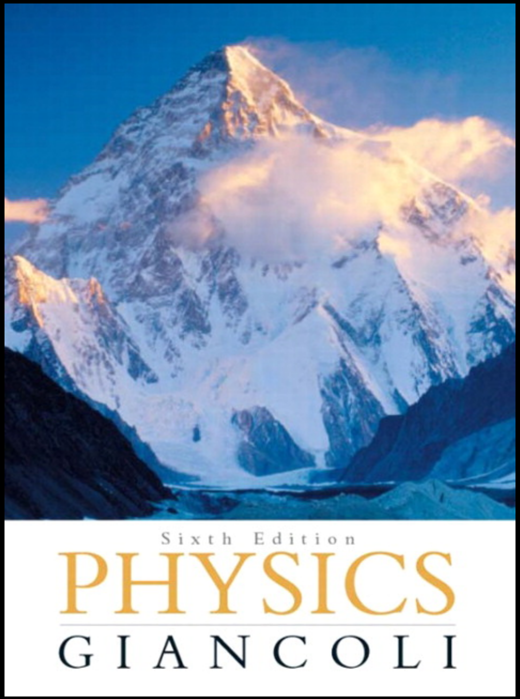


Lecture PowerPoints

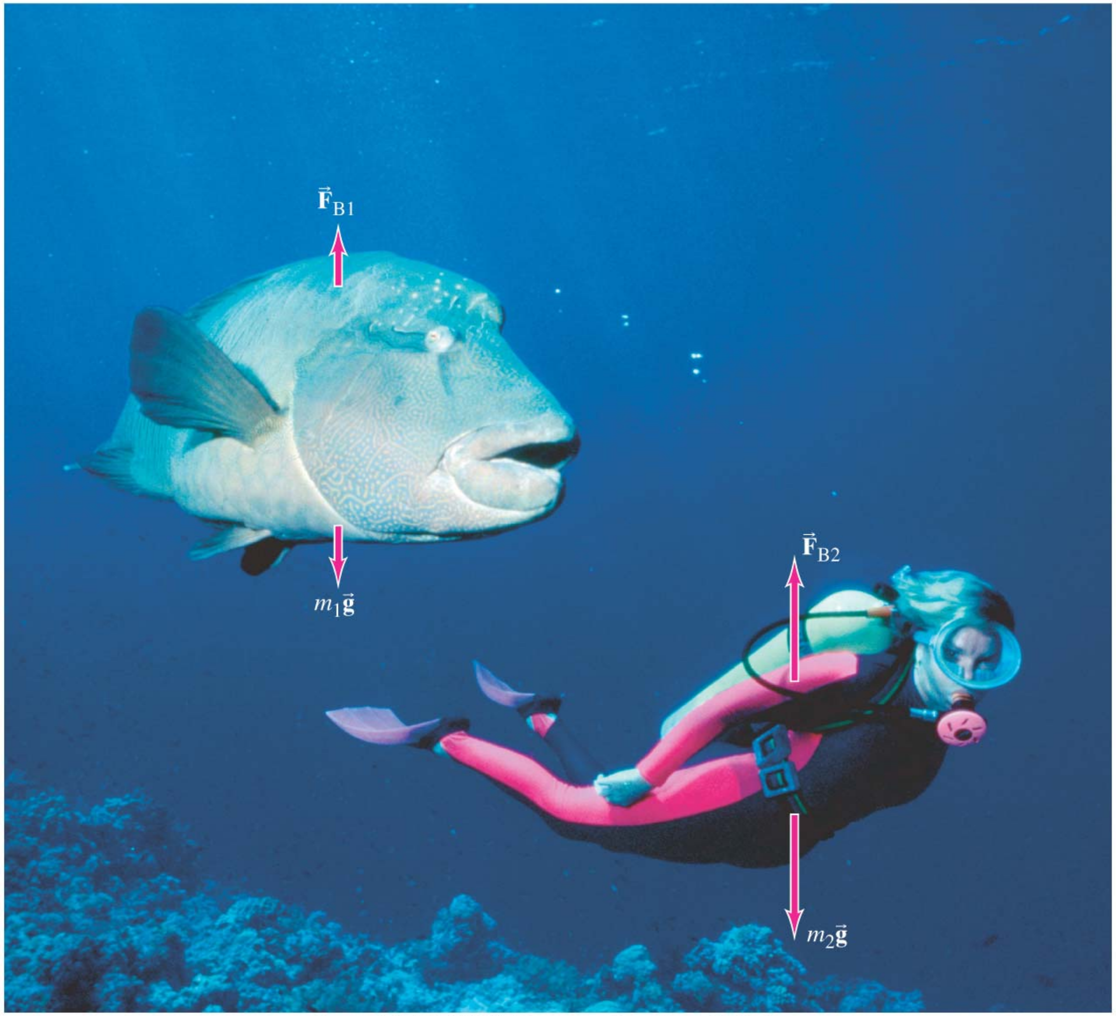
Chapter 10

Physics: Principles with Applications, 6th edition

Giancoli

Chapter 10

Fluids



Units of Chapter 10

- Phases of Matter
- Density and Specific Gravity
- Pressure in Fluids
- Atmospheric Pressure and Gauge Pressure
- Pascal’s Principle
- Measurement of Pressure; Gauges and the Barometer
- Buoyancy and Archimedes’ Principle

Units of Chapter 10

- Fluids in Motion; Flow Rate and the Equation of Continuity
- Bernoulli's Equation
- Applications of Bernoulli's Principle: from Torricelli to Airplanes, Baseballs, and TIA
- Viscosity
- Flow in Tubes: Poiseuille's Equation, Blood Flow
- Surface Tension and Capillarity
- Pumps, and the Heart

10-1 Phases of Matter

The three common phases of matter are **solid**, **liquid**, and **gas**.

A solid has a definite **shape** and **size**.

A liquid has a fixed **volume** but can be any shape.

A gas can be any shape and also can be easily **compressed**.

Liquids and gases both **flow**, and are called **fluids**.

10-2 Density and Specific Gravity

The **density** ρ of an object is its **mass** per unit **volume**:

$$\rho = \frac{m}{V} \qquad \text{(10-1)}$$

The SI unit for density is kg/m^3. Density is also sometimes given in g/cm^3; to convert g/cm^3 to kg/m^3, multiply by 1000.

Water at 4°C has a density of 1 g/cm^3 = 1000 kg/m^3.

