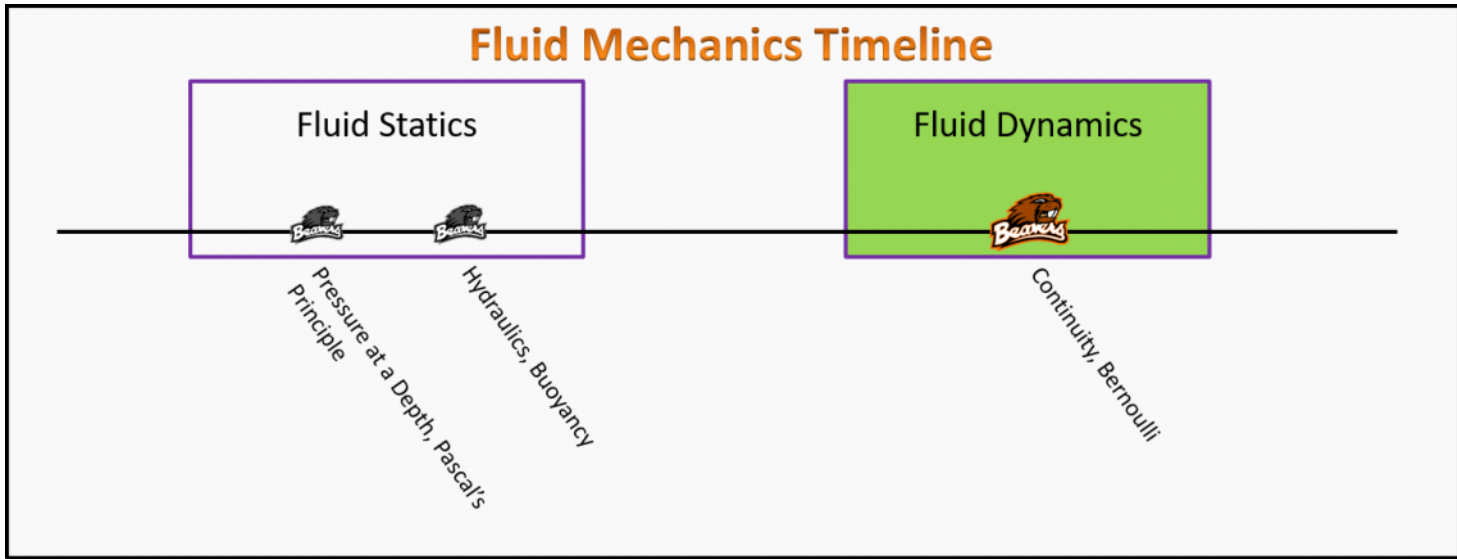# Fluid Mechanics
Foundation Stage (FD.2.L1)

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.2.L1-1:

Description: Describe what pressure means in terms of forces and areas.

Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

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 (m_f) moving through the pipe?

- (1) $1/2\ m_f\ v^2$
- (2) $m_f\ v$
- (3) $1/2\ I_{f,cm}\ \omega^2$
- (4) $I_{f,cm}\ \omega$

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

- (1) 0
- (2) $1/2\ m_f\ g$
- (3) $m_f\ g$
- (4) $m_f\ g\ y$

(c) Recall that work is $W = \vec{F} \cdot \Delta\vec{r}$. We know that there is a force ($\vec{F}^{\Delta P}$) 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 Δx?

- (1) $A\ P$
- (2) $A\ \Delta P$
- (3) $A\ \Delta P\ x$
- (4) $A\ \Delta P\ \Delta x$

(d) Re-write the translational kinetic energy of a certain mass of fluid in terms of density (ρ_f) and volume (**V**).

(e) Re-write the gravitational potential energy of a certain mass of fluid in terms of density (ρ_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.

Key Terms

- ○ Archimedes Principle
- ○ Buoyant force

Key Equations

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

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

Key Concepts

- ○

Questions

Act I: Continuity

FD.2.L1-2:

Description: Identify which PV diagram represents an isochoric process. (2 minutes + 2 minutes)

Learning Objectives: [1, 12, 13]

