed to be filled with gold. To see how ridiculous this is, determine the weight (in newtons) of the gold. To judge how large this weight is, remember that 1 N = 0.225 lb. (Cutnell 11.3) **3400 N**
13. A water bed has dimensions of 1.83 m × 2.13 m × 0.229 m. The floor of the bedroom will tolerate an additional weight of no more than 6660 N. Find the weight of the water in the bed and determine whether it should be purchased. (Cutnell 11.4) **8750 N**

Physics 05-02 Pressure and Depth	**Name: ____________________**

Pressure

Molecules of fluid sometimes ________________ with ________________ of container.

$$P = \frac{F}{A}$$

- P = ________________
- F = Force ________________ to surface
- A = ________________ of surface

Unit: N/m² = Pa (pascal)

- 1 Pa is ________________________ so we usually use ________________ or ________________

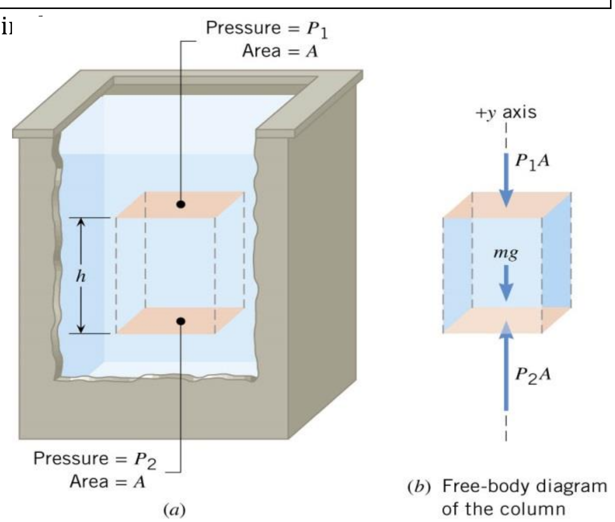
In a ________________ the pressure is exerted ____________________ to ________________ surfaces

A ____________ fluid _____________ produce a force ______________ to a surface since it is not _______________ parallel to surface

You are drinking a juice box. In the process you suck all the juice and air out of the box. The top of the box is 7.5 cm by 5 cm. If the air pressure is 1.013×10^5 Pa, how much force is acting on the top of the box?

Would the force of the side of the box be more or less than the top?

The force that squashes the juice box is from the ______________ of all the ai



Atmospheric Pressure at Sea Level

1.013×10^5 Pa = 1 atmosphere (1 atm)

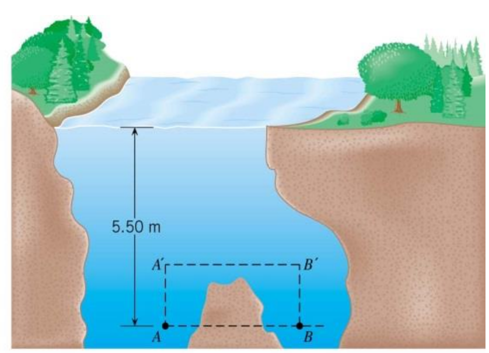
Pressure Varies with Depth

- The column of static fluid experiences several __________ forces
- Since the fluid is not moving, it is in equilibrium and __________
- If the pressure is known at a depth, the pressure lower down can be found by adding ________________
- This assumes ρ is ________________ with depth
- This is a good estimate for ________________, but not for ________________ unless h is small

$$P_2 = P_1 + \rho g h$$

Would Hoover Dam need to be just as strong if the entire lake behind the dam was reduced to an inch of water behind the dam, but the same depth as the lake?

What is the total pressure at points A and B?



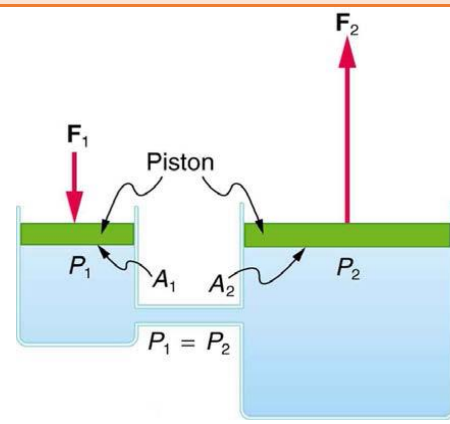
Physics 05-02 Pressure and Depth	***Name: ________________________***
Homework	

1. How is pressure related to the sharpness of a knife and its ability to cut?
2. Why is force exerted by static fluids always perpendicular to a surface?
3. Toe dancing (as in ballet) is much harder on toes than normal dancing or walking. Explain in terms of pressure.
4. Atmospheric pressure exerts a large force (equal to the weight of the atmosphere above your body—about 10 tons) on the top of your body when you are lying on the beach sunbathing. Why are you able to get up?
5. As a woman walks, her entire weight is momentarily placed on one heel of her high-heeled shoes. Calculate the pressure exerted on the floor by the heel if it has an area of 1.50 cm^2 and the woman's mass is 55.0 kg. Express the pressure in Pa. (In the early days of commercial flight, women were not allowed to wear high-heeled shoes because aircraft floors were too thin to withstand such large pressures.) (OpenStax 11.11) $\mathbf{3.59 \times 10^6}$ **Pa**
6. Nail tips exert tremendous pressures when they are hit by hammers because they exert a large force over a small area. What force must be exerted on a nail with a circular tip of 1.00 mm diameter to create a pressure of 3.00×10^9 N/m^2? (OpenStax 11.13) $\mathbf{2.36 \times 10^3}$ **N**
7. What depth of mercury creates a pressure of 1.00 atm? (OpenStax 11.14) **0.760 m**
8. The greatest ocean depths on the Earth are found in the Marianas Trench near the Philippines. Calculate the pressure due to the ocean at the bottom of this trench, given its depth is 11.0 km and assuming the density of seawater is constant all the way down. (OpenStax 11.15) $\mathbf{1.10 \times 10^8}$ **Pa**
9. Verify that the SI unit of $\rho g h$ is N/m^2. (OpenStax 11.16) **work**
10. Water towers store water above the level of consumers for times of heavy use, eliminating the need for high-speed pumps. How high above a user must the water level be to create a gauge pressure of 3.00×10^5 N/m^2? (OpenStax 11.17) **30.6 m**
11. What pressure is exerted on the bottom of a 0.500-m-wide by 0.900-m-long gas tank that can hold 50.0 kg of gasoline by the weight of the gasoline in it when it is full? (OpenStax 11.20) $\mathbf{1.09 \times 10^3}$ $\mathbf{N/m^2}$
12. The left side of the heart creates a pressure of 120 mmHg by exerting a force directly on the blood over an effective area of 15.0 cm^2. What force does it exert to accomplish this? (OpenStax 11.22) **24.0 N**
13. The human lungs can function satisfactorily up to a limit where the pressure difference between the outside and inside of the lungs is one-twentieth of an atmosphere. If a diver uses a snorkel for breathing, how far below the water can she swim? Assume the diver is in salt water whose density is 1025 kg/m^3? (Cutnell 11.24) **0.50 m**

