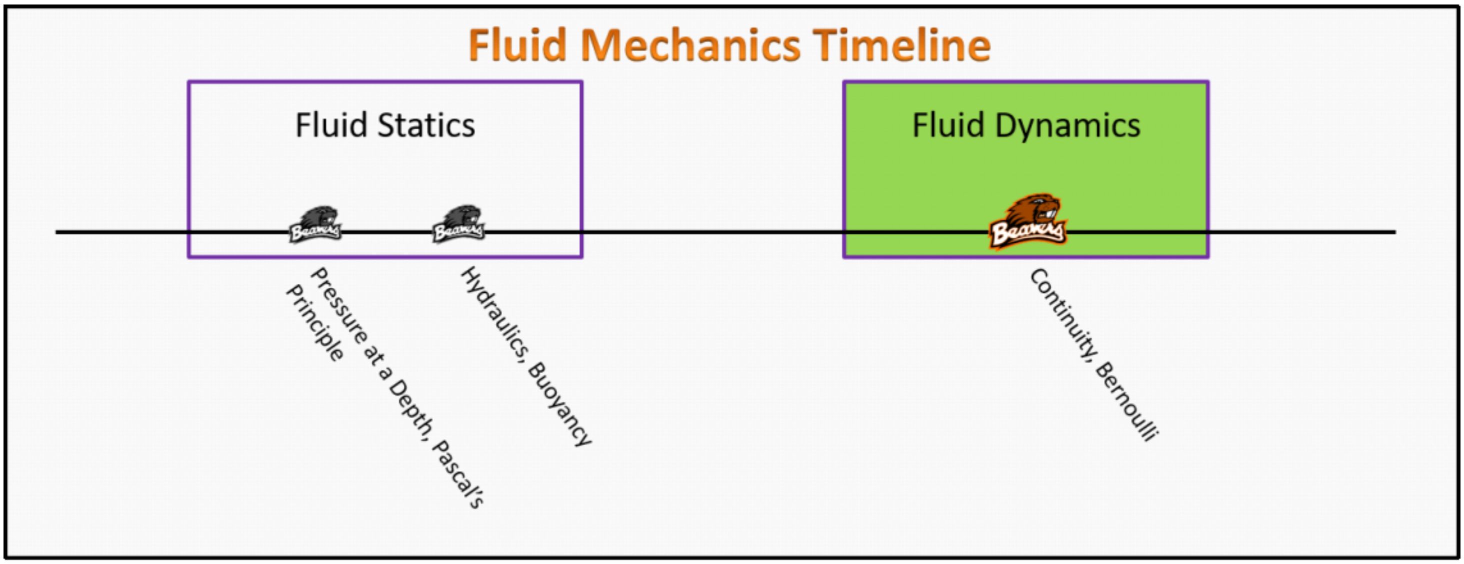
(FD.L1.123) Template for Boxsand

Monday, January 22, 2018 5:44 PM

Fluid Dynamics

Familiarize Stage (FD.L1.1)

Lecture 1
Continuity, Bernoulli

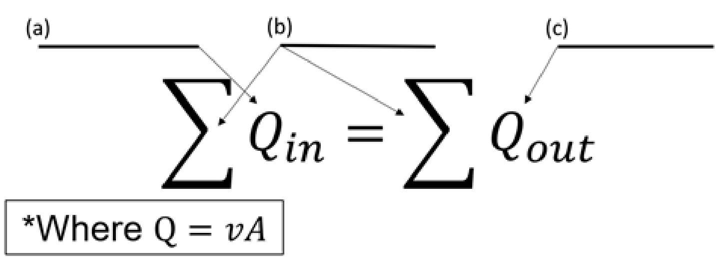


FD.L1.1-01

Description: Infographic quiz continuity mass flow rate - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list. (1) Volume flow rate in, (2) Summation, (3) Volume flow rate out



FD.L1.1-02

Description: Volume flow rate equation

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: What is the equation for volume flow rate?

(1) Q = (density)·(speed)
(2) Q = (density)/(speed)
(3) Q = (area)·(speed)
(4) Q = (area)/(speed)

FD.L1.1-03

Description: Volume flow rate units

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: What are the SI units of volume flow rate?

