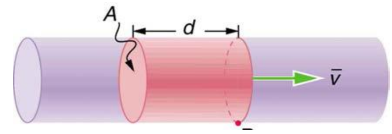
Physics 05-05 Flow Rate and Bernoulli's Equation Name: ________________________

Flow Rate

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



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

Since flow rate is ________________ for a given ________________ fluid

Equation of continuity

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

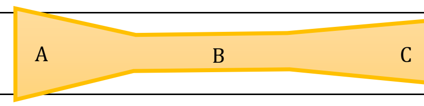
If ________________

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

If ________________ and several ________________

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

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

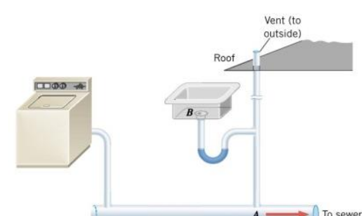
$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

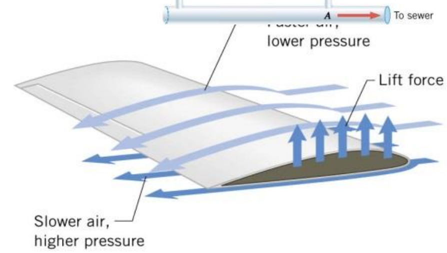
This is a form of conservation of ________________ $E_0 + W_{nc} = E_f$ where the net ________________ comes from the ________________ in the ________________

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)?

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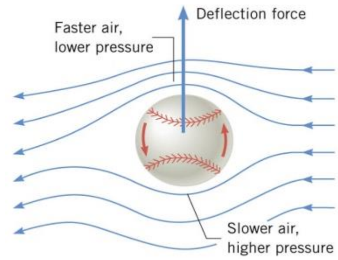
How does a curve ball in baseball work?



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, 8.33×10^{-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**