Physics 05-03 Pascal's Principle and Measuring Pressure — *Name: ____________________*

Pascal's Principle

A change in ______________ applied to an enclosed ______________ is transmitted ______________ to ______________ portions of the fluid and the ______________ of its container.

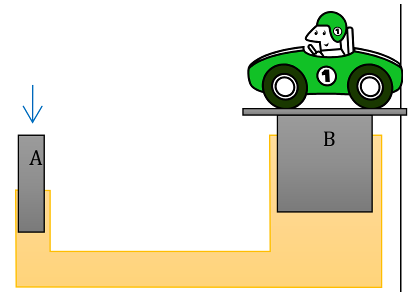


Basis of ______________

- Since $P = F/A$, if we change the ______________, the ______________ is changed

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

How much force must be exerted at A to support the 850-kg car at B? The piston at A has a diameter of 17 mm and the piston at B a diameter of 300 mm.



Measuring Pressure

Gauge Pressure

Used by pressure ______________

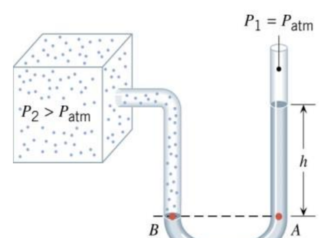
Measures pressure ______________ to ______________ pressure

Absolute Pressure

Sum of ______________ pressure and ______________ pressure

$$P_{abs} = P_{gauge} + P_{atm}$$

Open-Tube Manometer



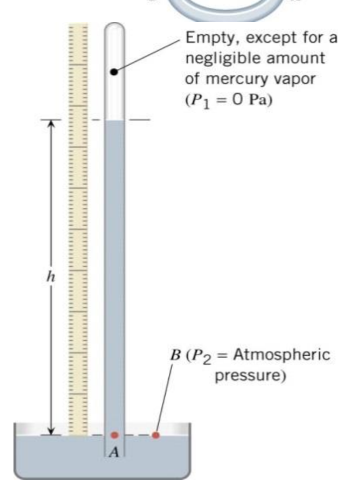
U-shaped ______________ with ______________ in it

One end is connected to the ______________ of which we want to measure the pressure

The other end is open to the ______________

$$P_2 = \rho g h + P_{atm}$$
$$P_2 = P_{abs}$$
$$P_2 - P_{atm} = P_{gauge}$$

Barometer



Used to measure ______________

A tube with the top ______________ and filled with ______________

The bottom is ______________ and sitting in a pool of ______________

Pressure at top = ______________

Pressure at bottom = ______________

$$P_{air} = \rho g h$$

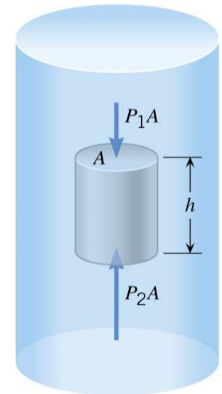
Physics 05-03 Pascal's Principle and Measuring Pressure	***Name: ________________________***
Homework	

1. Suppose the master cylinder in a hydraulic system is at a greater height than the slave cylinder. Explain how this will affect the force produced at the slave cylinder.
2. Explain why the fluid reaches equal levels on either side of a manometer if both sides are open to the atmosphere, even if the tubes are of different diameters.
3. The picture shows how a common measurement of arterial blood pressure is made. Is there any effect on the measured pressure if the manometer is lowered? What is the effect of raising the arm above the shoulder? What is the effect of placing the cuff on the upper leg with the person standing? Explain your answers in terms of pressure created by the weight of a fluid.