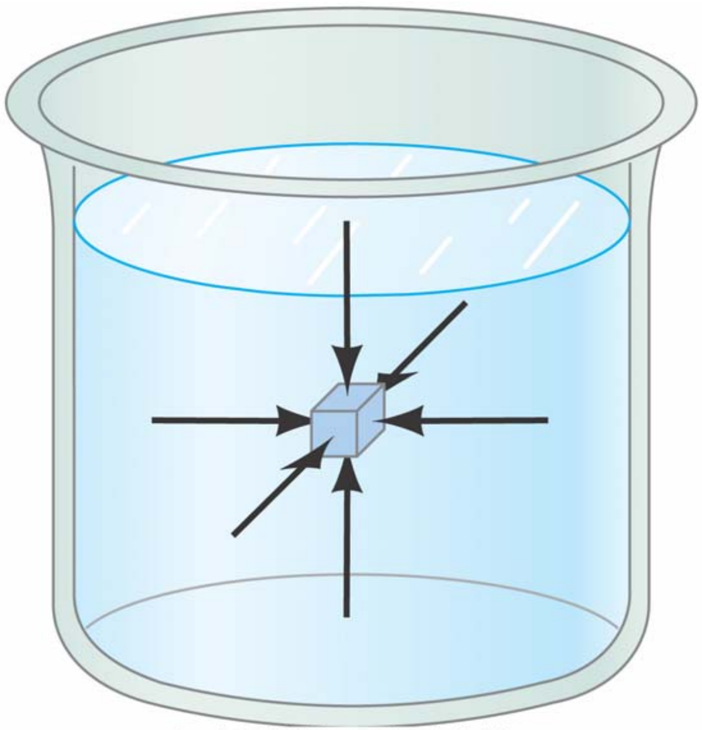
The **specific gravity** of a substance is the ratio of its density to that of water.

10-3 Pressure in Fluids

Pressure is defined as the **force** per unit **area**.

Pressure is a scalar; the units of pressure in the SI system are **pascals**:

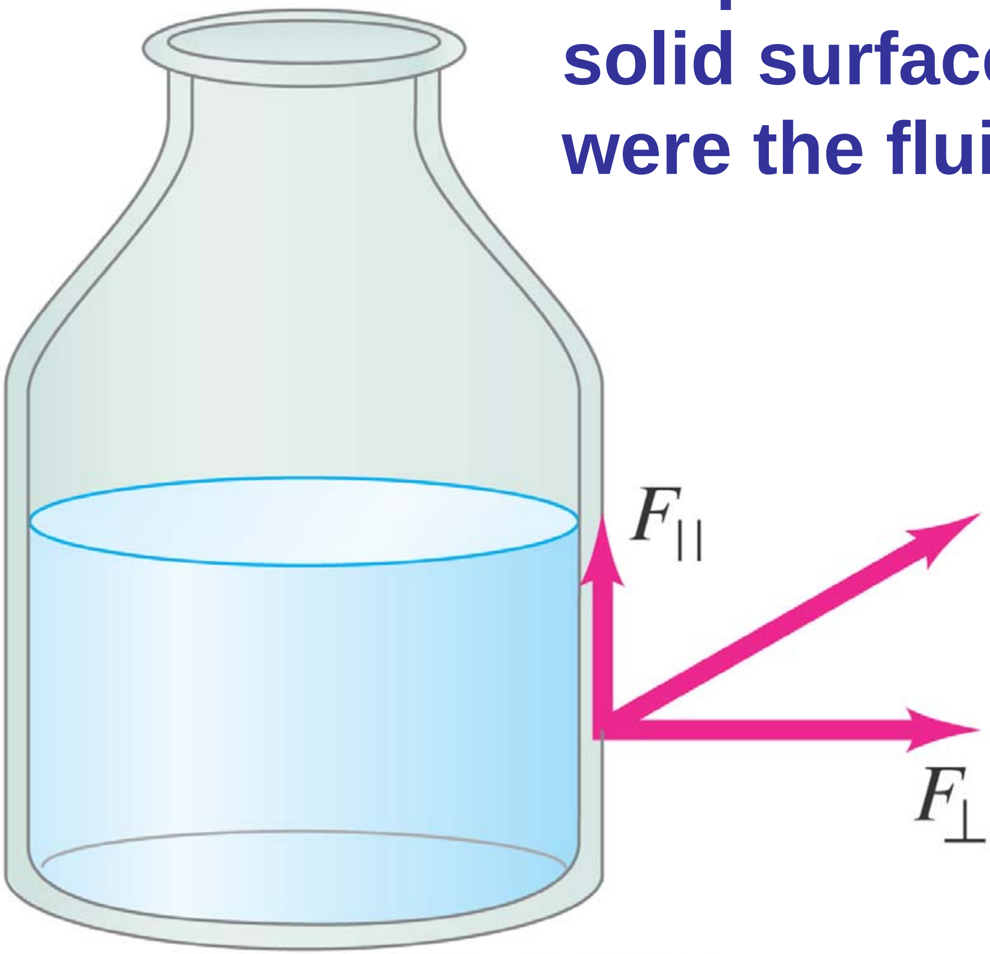
$$1 \text{ Pa} = 1 \text{ N/m}^2$$



Pressure is the same in every **direction** in a fluid at a given **depth**; if it were not, the fluid would flow.

10-3 Pressure in Fluids

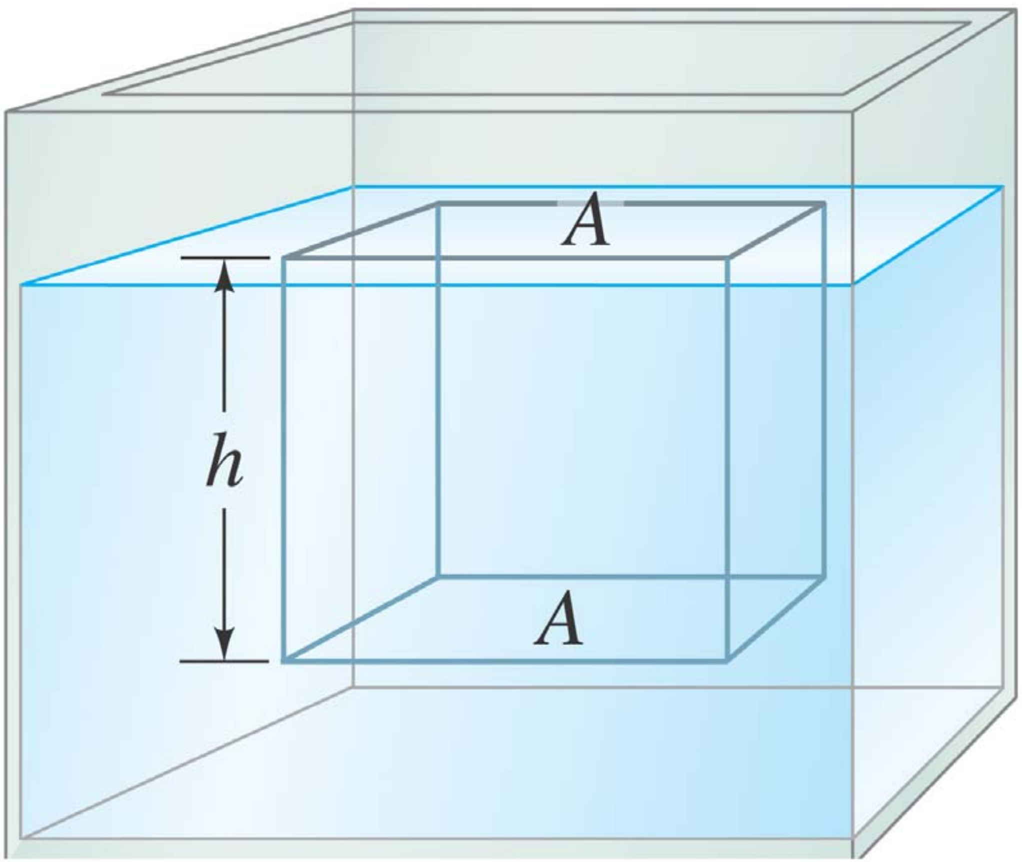
Also for a fluid at rest, there is no component of force **parallel** to any solid surface – once again, if there were the fluid would flow.



