



# Physic<sup>2</sup> 121: Phundament<sup>°</sup>Is of Phy<sup>2</sup>ics I

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PHYS 121



# Chapter 9

## Solids and Fluids



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## Buoyant Force

- The magnitude of the buoyant force always equals the weight of the displaced fluid
- The buoyant force is the same for a totally submerged object of any size, shape, or density

$$B = \rho_{fluid} V_{fluid} g = W_{fluid}$$

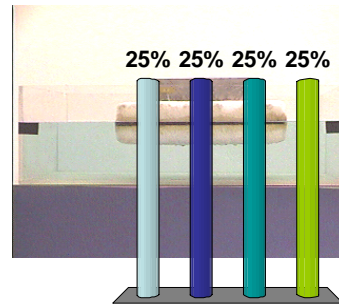
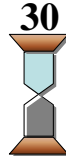


A (very light) Styrofoam block with a (much heavier) aluminum block attached to its top surface, as seen in the photograph at the left below, is placed into a container of water. The combined blocks float with one-half of the Styrofoam block immersed in the water, as seen in the photograph at the right below. It's a bit ratty looking, but it works.



When the inverted block combination is placed in the water (with the Styrofoam block on top) where will the water level be relative to the black line in the center of the Styrofoam block?

1. The black line will be *above* the water level
2. The black line will be *at* the water level, as in the original case
3. The black line will be *below* the water level
4. The blocks will sink



Here is a second question for extra bonus credit: The water level of the container with the blocks in their original configuration is marked by the top of the black tape on both sides of the tank. After the blocks are inverted and replaced in the water, will the water level in the tank be higher, lower, or the same?

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1	2	3	4	5															

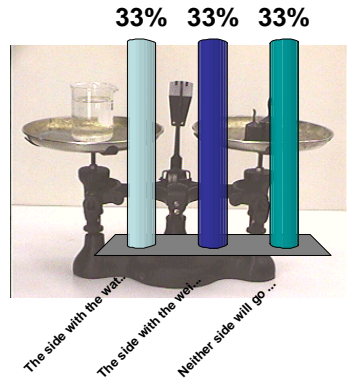
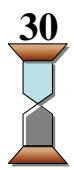


A beaker of water is in equilibrium with 300 grams of steel mass on a pan balance, as shown in the photograph below.



Now suppose that you slowly insert your finger into the water up to the first knuckle, being careful not to touch the beaker. What will happen to the equilibrium condition of the pan balance?

1. The side with the water will go down
2. The side with the weights will go down
3. Neither side will go down; the pan balance will remain in equilibrium



0 of 5

1	2	3	4	5															
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## Fluids in Motion: Streamline Flow



- **Streamline flow**
  - Every particle that passes a particular point moves exactly along the smooth path followed by particles that passed the point earlier
  - Also called laminar flow
- **Streamline is the path**
  - Different streamlines cannot cross each other
  - The streamline at any point coincides with the direction of fluid velocity at that point

## Streamline Flow, Example

Streamline flow shown around an auto in a wind tunnel



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## Fluids in Motion: Turbulent Flow

- The flow becomes irregular
  - exceeds a certain velocity
  - any condition that causes abrupt changes in velocity
- Eddy currents are a characteristic of turbulent flow



## Turbulent Flow, Example

- The rotating blade (dark area) forms a vortex in heated air
  - The wick of the burner is at the bottom
- Turbulent air flow occurs on both sides of the blade



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## Fluid Flow: Viscosity

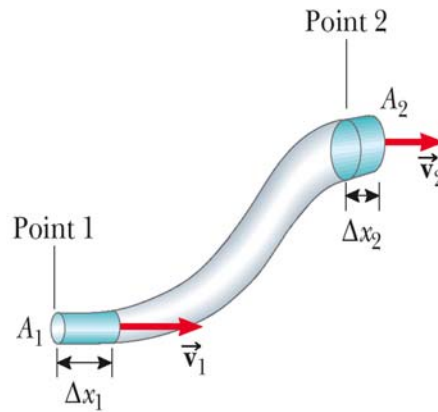
- Viscosity is the degree of internal friction in the fluid
- The internal friction is associated with the resistance between two adjacent layers of the fluid moving relative to each other

## Characteristics of an Ideal Fluid

- The fluid is nonviscous
  - There is no internal friction between adjacent layers
- The fluid is incompressible
  - Its density is constant
- The fluid motion is steady
  - Its velocity, density, and pressure do not change in time
- The fluid moves without turbulence
  - No eddy currents are present
  - The elements have zero angular velocity about its center

## Equation of Continuity

- $A_1v_1 = A_2v_2$
- The product of the cross-sectional area of a pipe and the fluid speed is a constant
  - Speed is high where the pipe is narrow and speed is low where the pipe has a large diameter
- $Av$  is called the *flow rate*