4. As you climb a mountain, your ears "pop" because of the changes in atmospheric pressure. In which direction does your eardrum move (a) as you climb up and (b) as you climb down? Give your reasoning.
5. A bottle of juice is sealed under partial vacuum, with the lid on which a red dot or "button" is painted. Around the button the following phrase is printed: "Button pops up when seal is broken." Explain why the button remains pushed in when the seal is intact.
6. Could you use a straw to sip a drink on the moon where there is no atmosphere? Explain.
7. What force must be exerted on the master cylinder of a hydraulic lift to support the weight of a 2000-kg car (a large car) resting on the slave cylinder? The master cylinder has a 2.00-cm diameter and the slave has a 24.0-cm diameter. (OpenStax 11.25) **136 N**
8. A certain hydraulic system is designed to exert a force 100 times as large as the one put into it. (a) What must be the ratio of the area of the slave cylinder to the area of the master cylinder? (b) What must be the ratio of their diameters? (c) By what factor is the distance through which the output force moves reduced relative to the distance through which the input force moves? Assume no losses to friction. (OpenStax 11.27) **100, 10.0, 1/100**
9. The atmospheric pressure above a swimming pool changes from 755 to 765 mmHg. The bottom of the pool is a 12-m × 24-m rectangle. By how much does the force on the bottom of the pool increase? (Cutnell 11.31) $\mathbf{3.8 \times 10^5}$ **N**
10. In the hydraulic press used in a trash compactor, the radii of the input piston and the output plunger are 6.4×10^{-3} m and 5.1×10^{-2} m, respectively. The height difference between the input piston and the output plunger can be neglected. What force is applied to the trash when the input force is 330 N? (Cutnell 11.32) $\mathbf{2.1 \times 10^4}$ **N**
11. How tall must a water-filled manometer be to measure blood pressures as high as 300 mm Hg? (OpenStax 11.31) **4.08 m**
12. Pressure cookers have been around for more than 300 years, although their use has strongly declined in recent years (early models had a nasty habit of exploding). How much force must the latches holding the lid onto a pressure cooker be able to withstand if the circular lid is 25.0 cm in diameter and the gauge pressure inside is 3.00 atm? Neglect the weight of the lid. (OpenStax 11.32) $\mathbf{1.49 \times 10^4}$ **N**
13. Suppose you measure a standing person's blood pressure by placing the cuff on his leg 0.500 m below the heart. Calculate the pressure you would observe (in units of mm Hg) if the pressure at the heart were 120 over 80 mm Hg. Assume that there is no loss of pressure due to resistance in the circulatory system (a reasonable assumption, since major arteries are large). (OpenStax 11.33) **159 over 119 mmHg**
14. A submarine is stranded on the bottom of the ocean with its hatch 25.0 m below the surface. Calculate the force needed to open the hatch from the inside, given it is circular and 0.450 m in diameter. Air pressure inside the submarine is 1.00 atm. (OpenStax 11.34) $\mathbf{3.99 \times 10^4}$ **N**

Physics 05-04 Archimedes' Principle **Name: ________________________**

Archimedes' Principle



All fluids push things _______________ because the pressure is ________________ at greater _______________
The upward force is ________________ **force**

$$F_B = mg = W_{liquid}$$

Archimedes' Principle

_______________ force = _______________ of the displaced _______________

$$\boldsymbol{F_B = W_{fl}}$$

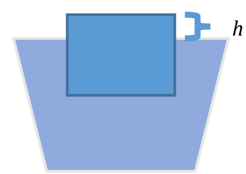
- If buoyant force ________________ gravity, then it ________________
- If buoyant force ________________ gravity, then it ________________
- An object will ________________ if its average density ________________ density of the fluid
- In other words, it will float if it _________________ more fluid than its own _______________

Specific Gravity

$$specific\ gravity = \frac{\bar{\rho}}{\rho_{fl}} = \text{fraction submerged}$$

- If specific gravity ________________ 1 it ________________
- If specific gravity ________________ 1 it ________________

An ice cube is floating in a glass of fresh water. The cube is 3 cm on each side. If the cube is floating so a flat face is facing up, what is the distance between the top of the cube and the water?



A man tied a bunch of helium balloons to a lawn chair and flew to a great altitude. If a single balloon is estimated as a sphere with a radius of 20 cm and is filled with helium, what is the net force on one balloon?

How many balloons would be required to lift a 80 kg man and chair?

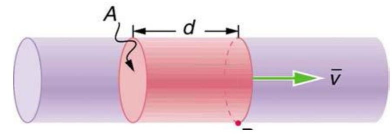
Physics 05-04 Archimedes' Principle	***Name: ________________________***
Homework	

1. Do fluids exert buoyant forces in a "weightless" environment, such as in the space shuttle? Explain your answer.
2. Will the same ship float higher in salt water than in freshwater? Explain your answer.
3. Marbles dropped into a partially filled bathtub sink to the bottom. Part of their weight is supported by buoyant force, yet the downward force on the bottom of the tub increases by exactly the weight of the marbles. Explain why.
4. Logs sometimes float vertically in a lake because one end has become water-logged and denser than the other. What is the average density of a uniform-diameter log that floats with 20.0% of its length above water? (OpenStax 11.37) **800 kg/m³**
5. Find the density of a fluid in which a hydrometer having a density of 0.750 g/mL floats with 92.0% of its volume submerged. (OpenStax 11.38) **815 kg/m³**
6. If your body has a density of 995 kg/m³, what fraction of you will be submerged when floating gently in: (a) Freshwater? (b) Salt water, which has a density of 1027 kg/m³? (OpenStax 11.39) **99.5% submerged, 96.8% submerged**
7. Bird bones have air pockets in them to reduce their weight—this also gives them an average density significantly less than that of the bones of other animals. Suppose an ornithologist weighs a bird bone in air and in water and finds its mass is 45.0 g and its apparent mass when submerged is 3.60 g (the bone is watertight). (a) What mass of water is displaced? (b) What is the volume of the bone? (c) What is its average density? (OpenStax 11.40) **41.4 g, 41.4 cm³, 1.09 g/cm³**
8. A rock with a mass of 540 g in air is found to have an apparent mass of 342 g when submerged in water. (a) What mass of water is displaced? (b) What is the volume of the rock? (c) What is its average density? Is this consistent with the value for granite? (OpenStax 11.41) **198 g, 198 cm³, 2.73 g/cm³**
9. Some fish have a density slightly less than that of water and must exert a force (swim) to stay submerged. What force must an 85.0-kg grouper exert to stay submerged in salt water if its body density is 1015 kg/m³? (OpenStax 11.44) **8.21 N**
10. A twin-sized air mattress used for camping has dimensions of 100 cm by 200 cm by 15 cm when blown up. The weight of the mattress is 2 kg. How heavy a person could the air mattress hold if it is placed in freshwater? (OpenStax 11.51) **2920 N**
11. A duck is floating on a lake with 25% of its volume beneath the water. What is the average density of the duck? (Cutnell 11.38) **250 kg/m³**
12. Only a small part of an iceberg protrudes above the water, while the bulk lies below the surface. The density of ice is 917 kg/m³ and that of seawater is 1025 kg/m³. Find the percentage of the iceberg's volume that lies below the surface. (Cutnell 11.40) **89.5%**