10-3 Pressure in Fluids

The **pressure** at a depth *h* below the surface of the liquid is due to the **weight** of the liquid above it. We can quickly calculate:

$$P = \rho g h \qquad (10\text{-}3)$$



This relation is valid for any liquid whose density does not change with depth.

10-4 Atmospheric Pressure and Gauge Pressure

At sea level the atmospheric pressure is about $1.013 \times 10^5\ \mathrm{N/m^2}$; this is called one atmosphere (atm).

Another unit of pressure is the bar:

$$1\ \text{bar} = 1.00 \times 10^5\ \mathrm{N/m^2}$$

Standard atmospheric pressure is just over 1 bar.

This pressure does not crush us, as our cells maintain an internal pressure that balances it.

10-4 Atmospheric Pressure and Gauge Pressure

Most **pressure gauges** measure the pressure **above** the atmospheric pressure – this is called the **gauge pressure**.

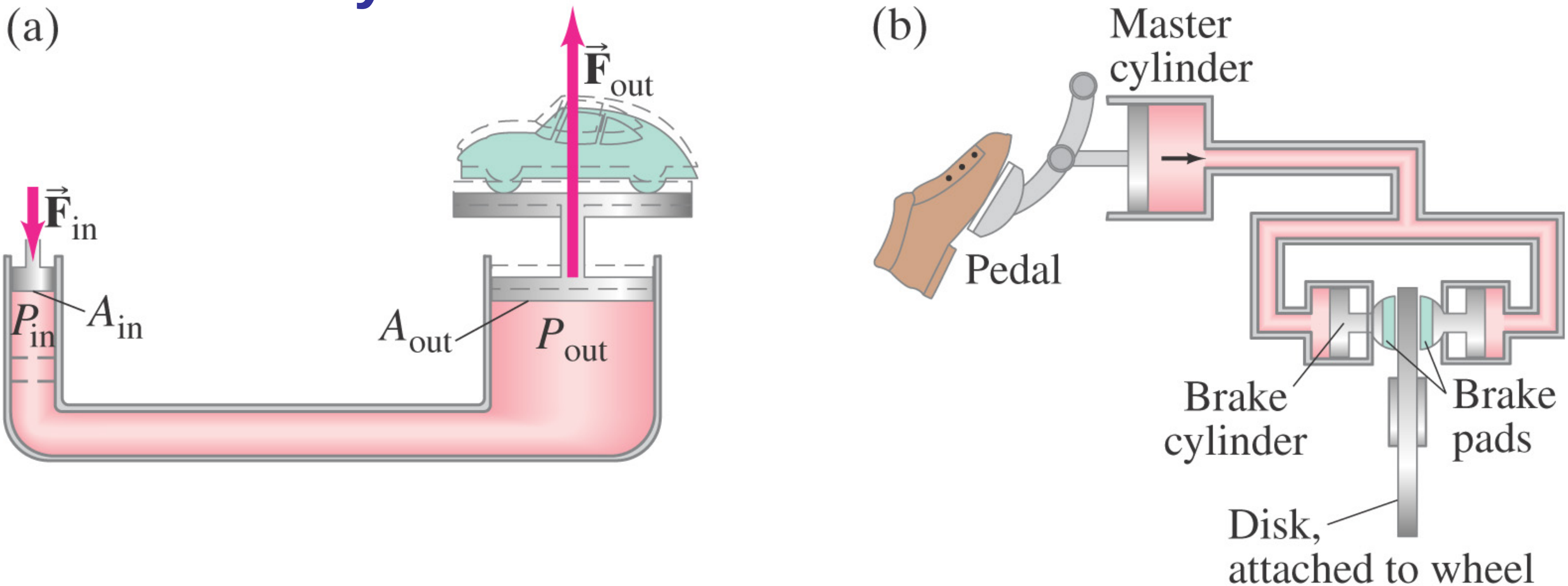
The **absolute pressure** is the sum of the atmospheric pressure and the gauge pressure.

$$P = P_A + P_G$$

10-5 Pascal's Principle

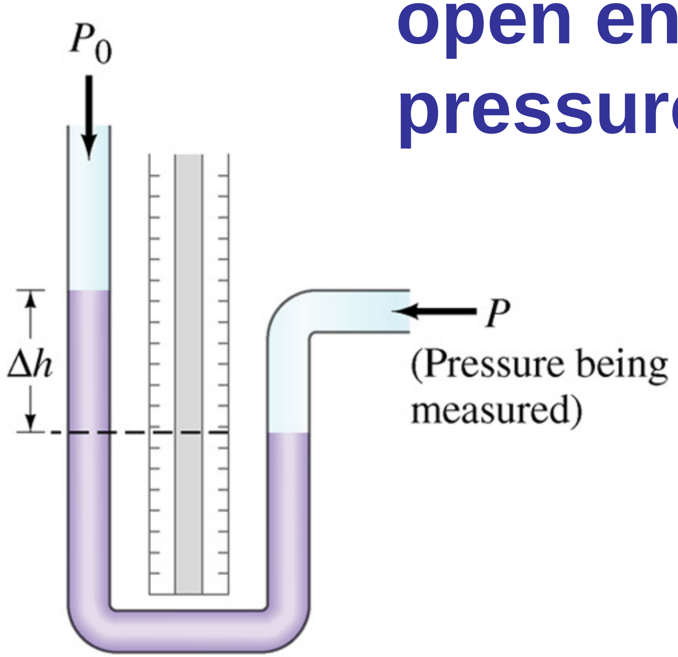
If an **external** pressure is applied to a **confined** fluid, the pressure at **every** point within the fluid increases by that amount.

