Physics 5B

Lecture 3, January 13, 2012

Chapter 13, Fluids

What fraction of an iceberg's volume is above water?

Density of sea water is 1025 kg/m^3.

Density of pure fresh water ice is 920 kg/m^3.

Another ice cube riddle

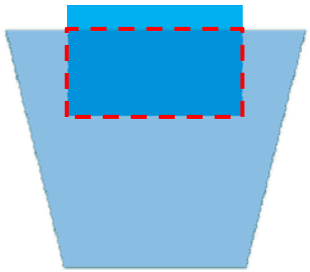
A cube of fresh-water ice is floating in a glass of salty sea water that is filled up exactly to the rim. As the ice melts,

Density of sea water is 1025 kg/m^3.

A. water overflows the rim.
B. no water overflows, and the water level doesn't change.
C. the water level drops.

Explanation

A cube of fresh-water ice is floating in a glass of salty sea water that is filled up exactly to the rim.



Density of sea water is 1025 kg/m^3.

- *The weight of the ice cube is equal to the buoyant force (it is floating).*
- *Archimedes' principle: the buoyant force is equal to the weight of salt water displaced (the amount that would fill the dashed red box).*
- So the weight of the ice is equal to the weight of displaced salt water.
- Therefore, the ice melts into fresh water of weight exactly equal to the weight of the displaced salt water.
- But a given mass of fresh water will take up more volume than the same mass of salt water, so the melted fresh water takes up more than the dashed red volume and therefore overflows the glass.

Laminar Flow Streamlines

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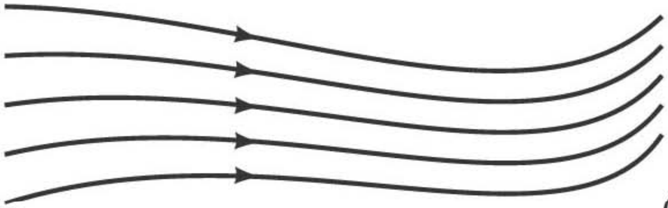
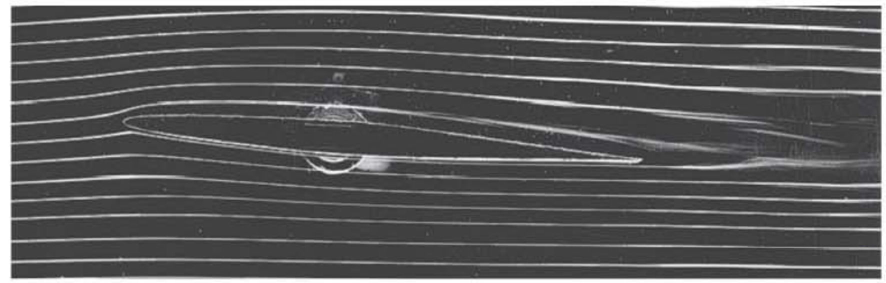
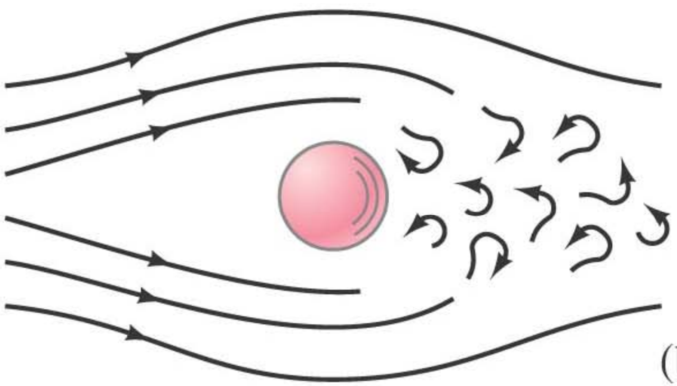
Laminar Flow vs Turbulence



(a)