Physics 05-05 Flow Rate and Bernoulli's Equation **Name:** ____________________

Flow Rate

$$Q = \frac{V}{t} = A\overline{v}$$



- Q = Flow rate; V = Volume of fluid; t = time
- A = cross-section area; $\overline{v}$ = average velocity of fluid

Since flow rate is ______________ for a given ______________ fluid

Equation of continuity

$$\rho_1 A_1 \overline{v}_1 = \rho_2 A_2 \overline{v}_2$$

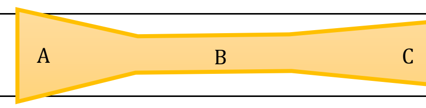
If ______________

$$A_1 \overline{v}_1 = A_2 \overline{v}_2$$

If ______________ and several ______________

$$n_1 A_1 \overline{v}_1 = n_2 A_2 \overline{v}_2$$

Where does the water flow the fastest?



A garden hose has a diameter of 2 cm and water enters it at 0.5 m/s. You block 90% of the end of the hose with your thumb. How fast does the water exit the hose?

Bernoulli's Equation

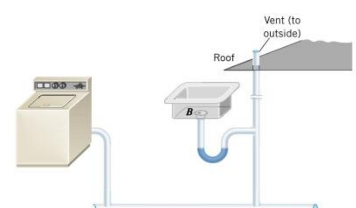
$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

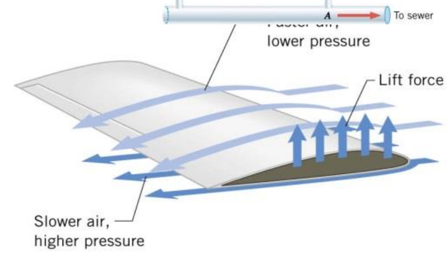
This is a form of conservation of ______________ $E_0 + W_{nc} = E_f$ where the net ______________ comes from the ______________ in the ______________

Think about driving down a road with something in your car trunk. The object is too large to completely shut the trunk lid. While the car is stopped, the lid quietly rests as far down as it can go. As you drive down the road, why does the trunk open?

The blood speed in a normal segment of a horizontal artery is 0.15 m/s. An abnormal segment of the artery is narrowed down by an arteriosclerotic plaque to one-half the normal cross-sectional area. What is the difference in blood pressures between the normal and constricted segments of the artery?

Why do all houses need a plumbing vent?

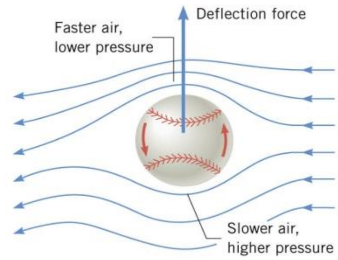




How do airplane wings work (even paper airplanes)?

Physics 05-05 Flow Rate and Bernoulli's Equation	Name: ______________________

How does a curve ball in baseball work?



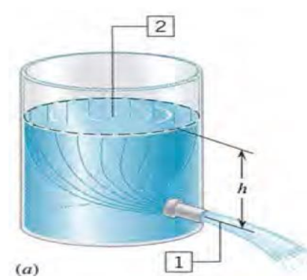
Homework

1. What is the difference between flow rate and fluid velocity? How are they related?
2. Many figures in the text show streamlines. Explain why fluid velocity is greatest where streamlines are closest together. (Hint: Consider the relationship between fluid velocity and the cross-sectional area through which it flows.)
3. Water is shot nearly vertically upward in a decorative fountain and the stream is observed to broaden as it rises. Conversely, a stream of water falling straight down from a faucet narrows. Explain why, and discuss whether surface tension enhances or reduces the effect in each case.
4. Some chimney pipes have a T-shape, with a crosspiece on top that helps draw up gases whenever there is even a slight breeze. Explain how this works in terms of Bernoulli's principle.
5. Why is it preferable for airplanes to take off into the wind rather than with the wind?
6. Roofs are sometimes pushed off vertically during a tropical cyclone, and buildings sometimes explode outward when hit by a tornado. Use Bernoulli's principle to explain these phenomena.
7. It is dangerous to stand close to railroad tracks when a rapidly moving commuter train passes. Explain why atmospheric pressure would push you toward the moving train.
8. The heart of a resting adult pumps blood at a rate of 5.00 L/min. (a) Convert this to cm^3/s. (b) What is this rate in m^3/s? (OpenStax 12.2) **83.3 cm^3/s, $\mathbf{8.33 \times 10^{-5}}$ m^3/s**
9. Blood is pumped from the heart at a rate of 5.0 L/min into the aorta (of radius 1.0 cm). Determine the speed of blood through the aorta. (OpenStax 12.3) **27 cm/s**
10. Blood is flowing through an artery of radius 2 mm at a rate of 40 cm/s. Determine the flow rate and the volume that passes through the artery in a period of 30 s. (OpenStax 12.4) **5.03 cm^3/s, 151 cm^3**
11. A major artery with a cross-sectional area of 1.00 cm^2 branches into 18 smaller arteries, each with an average cross-sectional area of 0.400 cm^2. By what factor is the average velocity of the blood reduced when it passes into these branches? (OpenStax 12.6) $\mathbf{0.139\bar{v}_1}$
12. The human circulation system has approximately 1×10^9 capillary vessels. Each vessel has a diameter of about 8 μm. Assuming cardiac output is 5 L/min, determine the average velocity of blood flow through each capillary vessel. (OpenStax 12.8) **0.166 cm/s**
13. Every few years, winds in Boulder, Colorado, attain sustained speeds of 45.0 m/s (about 100 mi/h) when the jet stream descends during early spring. Approximately what is the force due to the Bernoulli effect on a roof having an area of 220 m^2? Typical air density in Boulder is 1.14 kg/m^3, and the corresponding atmospheric pressure is 8.89×10^4 N/m^2. (Bernoulli's principle as stated in the text assumes laminar flow. Using the principle here produces only an approximate result, because there is significant turbulence.) (OpenStax 12.21) $\mathbf{2.54 \times 10^5}$ **N**
14. (a) Calculate the approximate force on a square meter of sail, given the horizontal velocity of the wind is 6.00 m/s parallel to its front surface and 3.50 m/s along its back surface. Take the density of air to be 1.29 kg/m^3. (The calculation, based on Bernoulli's principle, is approximate due to the effects of turbulence.) (b) Discuss whether this force is great enough to be effective for propelling a sailboat. (OpenStax 12.22) **15.3 N, small force, but big sail makes boat move**
15. (a) What is the pressure drop due to the Bernoulli effect as water goes into a 3.00-cm-diameter nozzle from a 9.00-cm-diameter fire hose while carrying a flow of 40.0 L/s? (b) To what maximum height above the nozzle can this water rise? (The actual height will be significantly smaller due to air resistance.) (OpenStax 12.23) $\mathbf{1.58 \times 10^6}$ **N/m^3, 163 m**
16. The blood speed in a normal segment of a horizontal artery is 0.11 m/s. An abnormal segment of the artery is narrowed down by an arteriosclerotic plaque to one-fourth the normal cross-sectional area. What is the difference in blood pressures between the normal and constricted segments of the artery? (Cutnell 11.58) **96 Pa**
17. An airplane wing is designed so that the speed of the air across the top of the wing is 251 m/s when the speed of the air below the wing is 225 m/s. The density of the air is 1.29 kg/m^3. What is the lifting force on a wing of area 24.0 m^2? (Cutnell 11.59) $\mathbf{1.92 \times 10^5}$ **N**