This principle is used, for example, in hydraulic **lifts** and hydraulic **brakes**.



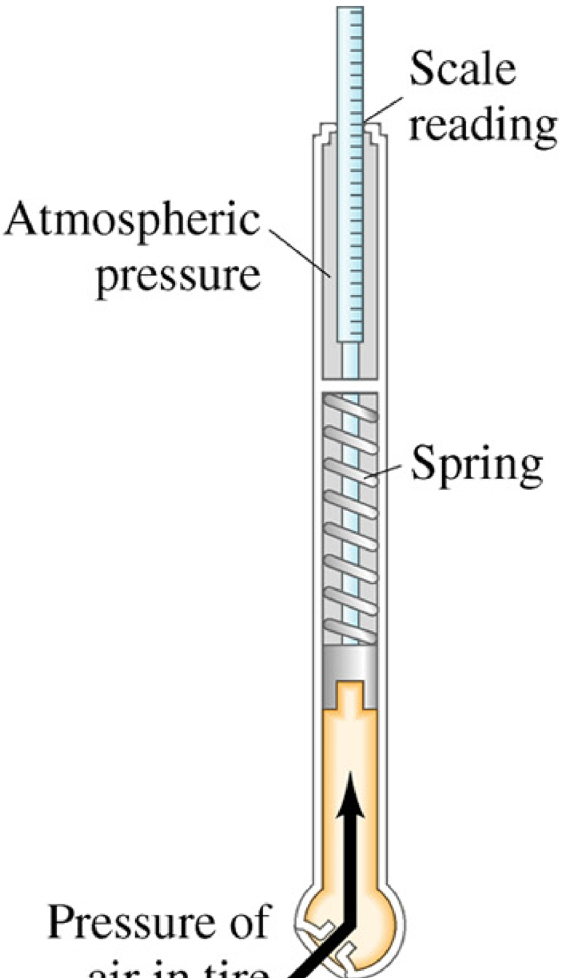
10-6 Measurement of Pressure; Gauges and the Barometer

There are a number of different types of **pressure gauges**. This one is an open-tube **manometer**. The pressure in the open end is **atmospheric** pressure; the pressure being measured will cause the fluid to **rise** until the pressures on both sides at the same height are **equal**.



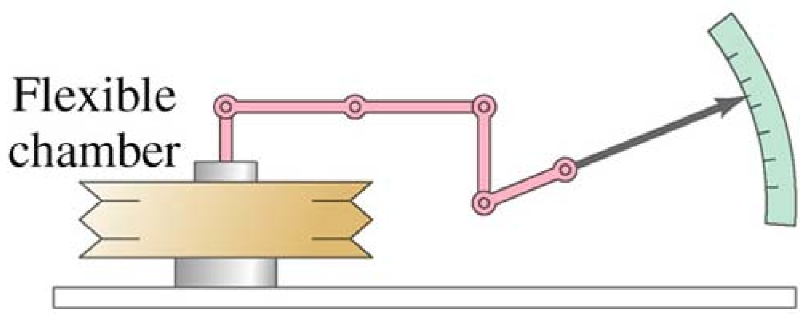
(a) Open-tube manometer

10-6 Measurement of Pressure; Gauges and the Barometer



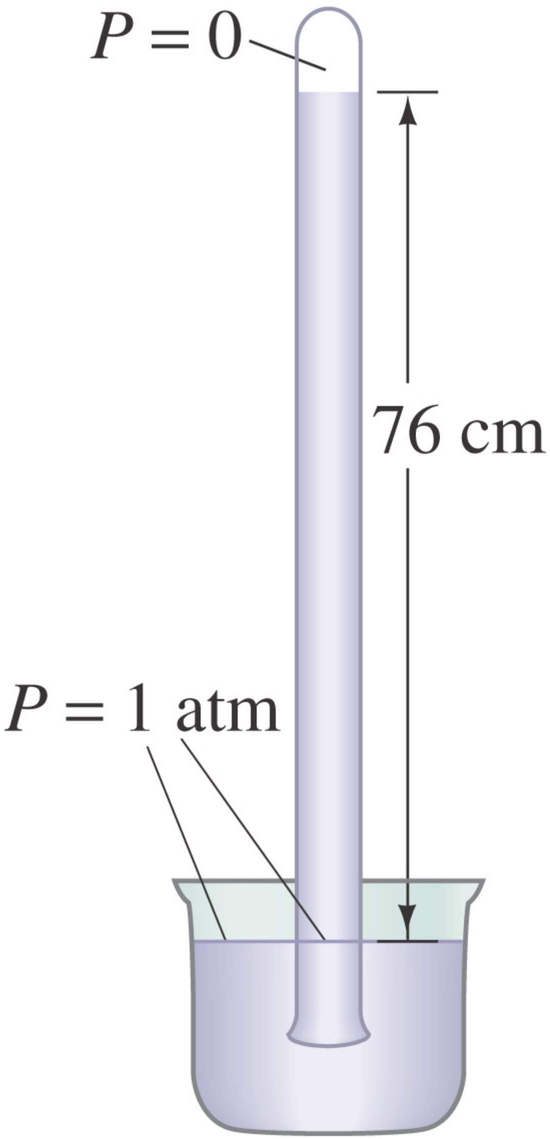
(c) Tire gauge

Here are two more devices for measuring pressure: the **aneroid gauge** and the **tire pressure gauge**.



(b) Aneroid gauge (used mainly for air pressure, and then called an aneroid barometer)

10-6 Measurement of Pressure; Gauges and the Barometer



This is a **mercury** barometer, developed by Torricelli to measure **atmospheric pressure**. The **height** of the column of **mercury** is such that the pressure in the tube at the surface level is 1 atm.