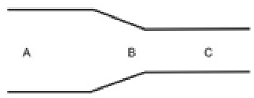
(1) kg·m/s
(2) kg·m·s
(3) J/s
(4) N·m/s
(5) m/s
(6) m^2/s
(7) m^3/s

FD.L1.1-04

Description: Applying continuity

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: Water flows through this pipe. Where is the fluid's speed highest?



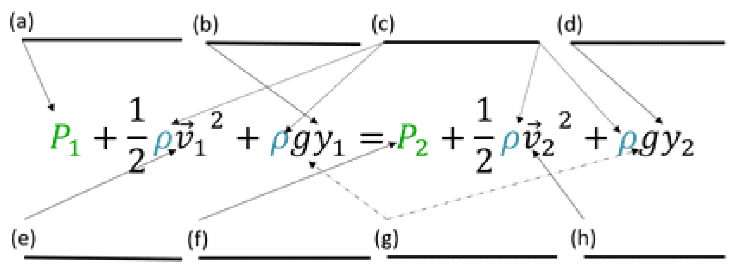
(1) A
(2) B
(3) C
(4) All the same

FD.L1.1-05

Description: Infographic quiz Bernoulli's principle - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list. (1) Gravity, (2) Density, (3) Velocity at point 1, (4) Pressure at point 2, (5) Velocity at point 2, (6) Vertical position at point 2, (7) Vertical position at point 1 (8) Pressure at point 1



FD.L1.1-06

Description: Nature of Bernoulli's equation

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: What type of equation is Bernoulli's equation?

(1) Conservation of momentum equation
(2) Conservation of momentum density equation
(3) Conservation of energy equation
(4) Conservation of energy density equation
(5) Force balance equation
(6) Pressure balance equation

FD.L1.1-07

Description: Bernoulli's principle on pressure of moving fluid

Learning Objectives: [x,xx,...] Put the learning objective numbers here

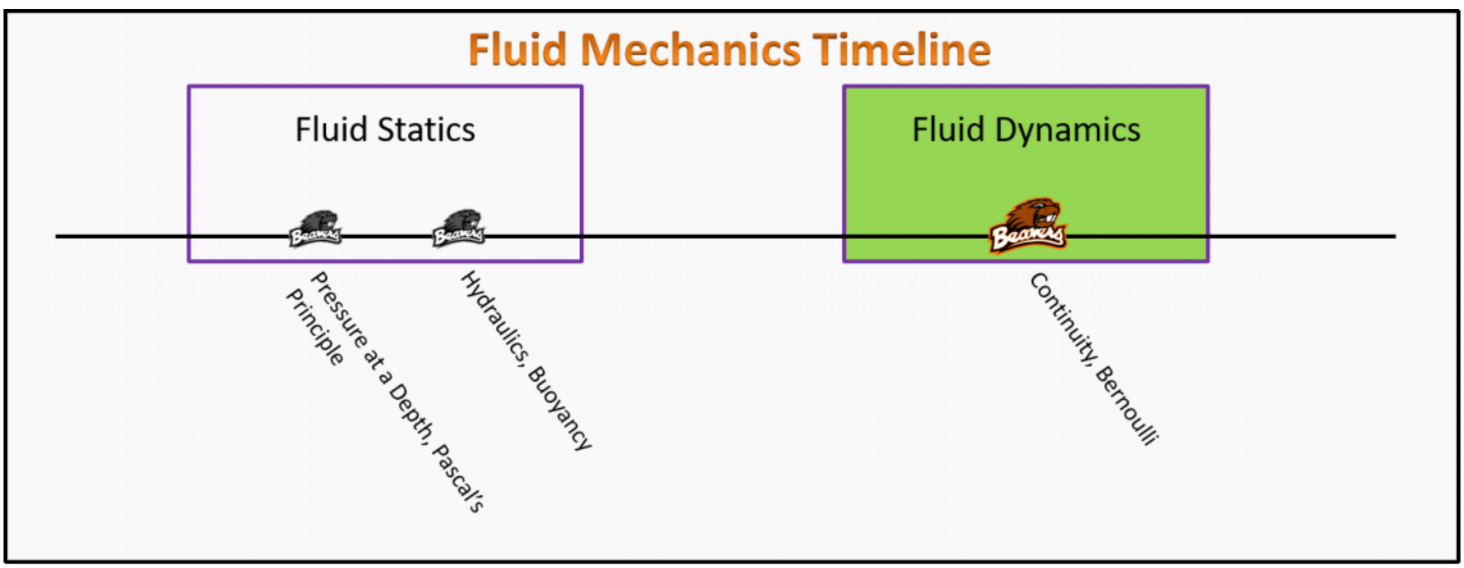
Problem Statement: Bernoulli's principle comes from his equation. For a moving fluid at a constant elevation what happens to the pressure as the speed increases?

