Physics 131- Fundamentals of Physics for Biologists I

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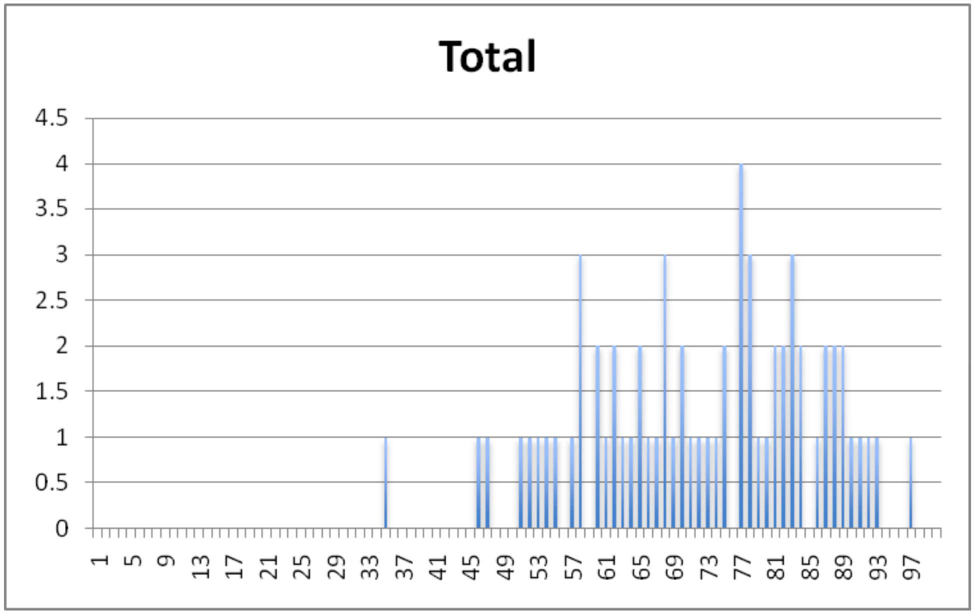
- EXAM 2 Review
- Fluid Flow
- Energy

EXAM 2



Average = 72.2
Standard Deviation = 13

	Q1	Q2	Q3	Q4	Q5
Score	17.4	14.2	12.5	8.8	19.8
STD	3.0	7.9	2.7	0.9	5.2
Max	25	25	15	10	25

Foothold ideas: Buoyancy

- ***Archimedes' principle***: When an object is immersed in a fluid (in gravity), the result of the fluid's pressure variation with depth is an upward force on the object equal to the weight of the water that would have been there if the object were not.
- As a result, an object whose density is less than that of the fluid will float, one whose density is greater than that of the fluid will sink.
- An object less dense than the fluid will float with a fraction of its volume under the fluid equal to the ratio of its density to the fluid's density.

Buoyancy and Flotation

A submerged object displaces its own **volume** of liquid

A floating object displaces its own **weight** in liquid (displaces liquid equal to its own weight)

Fraction of object submerged is equal to the **ratio** of the object's density to that of the fluid

Buoyancy

Example: Wood sphere in water

Weight of the wood:

$\mathbf{F}_g = -\rho_{Wood} V \mathbf{g}$

The fluid "provides" as much buoyant force as the weight of fluid pushed out of the way

$\mathbf{F}_{\mathbf{B}} = \rho_{fluid} V \mathbf{g}$

Net force on wood:

$\mathbf{F}_{net} = \rho_{fluid} V \mathbf{g} - \rho_{Wood} V \mathbf{g} = (\rho_{fluid} - \rho_{Wood}) V \mathbf{g}$

A boat carrying a large boulder is floating on a lake. The boulder is thrown overboard and sinks. The water level in the lake (with respect to the shore)

1. rises
2. **drops**
3. remains the same

Density of water = 1 g/cc
Density of rock = 10 g/cc
Volume of rock = 10 cc

In the boat:
Rock displaces own weight of water = 100 g of water = 100 cc

Sinking:
Rock displaces own volume of water = 10 cc

Less water displaced when rock is sinking, so water level drops

Buoyancy

V_{ice} is the total volume of the ice

V_{water} is the volume of the water displaced

- Equal to the volume of the ***submerged fraction of the iceberg*** (89% of the ice is below water)