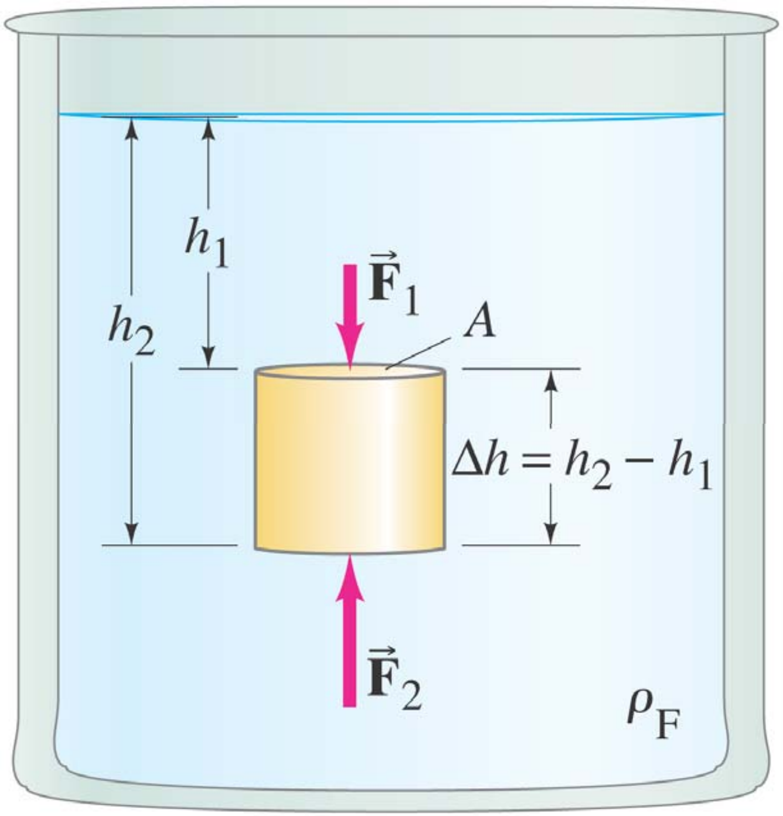
Therefore, pressure is often quoted in **millimeters** (or inches) of mercury.

10-6 Measurement of Pressure; Gauges and the Barometer

Any liquid can serve in a Torricelli-style barometer, but the most **dense** ones are the most convenient. This barometer uses **water**.

10-7 Buoyancy and Archimedes' Principle

This is an object **submerged** in a fluid. There is a net **force** on the object because the pressures at the top and bottom of it are different.

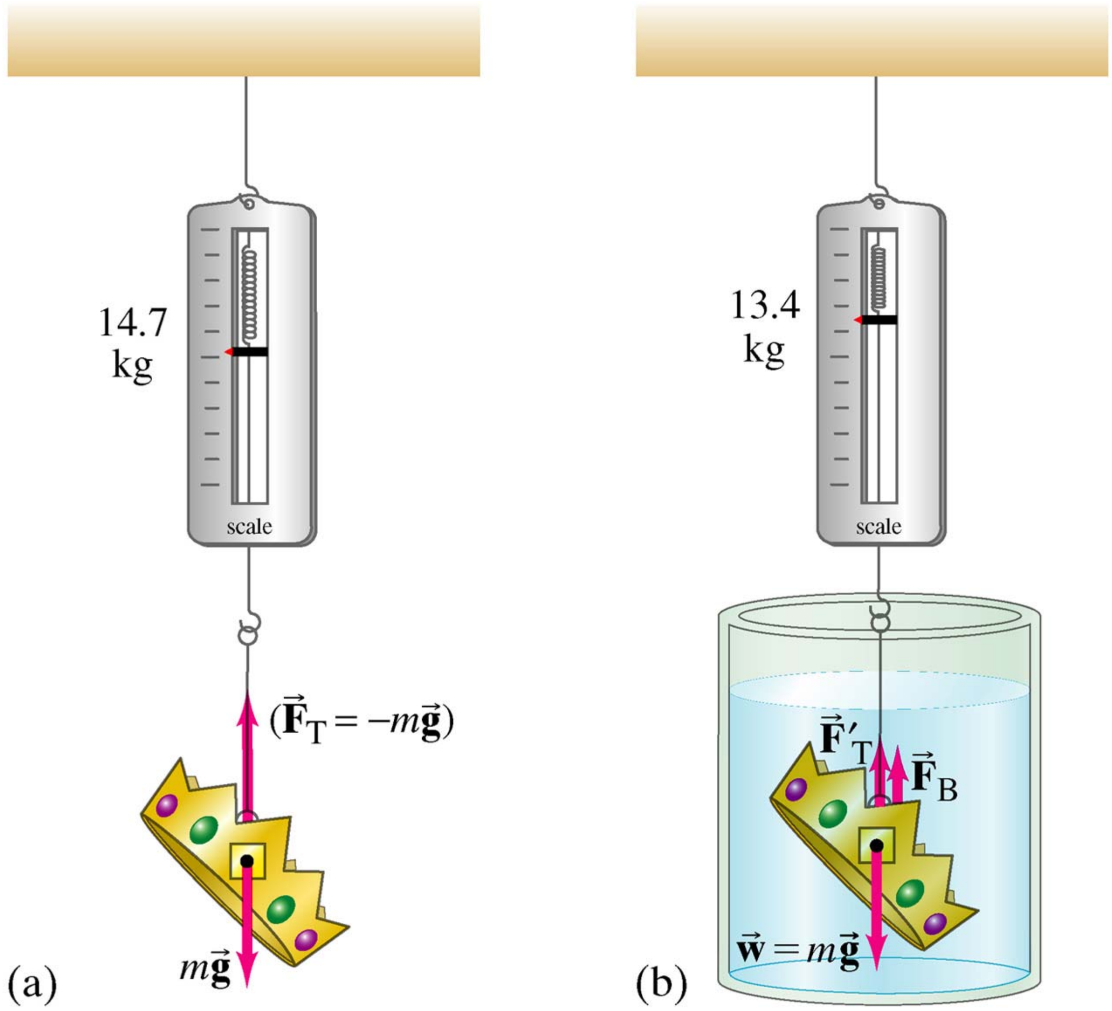


The **buoyant force** is found to be the **upward** force on the **same** volume of water:

$$
\begin{aligned}
F_B = F_2 - F_1 &= \rho_F g A (h_2 - h_1) \\
&= \rho_F g A \Delta h \\
&= \rho_F V g \\
&= m_F g,
\end{aligned}
$$