(1) Increases

(2) Decreases
(3) Stays the same

Fluid Dynamics
Foundation Stage (FD.L1.2)

Lecture 1
Continuity, Bernoulli



Textbook Chapters (* Calculus version)

- **BoxSand** :: KC videos (Continuity ; Bernoulli's Principle)
- **Knight** (College Physics : A strategic approach 3rd) :: 13.5 ; 13.6
- ***Knight** (Physics for Scientists and Engineers 4th) :: 14.5
- **Giancoli** (Physics Principles with Applications 7th) :: 10-8 ; 10-9 ; 10-10

Warm up

FD.L1.2-01:

Problem Statement: We wish to describe energies and work for a fluid moving through an enclosed horizontal pipe.

(a) What is the translational kinetic energy of a certain mass of fluid ($\mathbf{m_f}$) moving through the pipe?

1. 1/2 $\mathbf{m_f}\ \mathbf{v}^2$
2. $\mathbf{m_f}\ \mathbf{v}$
3. 1/2 $\mathbf{I_{f,cm}}\ \boldsymbol{\omega}^2$
4. $\mathbf{I_{f,cm}}\ \boldsymbol{\omega}$

(b) What is the gravitational potential energy of a certain mass of fluid ($\mathbf{m_f}$) as it moves through the pipe?

1. 0
2. 1/2 $\mathbf{m_f}\ \mathbf{g}$
3. $\mathbf{m_f}\ \mathbf{g}$
4. $\mathbf{m_f}\ \mathbf{g}\ \mathbf{y}$

(c) Recall that work is $\mathbf{W} = \vec{\mathbf{F}} \cdot \Delta\vec{\mathbf{r}}$. We know that there is a force ($\vec{\mathbf{F}}^{\Delta \mathbf{P}}$) associated with pressure differences; what is the work due to this pressure difference if the fluid is displaced horizontally to the right by some amount $\Delta\mathbf{x}$?

1. $\mathbf{A\ P}$
2. $\mathbf{A\ \Delta P}$
3. $\mathbf{A\ \Delta P\ x}$
4. $\mathbf{A\ \Delta P\ \Delta x}$

(d) Re-write the translational kinetic energy of a certain mass of fluid in terms of density ($\boldsymbol{\rho_f}$) and volume (**V**).

(e) Re-write the gravitational potential energy of a certain mass of fluid in terms of density ($\boldsymbol{\rho_f}$) and volume (**V**).

(f) Re-write the work due to the pressure difference across the fluid in terms of volume (**V**).

(g) Energy density is defined as energy/volume. What are the energy densities for the translational kinetic energy term, gravitational potential energy term, and work due to pressure difference term from the above parts of this problem?

Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- Archimedes Principle
- Buoyant force

Key Equations

$\dot{m}_{in} = \dot{m}_{out}$	$\mathbf{Q = v\ A}$	$v_1 A_1 = v_2 A_2 = v_3 A_3 = \cdots$

$$\mathbf{P_1 + \frac{1}{2}\rho_f v_1^2 + \rho_f\, g\, y_1 = P_2 + \frac{1}{2}\rho_f v_2^2 + \rho_f\, g\, y_2 = \cdots}$$

Key Concepts

- Coming soon to a lecture template near you.