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) $\dfrac{[L]^3}{[T]}$

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

    (3) $\dfrac{[M]}{[T]}$
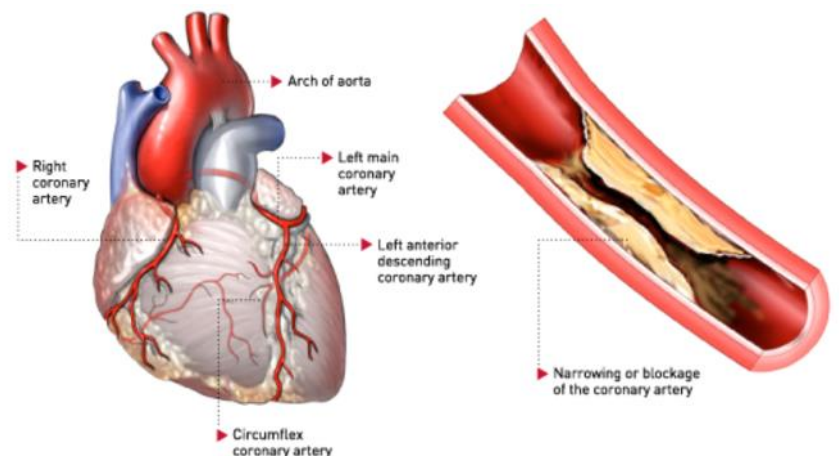
    (4) $\dfrac{[L]}{[T]^2}$

FD.2.L1-3:

Description: Proportional reasoning with ideal gas law. (3 minutes)

Learning Objectives: [1, 12, 13]

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.

Description: Determine signs of first law quantities. (5 minutes)

Learning Objectives: [1, 12, 13]

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?

Description: Identify which diagram represents an isothermal process. (2 minutes)

Learning Objectives: [1, 12, 13]

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

Description: Proportional reasoning with ideal gas law. (2 minutes + 4 minutes)

Learning Objectives: [1, 12, 13]

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?
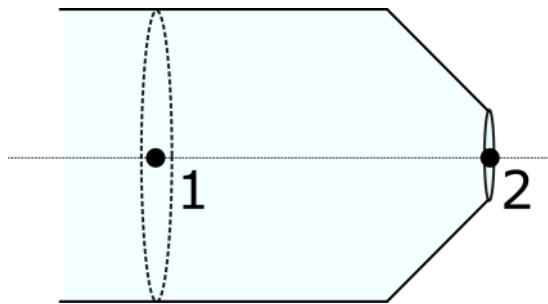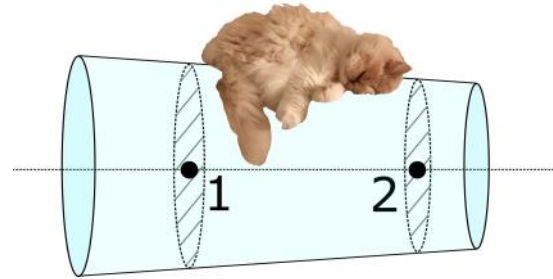

Act II: Bernoulli's Principle

FD.2.L1-7:

Description: Determine signs of first law quantities. (5 minutes)

Learning Objectives: [1, 12, 13]

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) $P_1 > P_2$
(2) $P_1 < P_2$
(3) $P_1 = P_2$
(4) None of the above.

Description: Identify which statements best represents an adiabatic curve on PV diagram (3 minutes)

Learning Objectives: [1, 12, 13]

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) $P_1 > P_2$
(2) $P_1 < P_2$
(3) $P_1 = P_2$
(4) P_1 could be less then or greater than P_2 depending on **h**.
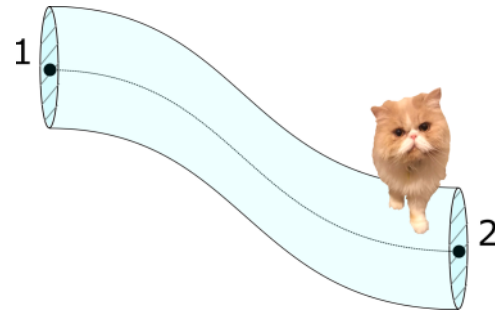
**Description:**   Identify proportionality for adiabatic process. (3 minutes)

Learning Objectives: [1, 12, 13]

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**.
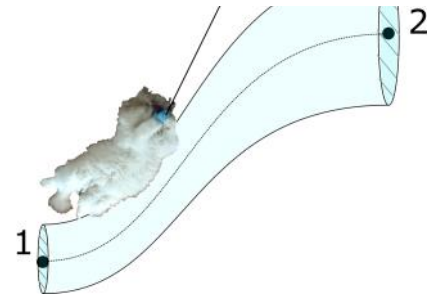
Description: Determine signs of first law quantities. (5 minutes)

Learning Objectives: [1, 12, 13]

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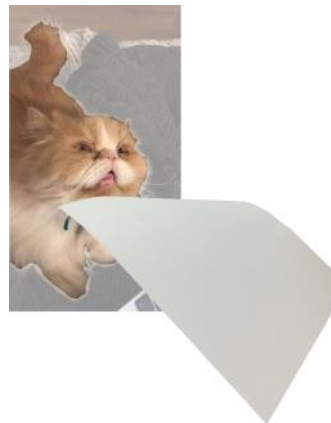
Problem Statement: Consider a device as shown below where an air pump is used to bring air in from the left to the right. The left most tube is far enough away from the other tubes that the air around it does not get disturbed by the air pump.