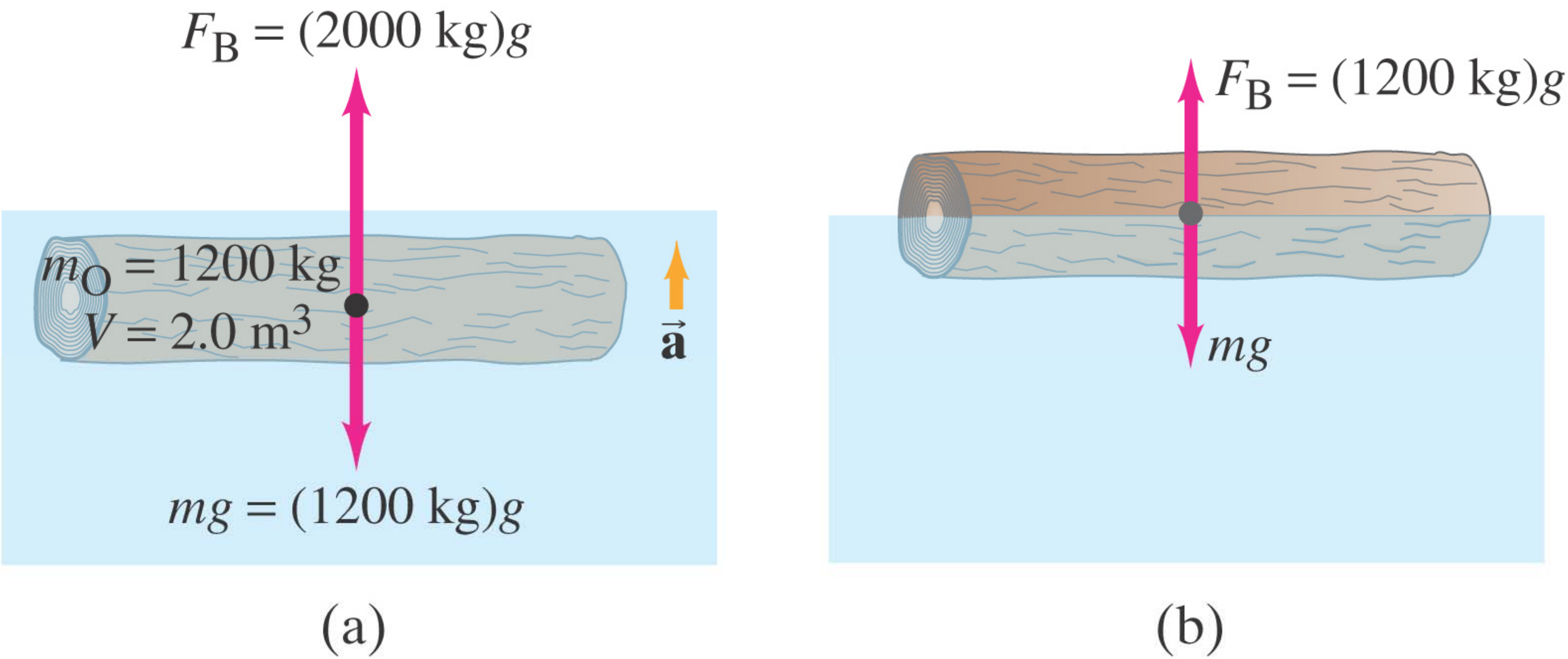
10-7 Buoyancy and Archimedes' Principle

The **net force on** the object is then the difference between the **buoyant force** and the **gravitational force.**



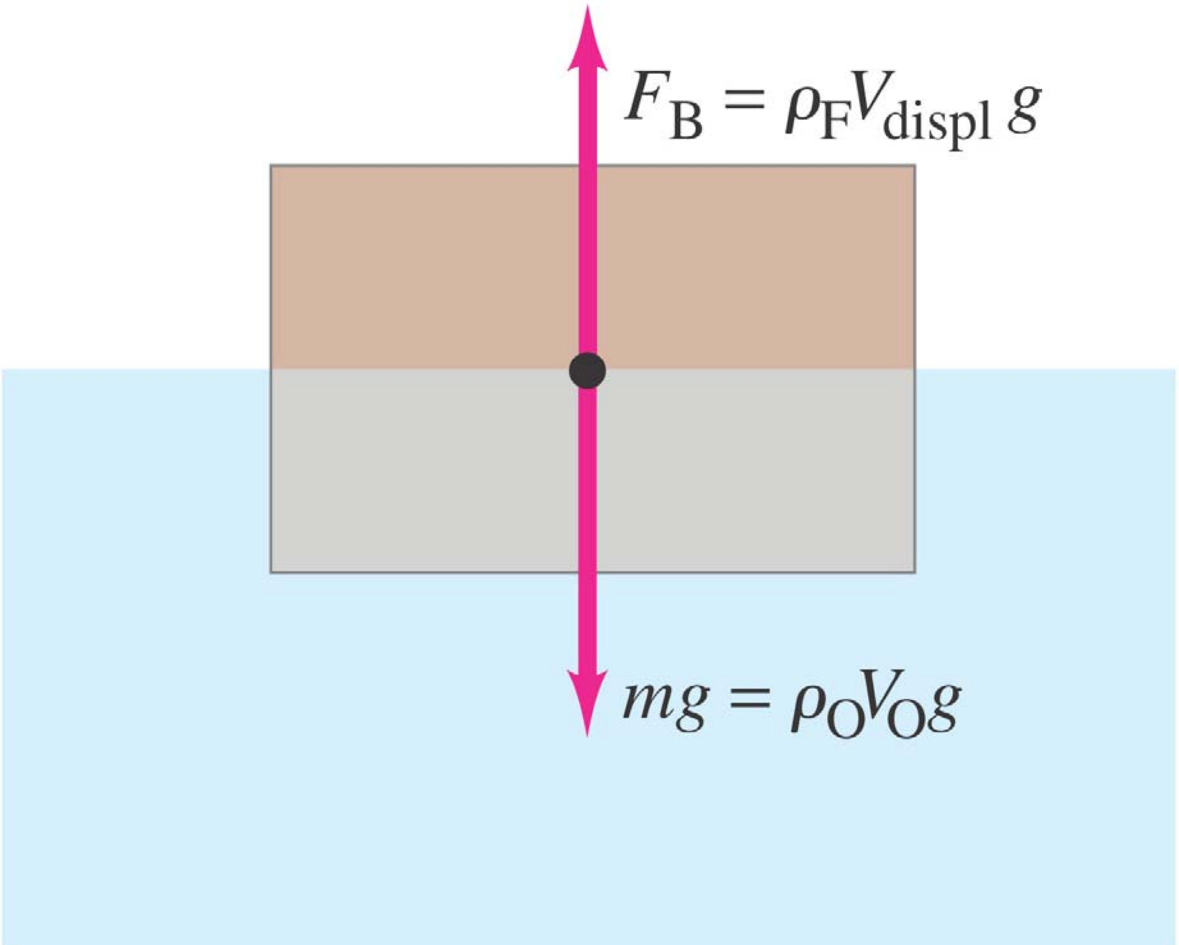
10-7 Buoyancy and Archimedes' Principle

If the object's **density** is **less** than that of water, there will be an **upward** net force on it, and it will rise until it is partially **out** of the water.