Questions

Act I: Continuity

FD.L1.2-02:

Problem Statement: Did someone say dimensions?

(a) What are the dimensions of volume flow rate?

(1) mass per time
(2) volume * velocity per time
(3) volume * time
(4) volume per time

(b) What are the dimensions of **Q** = **v A** ?

(1) $\frac{[L]^3}{[T]}$

(2) $\frac{[L]}{[T]}$

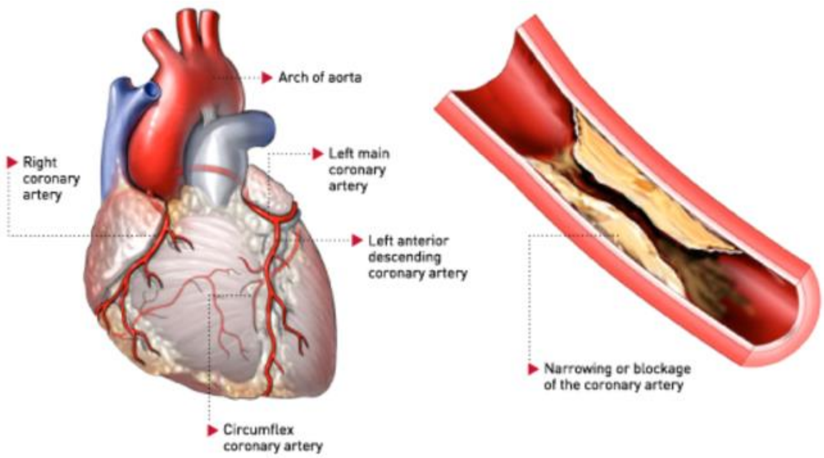
(3) $\frac{[M]}{[T]}$

(4) $\frac{[L]}{[T]^2}$

FD.L1.2-03:

Problem Statement: Blood flows through a coronary artery that is partially blocked by deposits along the artery wall.

(a) Circle the part of the artery where the flux (volume of blood per unit time) is the largest at any given snapshot in time.



(b) Circle the part of the artery where the velocity of the blood is the largest.

FD.L1.2-04:

Problem Statement: Consider a faucet with a diameter of 9.525 mm, and the speed of the water exiting the faucet is about 1.4 m/s.

(a) What is the volume flow rate, in SI units, at the exit location of the faucet?

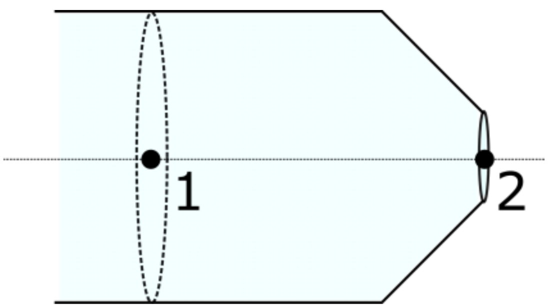
(b) What is the volume flow rate of the water in the pipes under the sink which have a diameter of 12.7 mm?

FD.L1.2-05:

Problem Statement: Why does the diameter of water stream decrease as the water falls from the faucet?.

FD.L1.2-06:

Problem Statement: Your little brother is standing at just the right distance away from you that the water in a garden hose does not reach him. Luckily you have taken physics, so you cover the end of the 8.00 mm radius hose such that you effectively create a 4.00 mm radius circular opening at the end. The water was coming out of the unobstructed hose at 3 m/s. What is the speed of the water coming out of the hose when you cover it with your thumb?



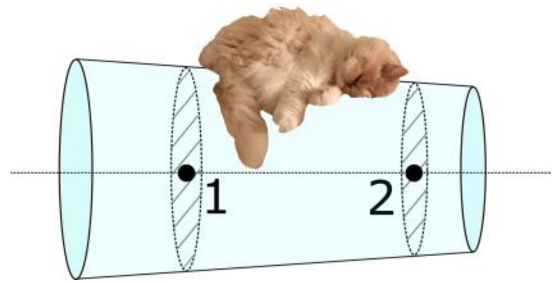
Act II: Bernoulli's Principle

FD.L1.2-07:

Problem Statement: Water flows through a horizontal pipe as shown in the figure. What can be said about the pressure at points **1** and **2**?