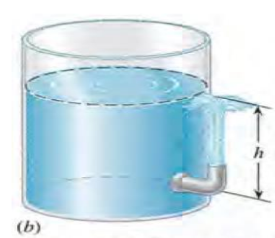
The Most General Applications of Bernoulli's Equation

Water circulates throughout a house in a hot-water heating system. If the water is pumped at a speed of 0.50 m/s through a 4.0-cm-diameter pipe in the basement under a pressure of 3.0 atm, what will be the flow speed and pressure in a 2.6-cm-diameter pipe on the second floor 5.0 m above? Assume the pipes do not divide into branches.

The tank is open to the atmosphere at the top. Find an expression for the speed of the liquid leaving the pipe at the bottom.



Since Bernoulli's Equation is conservation of ______________, the water would ______________ up to the same ______________ as the ______________ in the tank.



Power in Fluid Flow

$$Power = \left(\Delta P + \Delta \frac{1}{2}\rho v^2 + \Delta \rho g h\right) Q$$

Physics 05-06 The Most General Applications of Bernoulli's Equation	***Name:*** ________________________
Homework	

1. Have you ever had a large truck pass you from the opposite direction on a narrow two-lane road? You probably noticed that your car was pulled toward the truck as it passed. What can you conclude about the speed of the air between your car and the truck compared to that on the opposite side of the car? Provide a reason for your answer.
2. Based on Bernoulli's equation, what are three forms of energy in a fluid? (Note that these forms are conservative, unlike heat transfer and other dissipative forms not included in Bernoulli's equation.)
3. Water that has emerged from a hose into the atmosphere has a gauge pressure of zero. Why? When you put your hand in front of the emerging stream you feel a force, yet the water's gauge pressure is zero. Explain where the force comes from in terms of energy.
4. Water pressure inside a hose nozzle can be less than atmospheric pressure due to the Bernoulli effect. Explain in terms of energy how the water can emerge from the nozzle against the opposing atmospheric pressure.
5. Hoover Dam on the Colorado River is the highest dam in the United States at 221 m, with an output of 1300 MW. The dam generates electricity with water taken from a depth of 150 m and an average flow rate of 650 m^3/s. (a) Calculate the power in this flow. (b) What is the ratio of this power to the facility's average of 680 MW? (OpenStax 12.25) $\mathbf{9.56 \times 10^8}$ **W, 1.4**
6. A frequently quoted rule of thumb in aircraft design is that wings should produce about 1000 N of lift per square meter of wing. (The fact that a wing has a top and bottom surface does not double its area.) (a) At takeoff, an aircraft travels at 60.0 m/s, so that the air speed relative to the bottom of the wing is 60.0 m/s. Given the sea level density of air to be 1.29 kg/m^3, how fast must it move over the upper surface to create the ideal lift? (b) How fast must air move over the upper surface at a cruising speed of 245 m/s and at an altitude where air density is one-fourth that at sea level? (Note that this is not all of the aircraft's lift—some comes from the body of the plane, some from engine thrust, and so on. Furthermore, Bernoulli's principle gives an approximate answer because flow over the wing creates turbulence.) (OpenStax 12.26) **71.8 m/s, 257 m/s**
7. The left ventricle of a resting adult's heart pumps blood at a flow rate of 83.0 cm^3/s , increasing its pressure by 110 mmHg, its speed from zero to 30.0 cm/s, and its height by 5.00 cm. (All numbers are averaged over the entire heartbeat.) Calculate the total power output of the left ventricle. Note that most of the power is used to increase blood pressure. (OpenStax 12.27) **1.26 W**
8. A sump pump (used to drain water from the basement of houses built below the water table) is draining a flooded basement at the rate of 0.750 L/s, with an output pressure of 3.00×10^5 N/m^2. (a) The water enters a hose with a 3.00-cm inside diameter and rises 2.50 m above the pump. What is its pressure at this point? (b) The hose goes over the foundation wall, losing 0.500 m in height, and widens to 4.00 cm in diameter. What is the pressure now? You may neglect frictional losses in both parts of the problem. (OpenStax 12.28) $\mathbf{2.76 \times 10^5}$ $\mathbf{N/m^2}$**,** $\mathbf{2.81 \times 10^5}$ $\mathbf{N/m^2}$
9. The Ludington Pumped Storage Power Plant is a reservoir by Lake Michigan. To store the extra electric energy produced by the nearby windmill farm on windy days, water is pumped up from the lake into the reservoir 111 m higher. Then at during calm, the water is released through turbines to generate electrical energy. (a) If the maximum flow rate is 1.2×10^5 m^3/min, what is the maximum power produced by the falling water? (b) The power plant actually can only produce 1872 MW of power. What percentage of the power is lost? (RW) **2200 MW, 15%**