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

Flow of air

h_1 h_2 h_3 h_4 Air pump
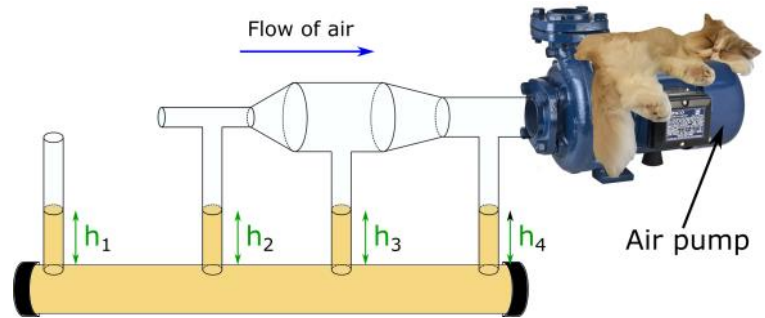
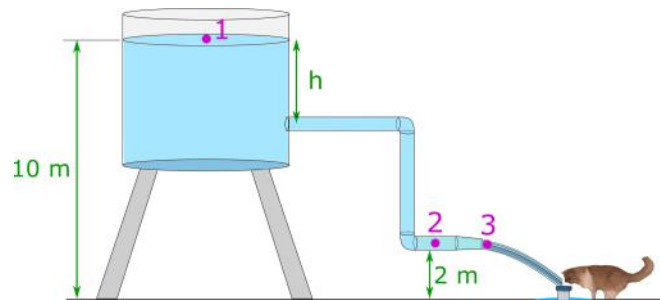**(b)** Rank the heights that the liquid rises to in each tube.

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?

$P_1 \approx$ $v_1 \approx$

$P_2 \approx$ $v_2 \approx$

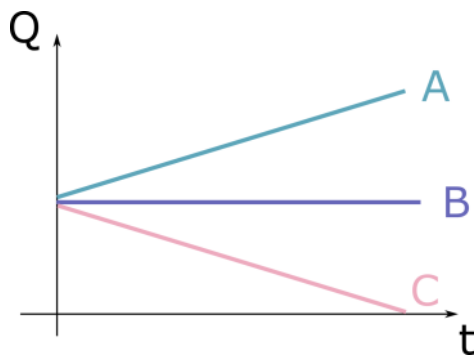$P_3 \approx$ $v_3 \approx$

10 m

2 m

h

(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?**
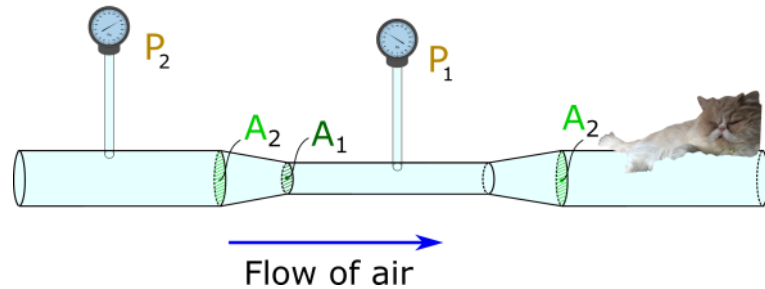
FD.2.L1-13:

Description: Determine signs of first law quantities. (5 minutes)

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 v_2 through a horizontal section of pipe whose cross-sectional area is $A_2 = 0.0700$ m². The gas has a density of 1.30 kg/m³. The Venturi meter has a cross-sectional area in the center of $A_1 = 0.050$ m². The pressure difference between the two sections is $P_2 - P_1 = 120$ Pa.

(a) Find the speed v_2 of the gas in the larger pipe.

Flow of air

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

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.2.L1-1: No hints.

FD.2.L1-2: No hints.

FD.2.L1-3: No hints.

FD.2.L11-4: No hints.

FD.2.L1-5: No hints.

FD.2.L1-6: No hints.

FD.2.L1-7: No hints.

FD.2.L1-8: No hints.

FD.2.L1-9: No hints.

FD.2.L1-10: No hints.

FD.2.L1-11: No hints.

FD.2.L1-12: No hints.

FD.2.L1-13: No hints.

FD.2.L1-14: No hints.