Problem Statement: Water flows through a horizontal pipe as shown in the figure. What can be said about the pressure at points **1** and **2**?

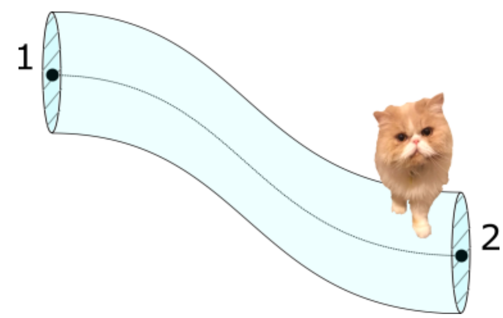
(1) $\mathbf{P_1} > \mathbf{P_2}$
(2) $\mathbf{P_1} < \mathbf{P_2}$
(3) $\mathbf{P_1} = \mathbf{P_2}$
(4) None of the above.



FD.L1.2-08:

Problem Statement: Water flows through a constant diameter pipe as shown in the figure below. What can be said about the pressures at locations **1** and **2**?

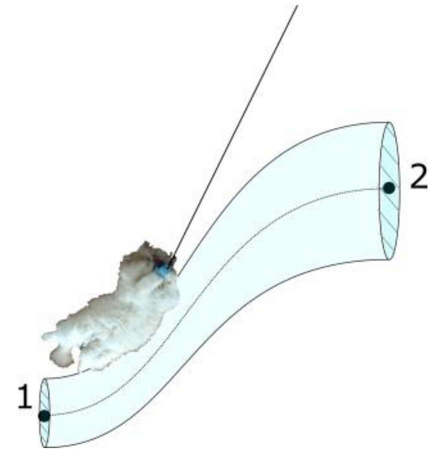
(1) $\mathbf{P_1} > \mathbf{P_2}$
(2) $\mathbf{P_1} < \mathbf{P_2}$
(3) $\mathbf{P_1} = \mathbf{P_2}$
(4) $\mathbf{P_1}$ could be less then or greater than $\mathbf{P_2}$ depending on **h**.



FD.L1.2-09:

Problem Statement: Water flows from location **1** to **2** in a pipe system shown below. The cross-sectional area at **1** is less than at **2** and location **2** is higher in elevation than at **1**. Which of the following statements are *plausible*? The drawing is not to scale.

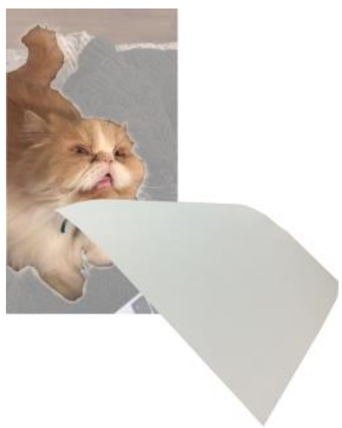
(1) The speed of the water at **1** is less than at **2**.
(2) The speed of the water at **1** is equal to that at **2**.
(3) The speed of the water at **1** is greater than at **2**.
(4) The pressure at **1** is less than that at **2**.
(5) The pressure at **1** is equal to that at **2**.
(6) The pressure at **1** is greater than that at **2**.



FD.L1.2-10:

Problem Statement: Consider holding a normal piece of paper horizontally in front of your mouth. Which of the following actions would result in the paper moving upwards?

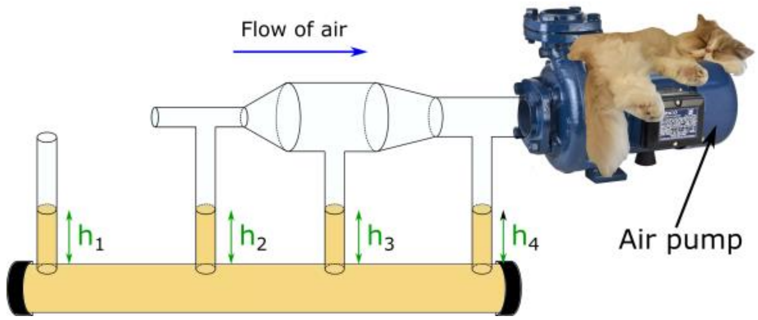
(1) Blow air across the top.
(2) Blow air across the bottom.
(3) Blow air upwards from the bottom.
(4) Blow air downwards from the top.