$V_{water} = 0.89 * V_{ice}$

Buoyancy force: $\rho_{water} V_{water} \mathbf{g}$

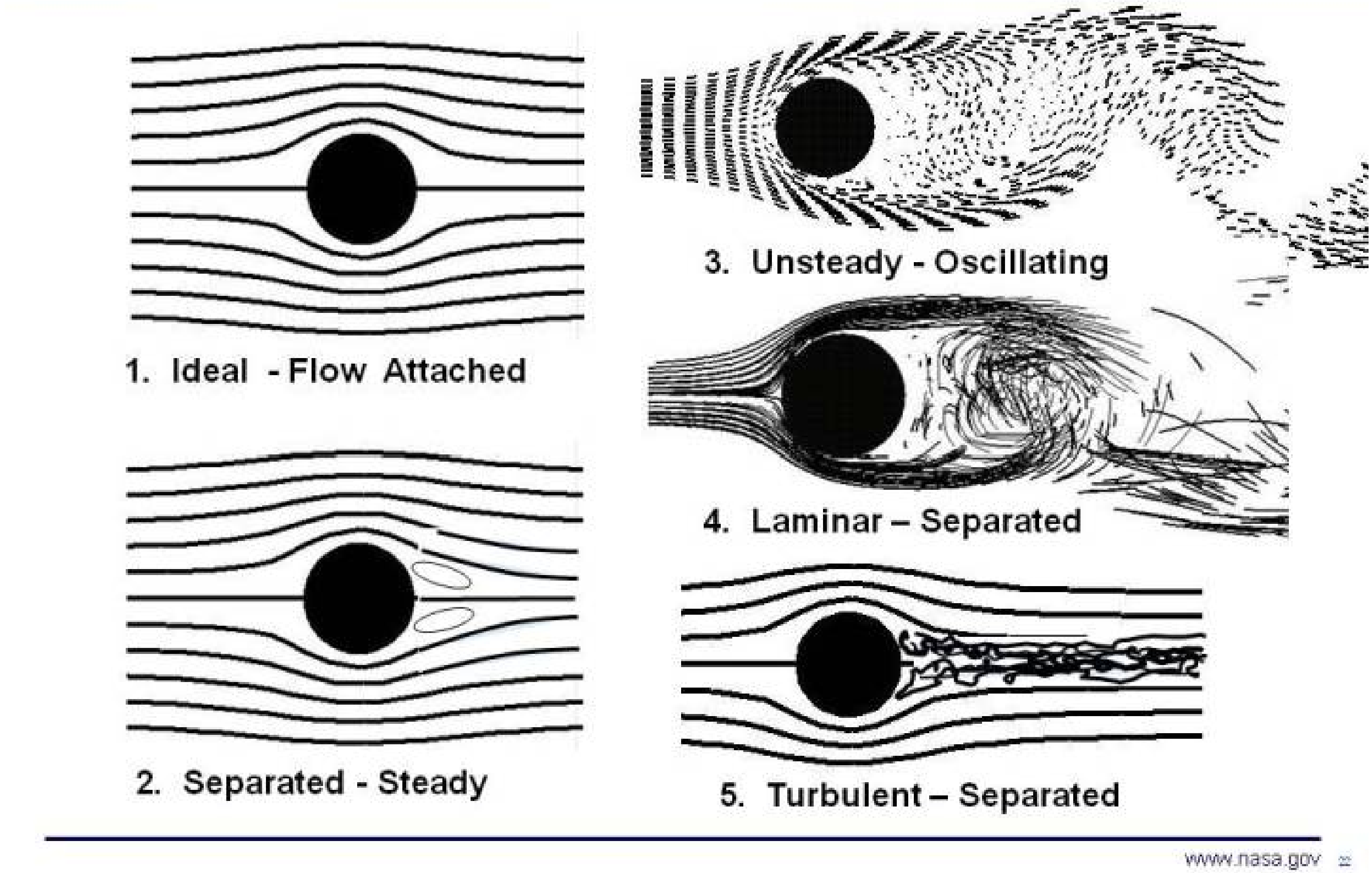
= Weight of iceberg: $\rho_{ice} V_{ice} \mathbf{g}$