Physics 05-07 Viscosity, Poiseuille's Law, and Turbulence **Name:** ________________________

Viscosity

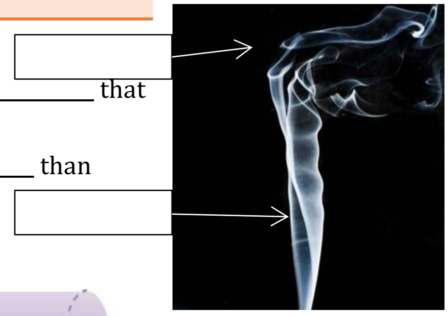
- Fluid ______________

Laminar Flow

- Smooth flow in ______________ that don't ______________

Turbulent Flow

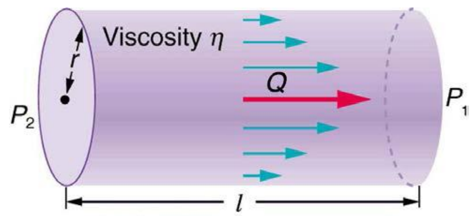
- Has ______________ and ______________ that ______________ layers of fluid
- Turbulent flow is ______________ than laminar flow



How viscosity is measured

- Two ______________ with fluid between
- Top plate ______________
- ______________ causes the fluid to move

$$\eta = \frac{FL}{vA}$$



Laminar flow in tubes

- Difference in ______________ causes fluids to ______________

$$Q = \frac{P_2 - P_1}{R}$$

- Q is flow rate; P_1 and P_2 are pressures; R is resistance

Poiseuille's law for resistance

$$R = \frac{8\eta l}{\pi r^4}$$

- η is viscosity; l is length of tube; r is radius of tube

Since flow rate depends on ______________

- Higher pressure difference, higher ______________
- Higher resistance, higher ____________________________ to maintain ______________ Q
- In blood vessels this is a ______________ with ______________ on artery walls

How to tell if laminar or turbulent flow

- ______________ speed with smooth, streamlined object → __________
- ______________ speed or rough object → ______________

Reynolds number

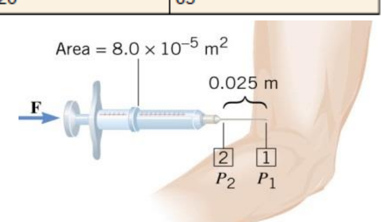
- Below 2000 → ______________
- Above 3000 → ______________
- Between 2000 and 3000 ____________________________

$$N_R = \frac{2\rho v r}{\eta}$$

Table 12.1 Coefficients of Viscosity of Various Fluids

Fluid	Temperature (ºC)	Viscosity η (mPa·s)
Gases		
Air	0	0.0171
	20	0.0181
	40	0.0190
	100	0.0218
Ammonia	20	0.00974
Carbon dioxide	20	0.0147
Helium	20	0.0196
Hydrogen	0	0.0090
Mercury	20	0.0450
Oxygen	20	0.0203
Steam	100	0.0130
Liquids		
Water	0	1.792
	20	1.002
	37	0.6947
	40	0.653
	100	0.282
Whole blood[1]	20	3.015
	37	2.084
Blood plasma[2]	20	1.810
	37	1.257
Ethyl alcohol	20	1.20
Methanol	20	0.584
Oil (heavy machine)	20	660
Oil (motor, SAE 10)	30	200
Oil (olive)	20	138
Glycerin	20	1500
Honey	20	2000–10000
Maple Syrup	20	2000–3000
Milk	20	3.0
Oil (Corn)	20	65

A hypodermic syringe is filled with a solution whose viscosity is 1.5×10^{-3} Pa · s. The plunger area of the syringe is 8.0×10^{-5} m^2, and the length of the needle is 0.025 m. The internal radius of the needle is 4.0×10^{-4} m. The gauge pressure in a vein is 1900 Pa (14 mmHg). What force must be applied to the plunger, so that 1.0×10^{-6} m^3 of solution can be injected in 3.0 s?



Is the flow laminar if the density is 1000 kg/m^3?