FD.L1.2-11:

Problem Statement: Consider a device as shown below where an air pump is used to bring air in from the left to the right. The left most tube is far enough away from the other tubes that the air around it does not get disturbed by the air pump.

(a) Rank the pressures across the top of each tube.

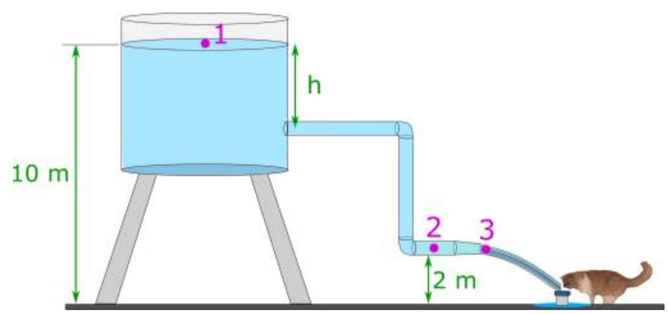


(b) Rank the heights that the liquid rises to in each tube.

FD.L1.2-12:

Problem Statement: Water flows steadily from an open tank near the surface of the earth filling a bow which Bernoulli is drinking from. The elevation of location **1** is 10.0 meters, and the elevation of points **2** and **3** is 2.00 m. The cross-sectional area at location **2** is 4.80×10^{-2} m^2 ; at location **3** where the water is discharged it is 1.60×10^{-2} m^2. The cross-sectional area of the tank is very large compared with the cross-sectional area of the pipes at 50.3 m^2.

(a) What is approximately true about the pressure and velocity at each location?



$P_1 \approx$ **$v_1 \approx$**

$P_2 \approx$ **$v_2 \approx$**

$P_3 \approx$ **$v_3 \approx$**

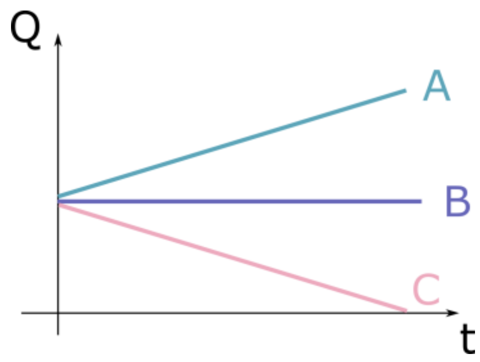
(b) Determine the flow rate.

(c) How long would it take to fill a 1 liter bottle?

(d) How long would it take to drain the tank if it's volume is roughly 302,000 liters?

(1) Less than 1510 s
(2) More than 1510 s
(3) Equal to 1510 s

(e) Below are three graphs representing the flow rate as a function of time. Which graph do you think best represents the real flow rate?



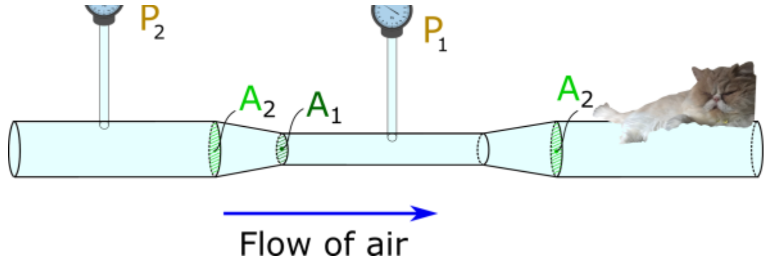
(f) How long would it take to drain the tank if it's volume is roughly 302,000 liters?