$\rho_{water} V_{water} \mathbf{g} = \rho_{ice} V_{ice} \mathbf{g}$

$\rho_{water*} * 0.89 * V_{ice} = \rho_{ice} V_{ice}$

$\rho_{water} * 0.89 = \rho_{ice}$

Fluid Flow


1. Ideal - Flow Attached
2. Separated - Steady
3. Unsteady - Oscillating
4. Laminar – Separated
5. Turbulent – Separated
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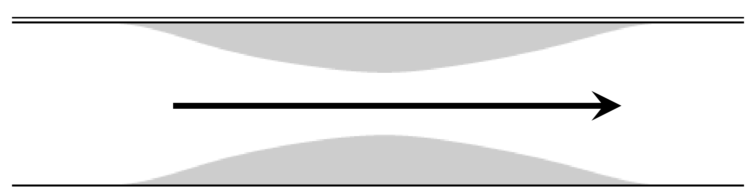
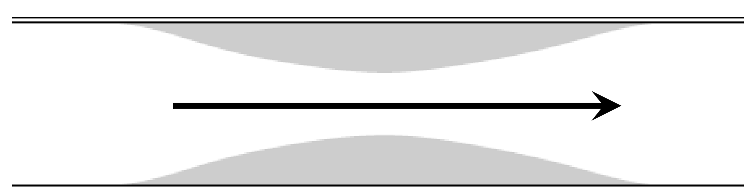
Blood flows through a coronary artery that is partially blocked by deposits along the artery wall. Through which part of the artery is the flux (volume of blood per unit time) largest?

1. The narrow part
2. The wide part
3. Same in both

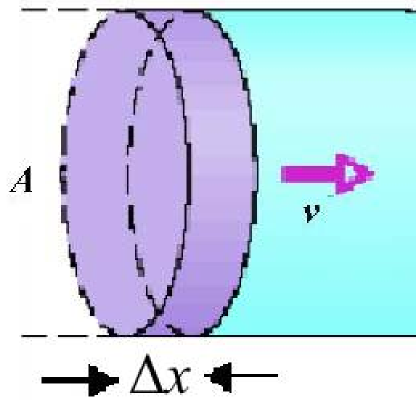


Blood flows through a coronary artery that is partially blocked by deposits along the artery wall. Through which part of the artery is the speed of the blood the largest?

1. The narrow part
2. The wide part
3. Same in both



Quantifying fluid flow



Area: A
Velocity: v

What is the volume of fluid flowing through area A in time Δt ?

What is the mass of fluid flowing through area A in time Δt ?

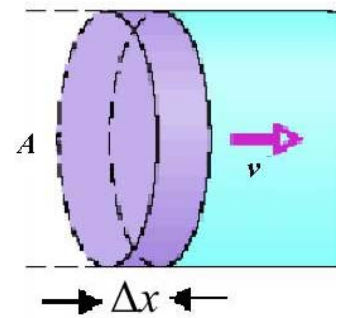
Whiteboard, TA & LA

Foothold ideas: Matter Current (incompressible)

- Q = Current = (volume crossing a surface)/s

$$[Q] = \text{m}^3/\text{s}$$

$$\vec{Q} = \frac{(A\Delta\vec{x})}{\Delta t} = \frac{(A\vec{v}\Delta t)}{\Delta t} = A\vec{v}$$

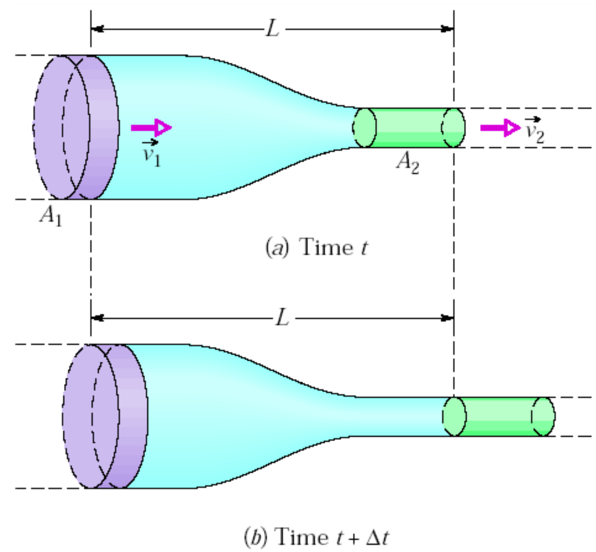


- Conservation of matter: "What goes in must come out."