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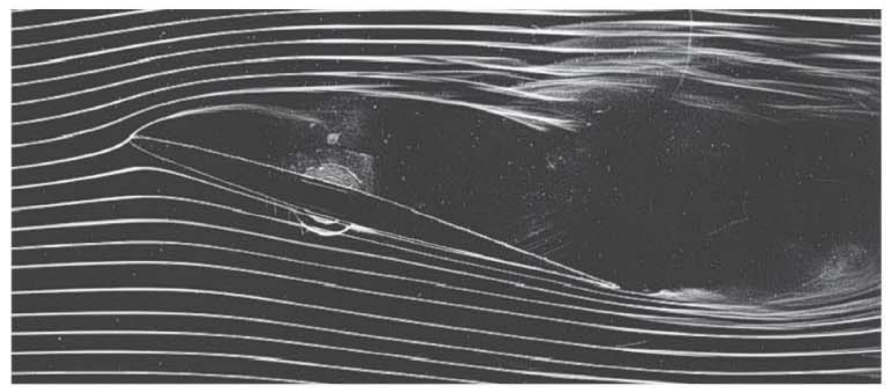


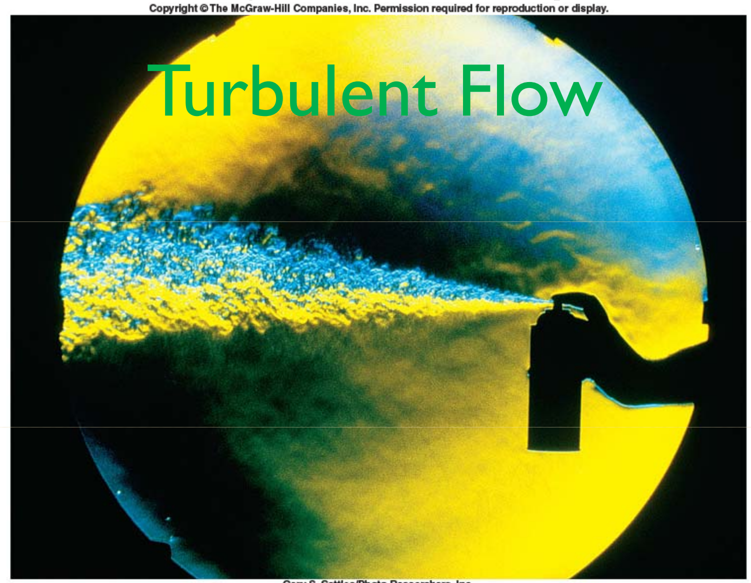
Contradiction?

- A fluid with near zero viscosity η (frictional drag) will not easily exhibit laminar flow. Instead, the flow will be turbulent, especially if the fluid is moving fast.
- But the equations that we will use (e.g. Bernoulli's equation) hold only for laminar flow and neglect viscosity!
- What this means is that *our results that ignore viscosity must be approximate in practice.*

Reynolds Number:

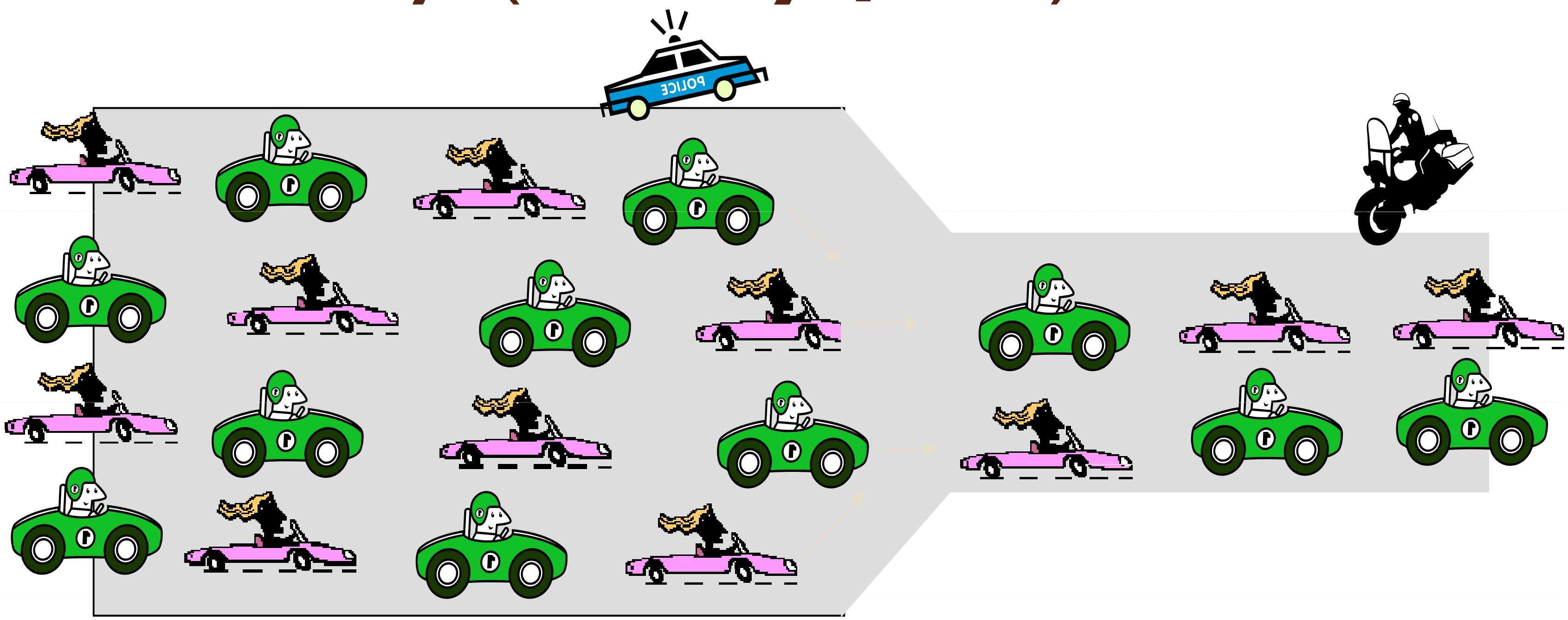
$$R \equiv \frac{2\bar{v}r\rho}{\eta}$$

If R is large, then the flow about the object of size r will be turbulent.



Gary S. Settles/Photo Researchers, Inc.

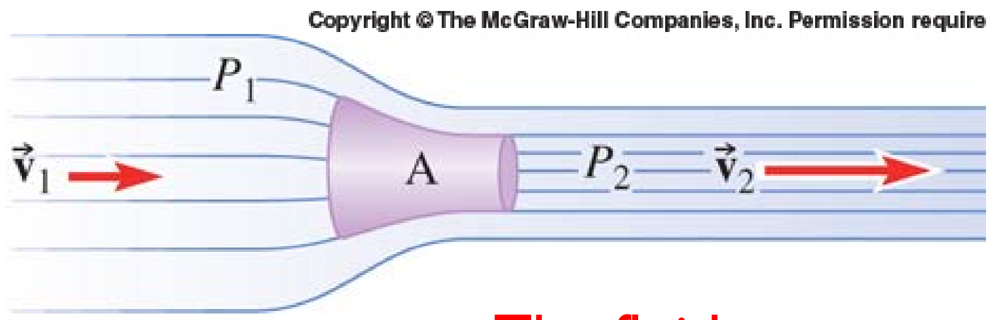
Continuity (***steady flow***)



A four-lane highway merges down to a two-lane highway. The officer in the police car observes 8 cars passing every second, at 30 mph. How many cars does the officer on the motorcycle observe passing every second? A) 4 B) 8 C) 16

How fast must the cars in the two-lane section be going?
A) 15 mph B) 30 mph C) 60 mph

As the incompressible fluid moves from the thick section of pipe into the thin section, it must (assuming steady flow)



The fluid must accelerate in order to get the same rate of flow in the thin section as in the thick section.