(g) Water flows steadily from an open tank near the surface of the earth filling a bow which Bernoulli is drinking from. The elevation of location **1** is 10.0 meters, and the elevation of points **2** and **3** is 2.00 m. The cross-sectional area at location **2** is 4.80 x 10^{-2} m^2 ; at location **3** where the water is discharged it is 1.60 x 10^{-2} m^2. The cross-sectional area of the tank is very large compared with the cross-sectional area of the pipes at 50.3 m^2. **What is the pressure at location 2?**

FD.L1.2-13:

Problem Statement: A Venturi meter is a device for measuring the speed of fluid within a pipe. The drawing shows a gas flowing at a speed of $\mathbf{v_2}$ through a horizontal section of pipe whose cross-sectional area is $\mathbf{A_2}$ = 0.0700 m^2. The gas has a density of 1.30 kg/m^3. The Venturi meter has a cross-sectional area in the center of $\mathbf{A_1}$ = 0.050 m^2. The pressure difference between the two sections is $\mathbf{P_2}$ - $\mathbf{P_1}$ = 120 Pa.

(a) Find the speed $\mathbf{v_2}$ of the gas in the larger pipe.



(b) Find the volume flow rate of the gas.

FD.L1.2-14:

Problem Statement: Planes and planes and planes.

(a) How does an airfoil, like the wings of a plane, fly?

(1) Bernoulli's principle.
(2) Momentum transfer.
(3) Continuity.
(4) Magic.
(5) Friction.
(6) Coffee.
(7) Money.

(b) Of the options provided above, three are the main ideas that can be used to describe where lift comes from. Discuss with your neighbors which three of those are and how they contribute to lift.

Conceptual questions for discussion

1. Coming soon.

Hints

FD.L1.2-01: No hints.

FD.L1.2-02: No hints.

FD.L1.2-03: No hints.

FD.L1.2-04: No hints.

FD.L1.2-05: No hints.

FD.L1.2-06: No hints.

FD.L1.2-07: No hints.

FD.L1.2-08: No hints.

FD.L1.2-09: No hints.

FD.L1.2-10: No hints.

FD.L1.2-11: No hints.

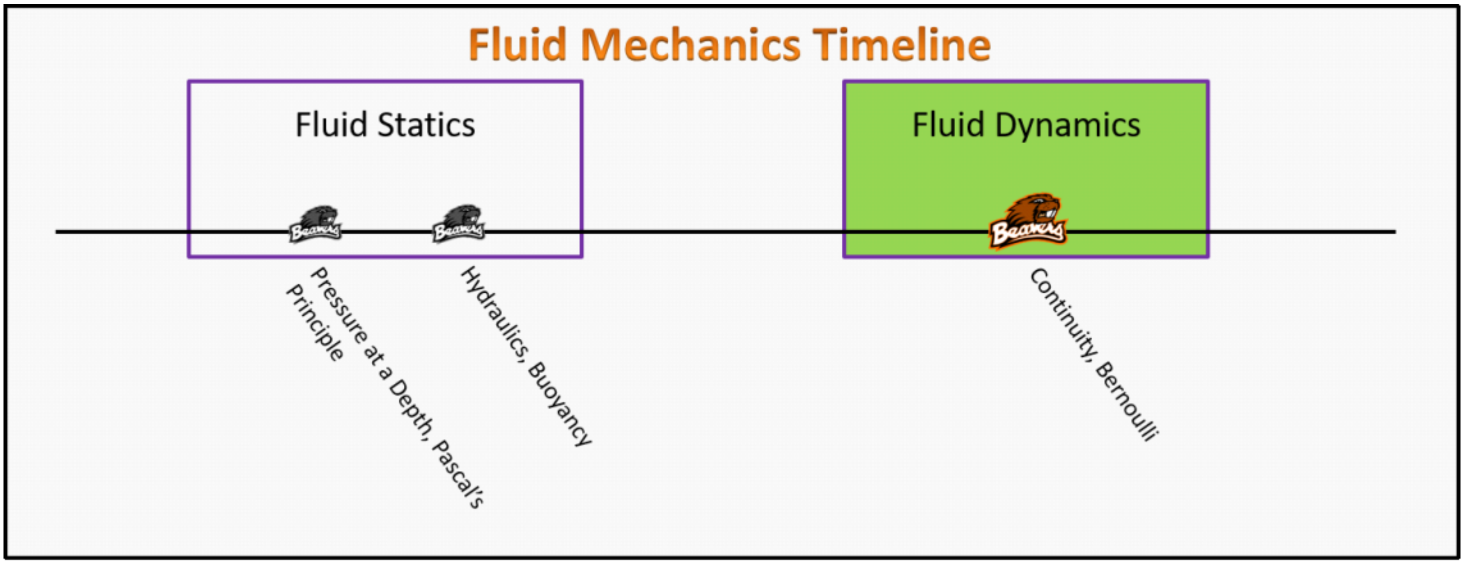
FD.L1.2-12: No hints.