$$\Delta V_{in} = \Delta V_{out}$$

$$A_1(v_1\Delta t) = A_2(v_2\Delta t)$$

$$Q = Av = \text{ constant}$$

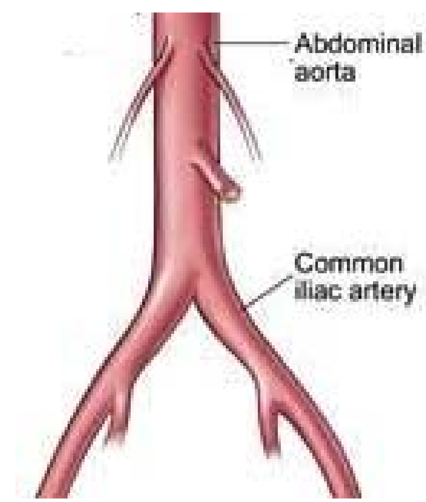


You can readily observe that when you run water from a faucet at a moderate steady flow rate, the stream of water narrows as it descends. This implies that the speed of the water at point 2 is ________ the speed at point 1.
Which best completes the sentence?

A. greater than (>)
B. less than (<)
C. equal to (=)

The main blood vessel carrying blood out of your heart is the aorta. It carries blood down towards the legs. In your abdomen it splits into two, the common iliac arteries. The diameter of a typical aorta is 2 cm, while the iliac arteries typically have diameters of about 1 cm. A typical value for the speed of the blood in the aorta is $v_A = 30$ cm/s when the heart is contracting. While this is occurring, the speed of the blood flowing in the iliac arteries will be closest to

1. 120 cm/s
2. 60 cm/s
3. 30 cm/s
4. 15 cm/s
5. 7.5 cm/s
6. It's not close to any of these.



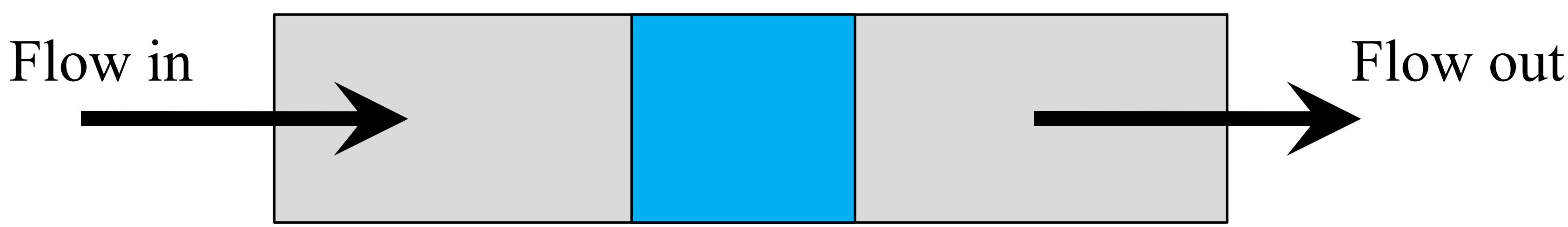
Remember: Viscous Drag

- A fluid flowing in a pipe doesn't slip through the pipe in a frictionless manner.
- The fluid sticks to the walls moves faster at the middle of the pipe than at the edges.
  As a result, it has to "slide over itself" (shear).
- There is friction between layers of fluid moving at different speeds that creates a viscous drag force, trying to reduce the sliding.
- The drag is proportional to the speed and the length of pipe.

$$F_{drag} = 8\pi\mu L v$$

Implication: Pressure drop

- If we have a fluid moving at a constant rate and there is drag, N2 tells us there must be another force to balance the drag.
- The internal pressure in the fluid must drop in the direction of the flow to balance drag.