A. maintain constant velocity.

B. accelerate (increase speed).

C. decelerate (decrease speed).

Continuity Equation

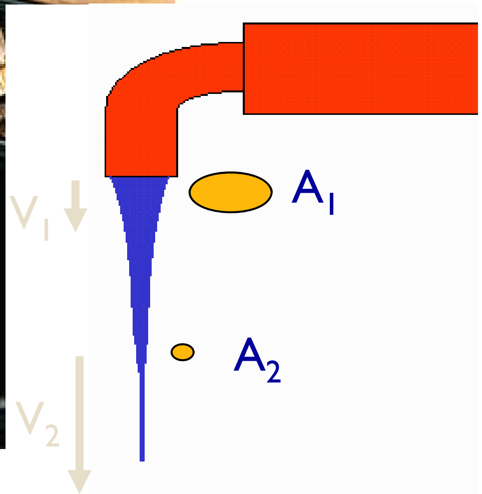
$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

Mass of fluid passing Point #1 each second

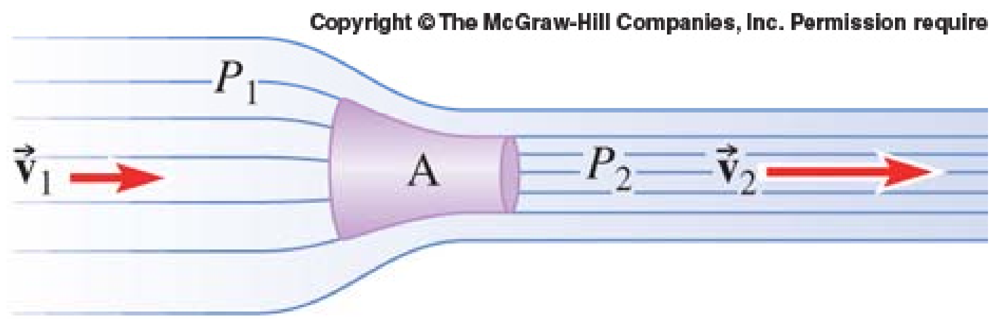
Mass of fluid passing Point #2 each second

Special case: incompressible fluid, for which $\rho_1 = \rho_2$.

Photo courtesy of Kohler Co.



Considering the answer to the previous question and recalling Newton's second law, what happens to the pressure of the fluid as it moves from the thick section to the thin section?



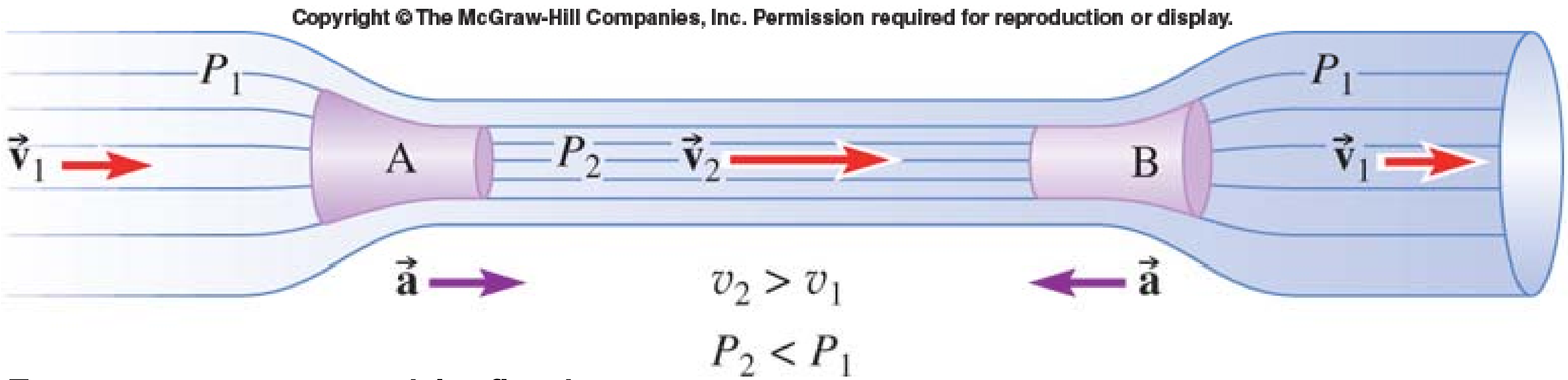
A. $P_1 = P_2$

B. $P_1 > P_2$

C. $P_2 > P_1$

The only force present to accelerate the water to higher velocity is the pressure, so P_1 must be greater than P_2 in order to give a net force and acceleration in the direction of the flow.