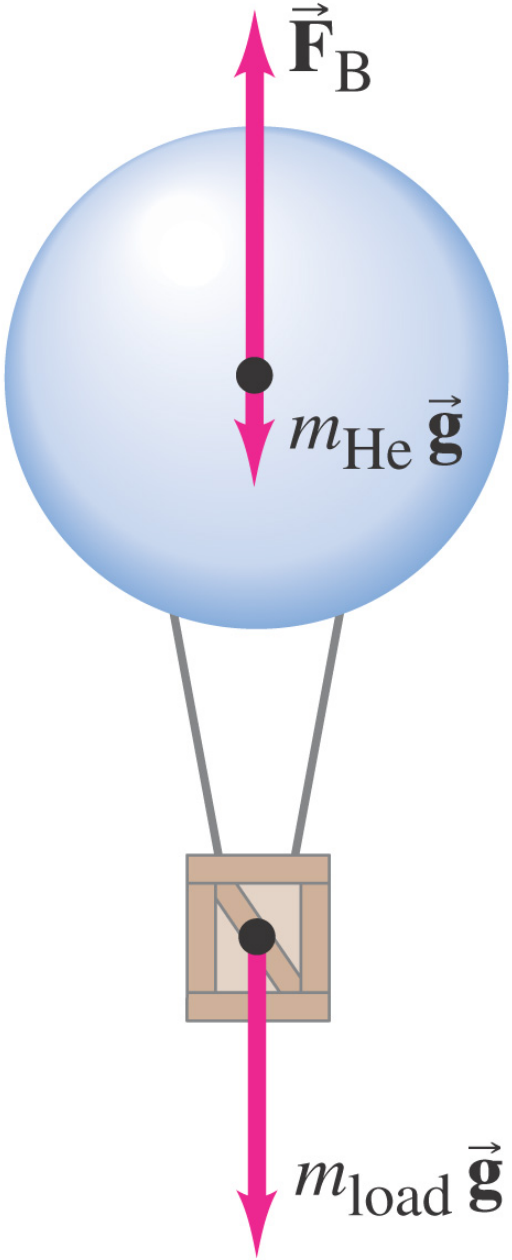


10-7 Buoyancy and Archimedes' Principle

For a **floating** object, the fraction that is **submerged** is given by the ratio of the object's **density** to that of the fluid.



10-7 Buoyancy and Archimedes' Principle

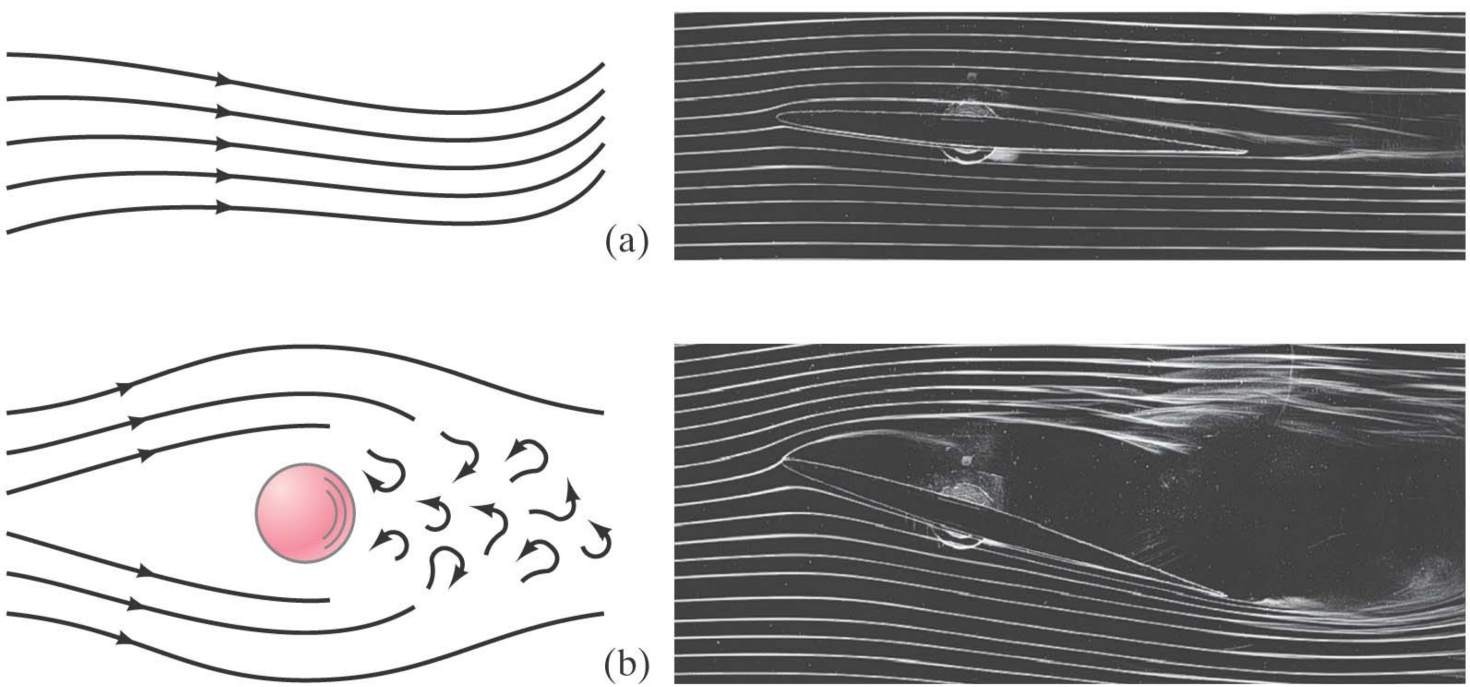


This principle also works in the air; this is why **hot-air** and **helium** balloons rise.

10-8 Fluids in Motion; Flow Rate and the Equation of Continuity

If the flow of a fluid is smooth, it is called streamline or laminar flow (a).

Above a certain speed, the flow becomes turbulent (b). Turbulent flow has eddies; the viscosity of the fluid is much greater when eddies are present.



10-8 Fluids in Motion; Flow Rate and the Equation of Continuity

We will deal with **laminar** flow.