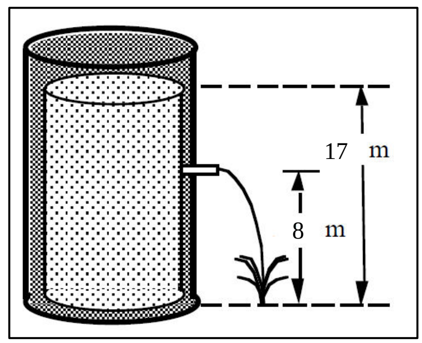
Homework

1. When paddling a canoe upstream, it is wisest to travel as near to the shore as possible. When canoeing downstream, it may be best to stay near the middle. Explain why.
2. What force is needed to pull one microscope slide over another at a speed of 1.00 cm/s, if there is a 0.500-mm-thick layer of 20 °C water between them and the contact area is 8.00 cm^2? (OpenStax 12.30) $\mathbf{1.61 \times 10^{-5}}$ **N**
3. A glucose solution being administered with an IV has a flow rate of 4.00 cm^3/min . What will the new flow rate be if the glucose is replaced by whole blood having the same density but a viscosity 2.50 times that of the glucose? All other factors remain constant. (OpenStax 12.31) **1.60 cm^3/min**
4. A small artery has a length of 1.1×10^{-3} m and a radius of 2.5×10^{-5} m . If the pressure drop across the artery is 1.3 kPa, what is the flow rate through the artery? (Assume that the temperature is 37° C .) (OpenStax 12.33) $\mathbf{8.7 \times 10^{-2}}$ **mm^3/s**
5. The arterioles (small arteries) leading to an organ, constrict in order to decrease flow to the organ. To shut down an organ, blood flow is reduced naturally to 1.00% of its original value. By what factor did the radii of the arterioles constrict? Penguins do this when they stand on ice to reduce the blood flow to their feet. (OpenStax 12.35) $\mathbf{0.316 r_1}$
6. Angioplasty is a technique in which arteries partially blocked with plaque are dilated to increase blood flow. By what factor must the radius of an artery be increased in order to increase blood flow by a factor of 10? (OpenStax 12.36) $\mathbf{1.8 r_1}$
7. (a) Suppose a blood vessel's radius is decreased to 90.0% of its original value by plaque deposits and the body compensates by increasing the pressure difference along the vessel to keep the flow rate constant. By what factor must the pressure difference increase? (b) If turbulence is created by the obstruction, what additional effect would it have on the flow rate? (OpenStax 12.37) **1.52**
8. Verify that the flow of oil is laminar (barely) for an oil gusher that shoots crude oil 25.0 m into the air through a pipe with a 0.100-m diameter. The vertical pipe is 50 m long. Take the density of the oil to be 900 kg/m^3 and its viscosity to be 1.00 (N/m^2) · s (or 1.00 Pa · s). (OpenStax 12.51) **1990**
9. Calculate the Reynolds numbers for the flow of water through (a) a nozzle with a radius of 0.250 cm and (b) a garden hose with a radius of 0.900 cm, when the nozzle is attached to the hose. The flow rate through hose and nozzle is 0.500 L/s. Can the flow in either possibly be laminar? (OpenStax 12.53) **35100, 127000**
10. A fire hose has an inside diameter of 6.40 cm. Suppose such a hose carries a flow of 40.0 L/s starting at a gauge pressure of 1.62×10^6 N/m^2. The hose goes 10.0 m up a ladder to a nozzle having an inside diameter of 3.00 cm. Calculate the Reynolds numbers for flow in the fire hose and nozzle to show that the flow in each must be turbulent. (OpenStax 12.54) $\mathbf{7.90 \times 10^5}$
11. At what flow rate might turbulence begin to develop in a water main with a 0.200-m diameter? Assume a 20° C temperature. (OpenStax 12.56) $\mathbf{3.16 \times 10^{-4}}$ **m^3/s**
12. A blood vessel is 0.10 m in length and has a radius of 1.5×10^{-3} m. Blood ($\eta = 4 \times 10^{-3}$ Pa·s) flows at a rate of 1.0×10^{-7} m^3/s. Determine the difference in pressure that must be maintained between the two ends of the vessels. (Cutnell 11.70) **20 Pa**

Physics

Unit 5: Fluids

1. Meanings and concepts of terms like fluid, density, barometer, Pascal's principle, Bernoulli's principle, Archimedes' principle, continuity equation, pressure, buoyant force, gauge pressure, absolute pressure, Poiseuille's Law, laminar flow, turbulent flow, viscosity
2. The density of mercury is 1.36×10^4 kg/m^3. What is the mass of a 10-m^3 sample of mercury?
3. The average density of the material in intergalactic space is approximately 2.5×10^{-27} kg/m^3. What is the volume of a gold sample, ρ = 19300 kg/m^3, that has the same mass as 5×10^{24} m^3 of intergalactic space?
4. A barometer is taken from the base to the top of a 10-m tower. Assuming the density of air is 1.29 kg/m^3, what is the measured change in pressure?
5. How much force does the atmosphere exert on one side of a vertical wall 10-m high and 20-m long?
6. A force of 500 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 2 m, approximately how much mass can be lifted by the jack? Ignore any difference in height between the pistons.
7. A balloon inflated with helium gas (density = 0.2 kg/m^3) has a volume of 5 m^3. If the density of air is 1.3 kg/m^3, what is the buoyant force exerted on the balloon?
8. Water enters a pipe of diameter 10 cm with a velocity of 5 m/s. The water encounters a constriction where its velocity is 20 m/s. What is the diameter of the constricted portion of the pipe?
9. A large tank is filled with water to a depth of 17 m. A spout located 8 m above the bottom of the tank is then opened as shown in the drawing. With what speed will water emerge from the spout?



10. A small crack occurs at the base of a 10 .0-m-high dam. The effective crack area through which water leaves is 1.30×10^{-3} m^2. Ignoring viscous losses, what is the speed of the water flowing through the crack?
11. Water flows through a pipe with radius 2 m and speed of 10 m/s. The density of water is 1000 kg/m^3 and its viscosity is 1.002×10^{-3} Pa•s. Calculate the Reynold's number for this situation.
12. The density of ice is 800 kg/m^3; and the density of seawater is 900 kg/m^3. A large iceberg floats in Arctic waters. What fraction of the volume of the iceberg is exposed?
13. A small artery has a length of 3×10^{-4} m and a radius of 1×10^{-6} m . If the pressure drop across the artery is 2000 Pa, what is the flow rate through the artery? (Assume that the viscosity of blood is 1.257 mPa/s.)