## Equation of Continuity, cont

- The equation is a consequence of conservation of mass and a steady flow
- $A v = \text{constant}$ 
  - This is equivalent to the fact that the volume of fluid that enters one end of the tube in a given time interval equals the volume of fluid leaving the tube in the same interval
    - Assumes the fluid is incompressible and there are no leaks

## Daniel Bernoulli

- 1700 – 1782
- Swiss physicist and mathematician
- Wrote *Hydrodynamica*
- Also did work that was the beginning of the kinetic theory of gases



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## Bernoulli's Equation

- Relates pressure to fluid speed and elevation
- Bernoulli's equation is a consequence of Conservation of Energy applied to an ideal fluid
- Assumes the fluid is incompressible and nonviscous, and flows in a nonturbulent, steady-state manner

## Bernoulli's Equation, cont.

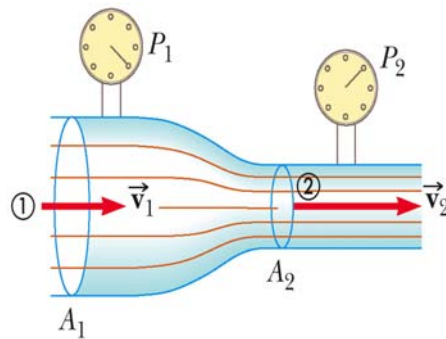
- States that the sum of the pressure, kinetic energy per unit volume, and the potential energy per unit volume has the same value at all points along a streamline

$$P + \frac{1}{2}\rho v^2 + \rho gy = \text{constant}$$



## Applications of Bernoulli's Principle: Venturi Tube

- Shows fluid flowing through a horizontal constricted pipe
- Speed changes as diameter changes
- Can be used to measure the speed of the fluid flow
- Swiftly moving fluids exert less pressure than do slowly moving fluids

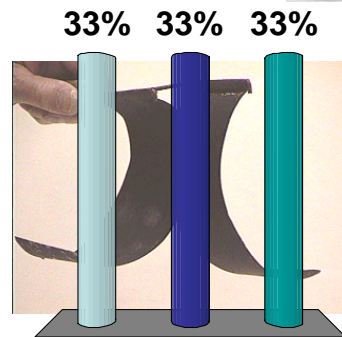
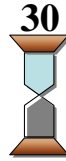




Two thin sheets of metal are configured as shown in the picture below. Suppose you were to blow air between them. What would happen?



1. They would blow apart
2. They would pull closer together
3. Nothing would happen



You can try this yourself. Tear two narrow strips of paper about 1 inch wide and 6~8 inches long and hold them as shown.



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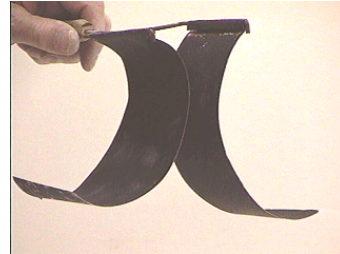
## Clicker Question



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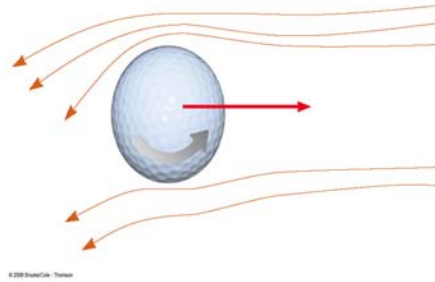
## An Object Moving Through a Fluid



- Many common phenomena can be explained by Bernoulli's equation
  - At least partially
- In general, an object moving through a fluid is acted upon by a net upward force as the result of any effect that causes the fluid to change its direction as it flows past the object

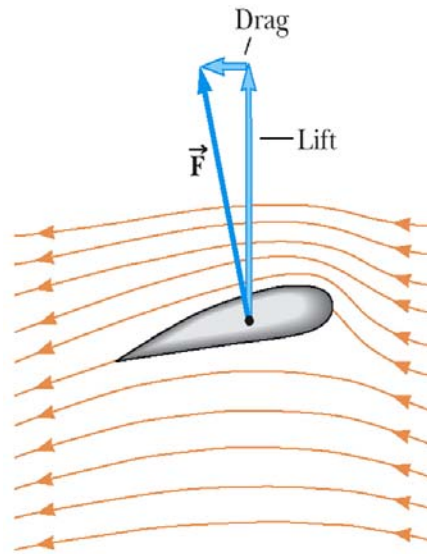
## Application – Golf Ball

- The dimples in the golf ball help move air along its surface
- The ball pushes the air down
- Newton's Third Law tells us the air must push up on the ball
- The spinning ball travels farther than if it were not spinning



## Application – Airplane Wing

- The air speed above the wing is greater than the speed below
- The air pressure above the wing is less than the air pressure below
- There is a net upward force
  - Called *lift*
- Other factors are also involved



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