FD.L1.2-13: No hints.

FD.L1.2-14: No hints.

Fluid Dynamics
Practice Stage (FD.L1.3)

Lecture 1
Continuity, Bernoulli



FS.L2.3-01

Description: Continuity and capillaries

Learning Objectives: [x]

Problem Statement: As blood passes through the capillary bed in an organ, the capillaries join to form venules (small veins). If the blood speed increases by a factor of 4.00 and the total cross-sectional area of the venules is 10.0 cm^2, what is the total cross-sectional area of the capillaries feeding these venules?

(a) If the blood speed increases by a factor of 4.00 and the total cross-sectional area of the venules is 10.0 cm^2, what is the total cross-sectional area of the capillaries feeding these venules?

(1) 2.50 cm^2
(2) 40.0 cm^2
(3) 0.40 cm^2
(4) 6.00 cm^2

(b) How many capillaries are involved if their average diameter is 10.0 μm?

(1) 3.18×10^6
(2) 1.27×10^7
(3) 5.09×10^7
(4) 5.22×10^1

FS.L2.3-02

Description: Bernoulli's conceptual problem

Learning Objectives: [x]

Problem Statement: A baby elephant sprays water through its trunk at another baby elephant. The base of the elephant's trunk has twice the cross sectional area as the opening at the end. If the pressure in the water is atmospheric at both the start and end of the trunk, which of the following statements are true?

(1) The end of the elephant's trunk is higher than the base
(2) The end of the elephant's trunk is lower than the base
(3) The end of the elephant's trunk is at the same height as the base
(4) There is not enough information given to determine the relative heights of the base and end of the trunk

FS.L2.3-03

Description: Bernoulli's work out problem

Learning Objectives: [x]

Problem Statement: A baby elephant sprays water through its trunk at another baby elephant. The base of the elephant's trunk has twice the cross sectional area as the opening at the end. If the pressure in the water is the same at the start and end of the trunk and the water exit's the baby elephant's trunk at 3.61 m/s, how much higher or lower is the end of the trunk from the base?

(1) 2 meters higher
(2) 55 cm higher
(3) The same height
(4) 55 cm lower
(5) 2 meters lower
(6) It is not possible to determine

FS.L2.3-04

Description: Bernoulli's conceptual problem

Learning Objectives: [x]

Problem Statement: A baby elephant sprays water through its trunk at another baby elephant. The base of the elephant's trunk has twice the cross sectional area as the opening at the end. If the pressure in the water at the start of the trunk is larger than atmospheric pressure, and the baby elephant is pointing her trunk upwards, which of the following statements are true?

(1) The water will exit the trunk at a higher speed than it had at the start of the trunk
(2) The water will exit the trunk at a lower speed than it had at the start of the trunk

(3) The water will exit the trunk at the same speed as it had at the start of the trunk
(4) There is not enough information given to determine the relative speed of the water

FS.L2.3-05

Description: Bernoulli's work out problem

Learning Objectives: [x]

Problem Statement: A baby elephant sprays water through its trunk at another baby elephant. The base of the elephant's trunk has twice the cross sectional area as the opening at the end. The pressure in the water at the start of the trunk is twice atmospheric and the end of the baby elephant's trunk is 2 meters higher than the start of her trunk. How fast does the water exit the trunk?

(1) 14.8 m/s
(2) 218 m/s
(3) 22.0 m/s
(4) 18.1 m/s