Pressure vs. Velocity in Laminar Flow

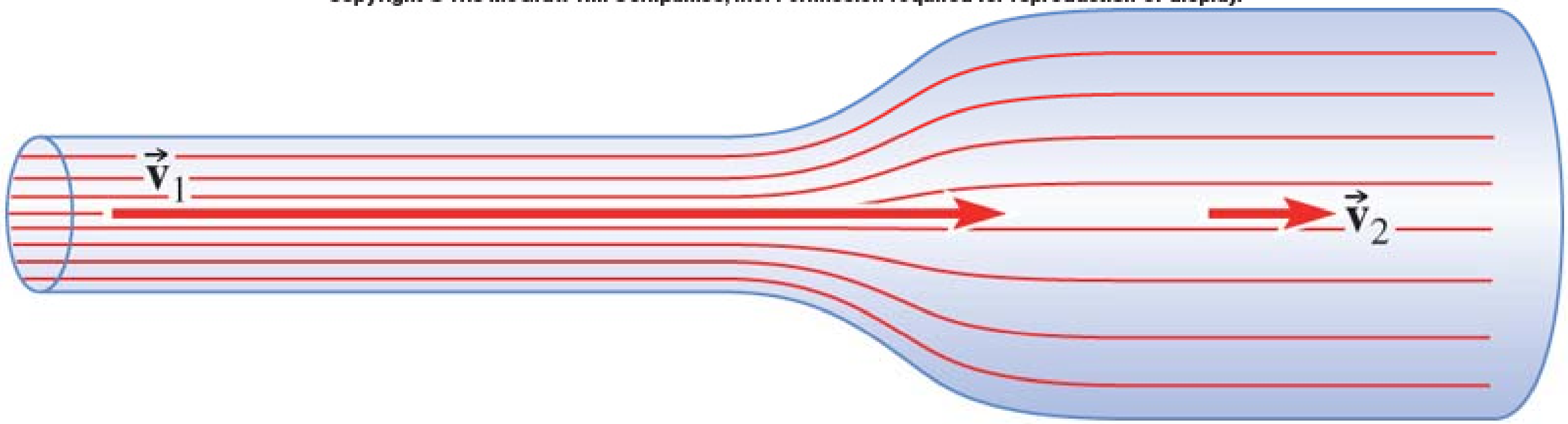


For an incompressible fluid:

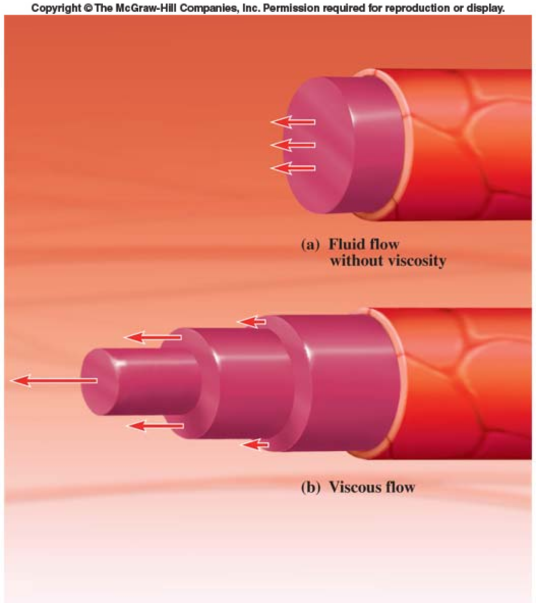
$$A_1 v_1 = A_2 v_2 \quad \text{Continuity Equation}$$

$$p_1 + \frac{1}{2}\rho_1 v_1^2 = p_2 + \frac{1}{2}\rho_2 v_2^2 \quad \text{Bernoulli's Equation}$$