Draw the forces on the blue cylinder of liquid

Whiteboard, TA & LA

Implication: Pressure drop

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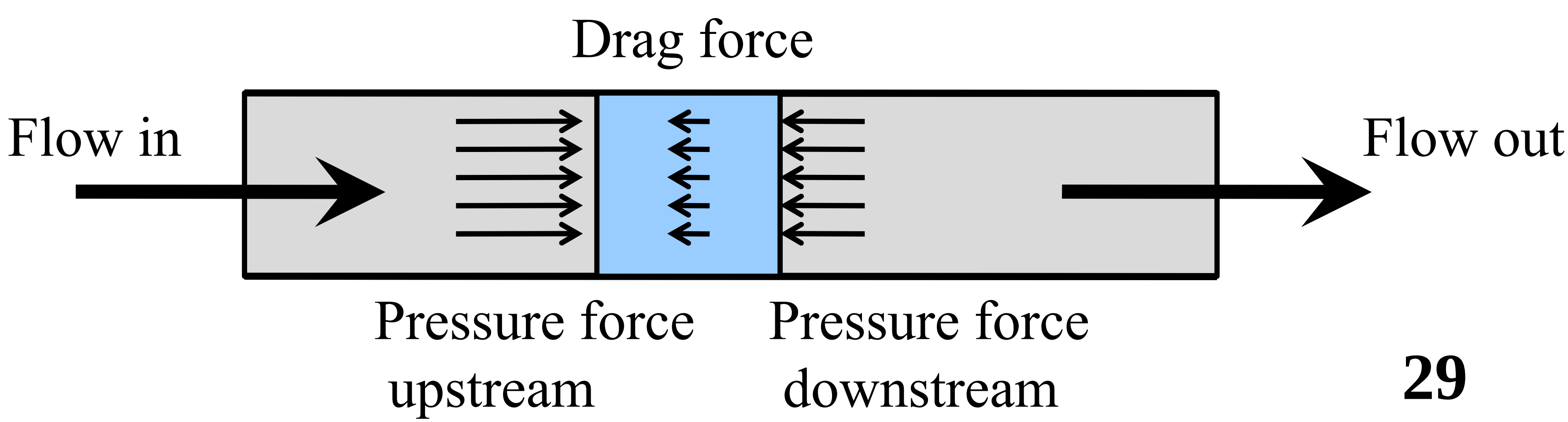
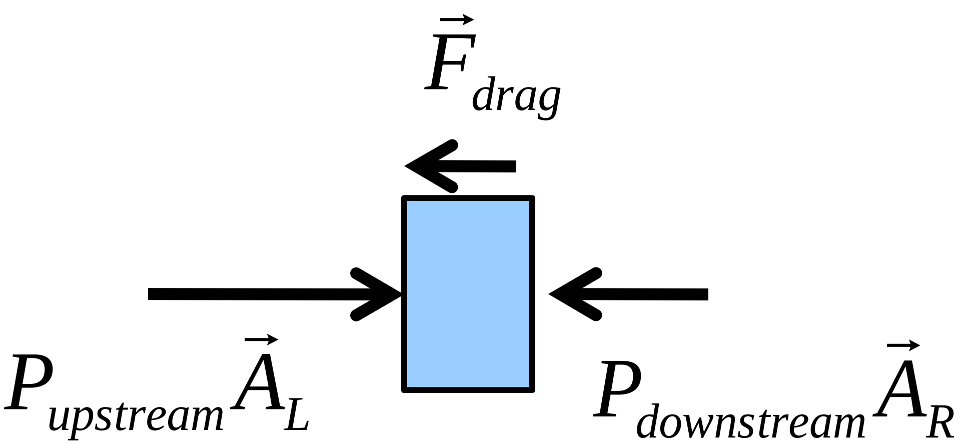


The Hagen-Poiseuille Law

- If the pressure drop balances the drag (and thereby maintains a constant flow) N2 tells us



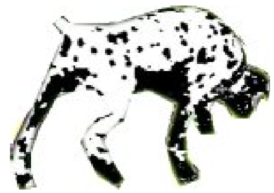
$$\Delta P\, A = 8\pi\mu L v$$

$$\Delta P\, A = 8\pi\mu L\left(\frac{Q}{A}\right)$$

$$\Delta P = \left(\frac{8\pi\mu L}{A^2}\right)Q = \left(\frac{8\mu L}{\pi R^4}\right)Q$$

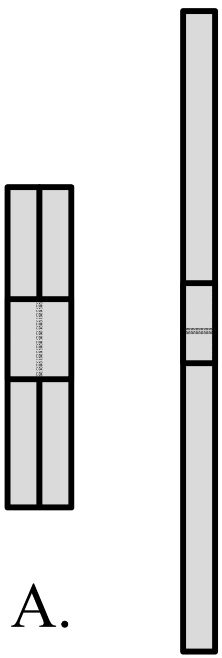
$$\Delta P = ZQ$$

Flow rate Q is directly proportional to pressure gradient
is inversely proportional to viscosity
depends on the 4th power of radius!



Seeing the implications

Construct the two combinations of coffee straws as shown in the figure below. Fill your lungs with air and blow as hard as you can through each one.



A.

B.

Which did you find?

A. Arrangement A was faster.
B. Arrangement B was faster.
C. Both were the same.