2. $\rho = 1.36 \times 10^4 \frac{kg}{m^3}, V = 10\ m^3$

$\rho = \frac{m}{V}$

$1.36 \times 10^4 \frac{kg}{m^3} = \frac{m}{10\ m^3}$

$m = \mathbf{1.36 \times 10^5\ kg}$

3. $\rho_{space} = 2.5 \times 10^{-27} \frac{kg}{m^3}, \rho_{gold} = 19300 \frac{kg}{m^3}, V_{space} = 5 \times 10^{24}\ m^3$

$\rho = \frac{m}{V}$

$2.5 \times 10^{-27} \frac{kg}{m^3} = \frac{m}{5 \times 10^{24}\ m^3}$

$m = 0.0125\ kg$

$19300 \frac{kg}{m^3} = \frac{0.0125\ kg}{V}$

$V = \mathbf{6.48 \times 10^{-7}\ m^3}$

4. $h = 10\ m, \rho_{air} = 1.29 \frac{kg}{m^3}$

$P = h\rho g$

$P = (10\ m)\left(1.29 \frac{kg}{m^3}\right)\left(9.8 \frac{m}{s^2}\right) = \mathbf{126\ Pa}$

5. $h = 10\ m, \ell = 20\ m$

$P = \frac{F}{A}$

$1.01 \times 10^5\ Pa = \frac{F}{(10\ m)(20\ m)}$

$F = \mathbf{2.02 \times 10^7\ N}$

6. $F_1 = 500\ N, d_1 = 0.01\ m, d_2 = 2\ m$

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

$\frac{500\ N}{\pi(0.005\ m)^2} = \frac{F_2}{\pi(1\ m)^2}$

$F_2 = 2.0 \times 10^7\ N$

$W = mg$

$m = \frac{W}{g} = \frac{2.0 \times 10^7\ N}{9.8\ m/s^2} = \mathbf{2.04 \times 10^6\ kg}$

7. $\rho_{He} = 0.2 \frac{kg}{m^3}, V = 5\ m^3, \rho_{air} = 1.3 \frac{kg}{m^3}$

$F_B = w_{fl}$

$F_B = m_{air} g$

$\rho = \frac{m}{V}$

$1.3 \frac{kg}{m^3} = \frac{m_{air}}{5\ m^3}$

$m_{air} = 6.5\ kg$

$F_B = (6.5\ kg)\left(9.8 \frac{m}{s^2}\right) = \mathbf{63.7\ N}$

8. $d_1 = 10\ cm, v_1 = 5 \frac{m}{s}, v_2 = 20 \frac{m}{s}$

$A_1 \overline{v}_1 = A_2 \overline{v}_2$

$(\pi(0.05\ m)^2)\left(5 \frac{m}{s}\right) = (\pi r_2^2)\left(20 \frac{m}{s}\right)$

$r_2 = 0.025\ m$

$d_2 = \mathbf{0.05\ m}$

9. $h_1 = 17\ m, h_2 = 8\ m, \rho = 1000 \frac{kg}{m^3}$

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

$$1\ atm + 0 + \left(1000 \frac{kg}{m^3}\right)\left(9.8 \frac{m}{s^2}\right)(17\ m) = 1\ atm + \frac{1}{2}\left(1000 \frac{kg}{m^3}\right) v_2^2 + \left(1000 \frac{kg}{m^3}\right)\left(9.8 \frac{m}{s^2}\right)(8\ m)$$

$166600 \frac{N}{m^2} = \left(500 \frac{kg}{m^3}\right) v_2^2 + 78400 \frac{N}{m^2}$

$88200 \frac{N}{m^2} = \left(500 \frac{kg}{m^2}\right) v_2^2$

$v_2 = \mathbf{13.3 \frac{m}{s}}$

10. $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

$$1\ atm + 0 + \left(1000 \frac{kg}{m^3}\right)\left(9.8 \frac{m}{s^2}\right)(10\ m) = 1atm + \frac{1}{2}\left(1000 \frac{kg}{m^3}\right) v_2^2 + 0$$

$98000 \frac{J}{m^2} = 500 \frac{kg}{m^3}\ v_2^2$

$v_2 = 14 \frac{m}{s}$

11. $r = 2\ m, v = 10 \frac{m}{s}, \rho = 1000 \frac{kg}{m^3}, \eta = 1.002 \times 10^{-3} Pa \cdot s$

$N_R = \frac{2\rho v\ r}{\eta}$

$N_R = \frac{2\left(1000 \frac{kg}{m^3}\right)\left(10 \frac{m}{s}\right)(2\ m)}{1.002 \times 10^{-3} Pa \cdot s}$

$N_R = \mathbf{3.99 \times 10^7}$

12. $\rho_{ice} = 800 \frac{kg}{m^3}, \rho = 900 \frac{kg}{m^3}$

$Fraction\ submerged = \frac{\rho_{obj}}{\rho_{fl}}$

$Fraction\ submerged = \frac{800 \frac{kg}{m^3}}{900 \frac{kg}{m^3}}$

$Fraction\ submerged = \frac{8}{9} = 88.9\ \%$

$Fraction\ exposed = 1 - Fraction\ submerged$

$Fraction\ exposed = 1 - \frac{8}{9}$

$Fraction\ exposed = \mathbf{\frac{1}{9} = 11.1}\ \%$

13. Start by finding Q. $R = \frac{8\eta\ell}{\pi r^4}$

$$R = \frac{8(1.257 \times 10^{-3}\ Pa \cdot s)(3 \times 10^{-4}\ m)}{\pi(1 \times 10^{-6}\ m)^4} = 9.60 \times 10^{17} \frac{Pa \cdot s}{m^3}$$

Now find Q. $Q = \frac{P_2 - P_1}{R}$

$$Q = \frac{2000\ Pa}{9.60 \times 10^{17} \frac{Pa \cdot s}{m^3}} = \mathbf{2.08 \times 10^{-15} \frac{m^3}{s}}$$