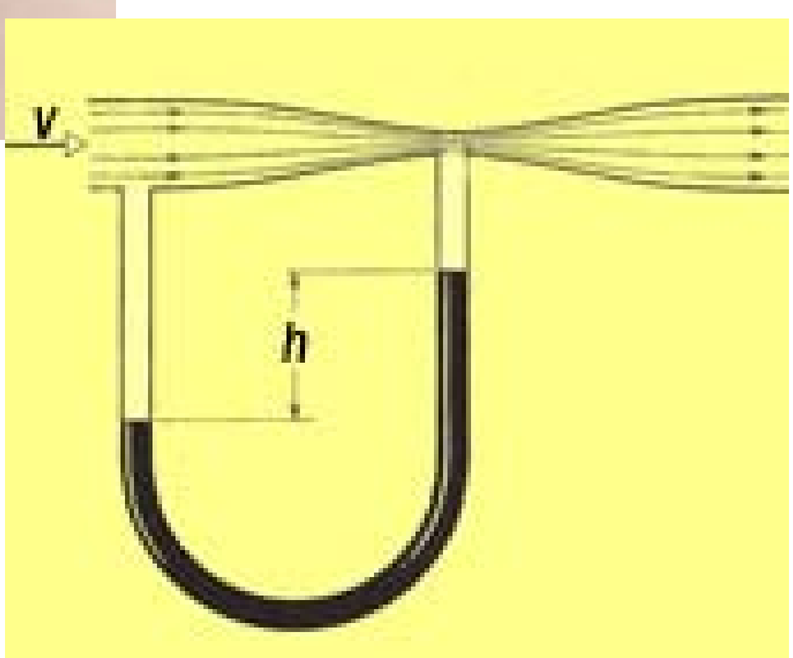
Illustration of Laminar Flow



Note: in a real situation with viscosity, the velocity will be near zero close to the wall of the pipe and highest in the center, not constant across the diameter. However, the continuity equation and Bernoulli's equation *still hold along any individual streamline*.



Venturi Demo

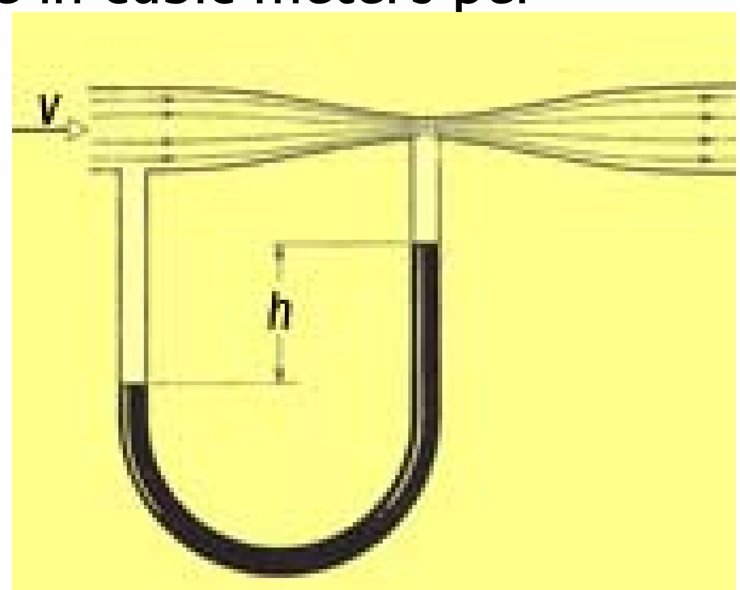


Venturi Flowmeter

A 1.0-cm diameter venturi flowmeter is inserted in a 2.0-cm diameter pipe carrying water.

a) What is the flow speed *v* in the pipe if the pressure difference between the venturi and the unconstricted pipe is 17 kPa?

b) What is the volume flow rate in cubic meters per second?



Concept Quiz

If I gently blow air ***between*** the light bulbs, what will they do?

A. Move together

B. Move apart

C. Remain as they are