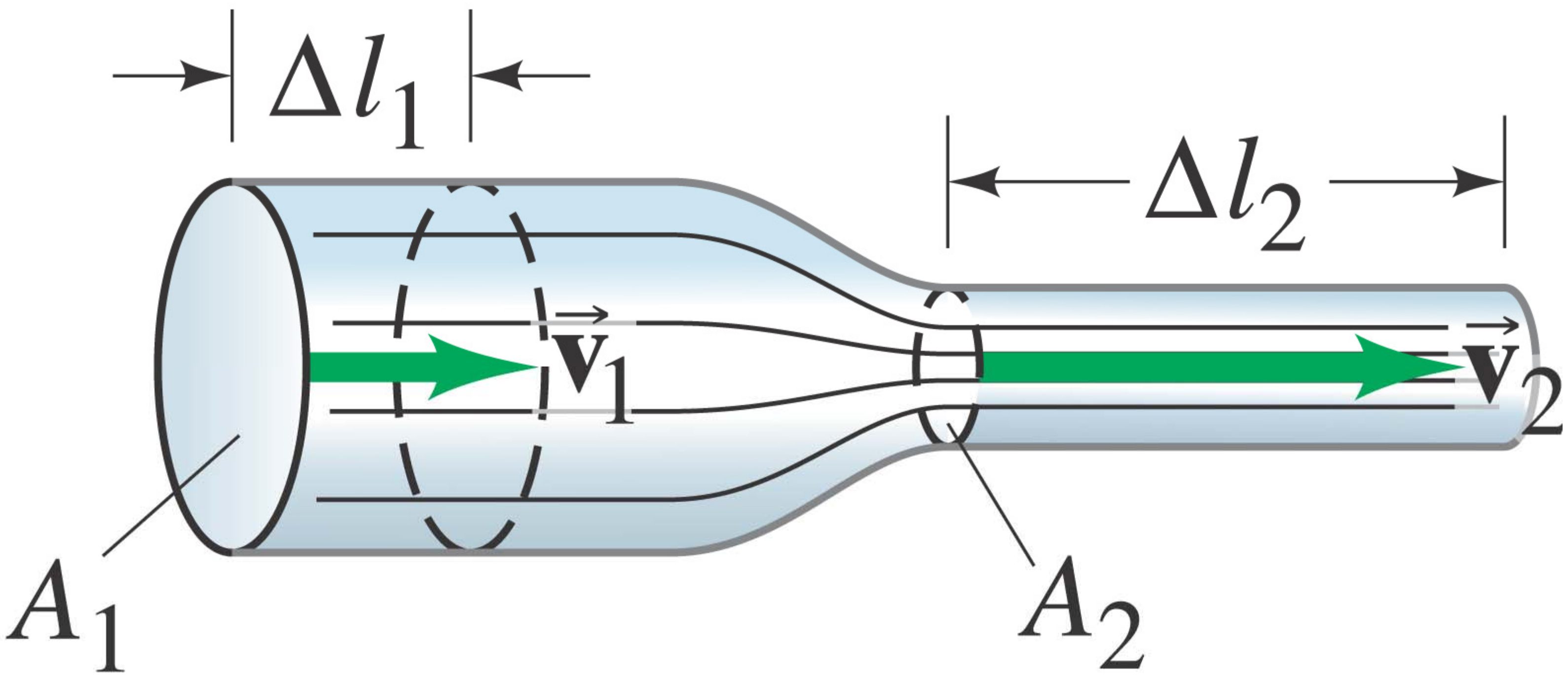
The **mass flow rate** is the mass that passes a given point per unit time. The flow rates at any two points must be **equal**, as long as no fluid is being added or taken away.

This gives us the **equation of continuity**:

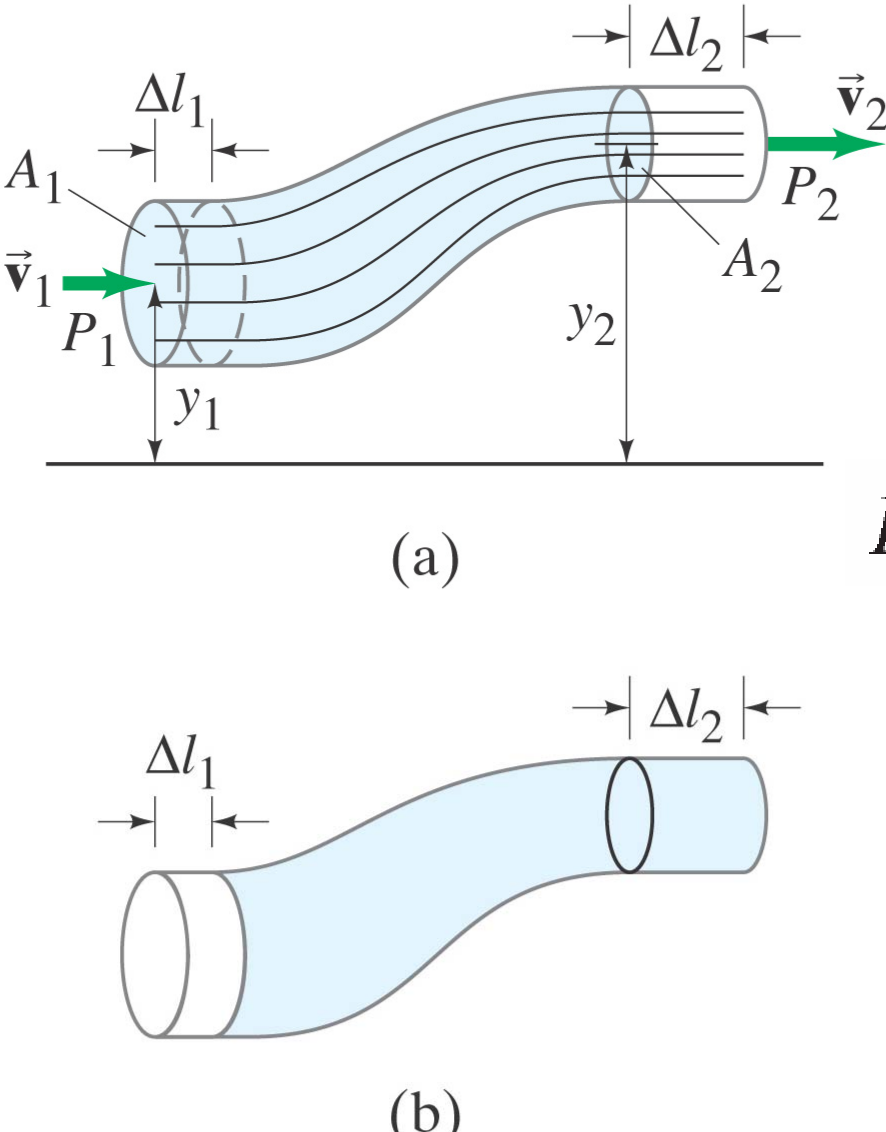
$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2 \qquad \textbf{(10-4a)}$$

10-8 Fluids in Motion; Flow Rate and the Equation of Continuity

If the density doesn't change – typical for liquids – this simplifies to $A_1 v_1 = A_2 v_2$.
Where the pipe is wider, the flow is slower.



10-9 Bernoulli's Equation



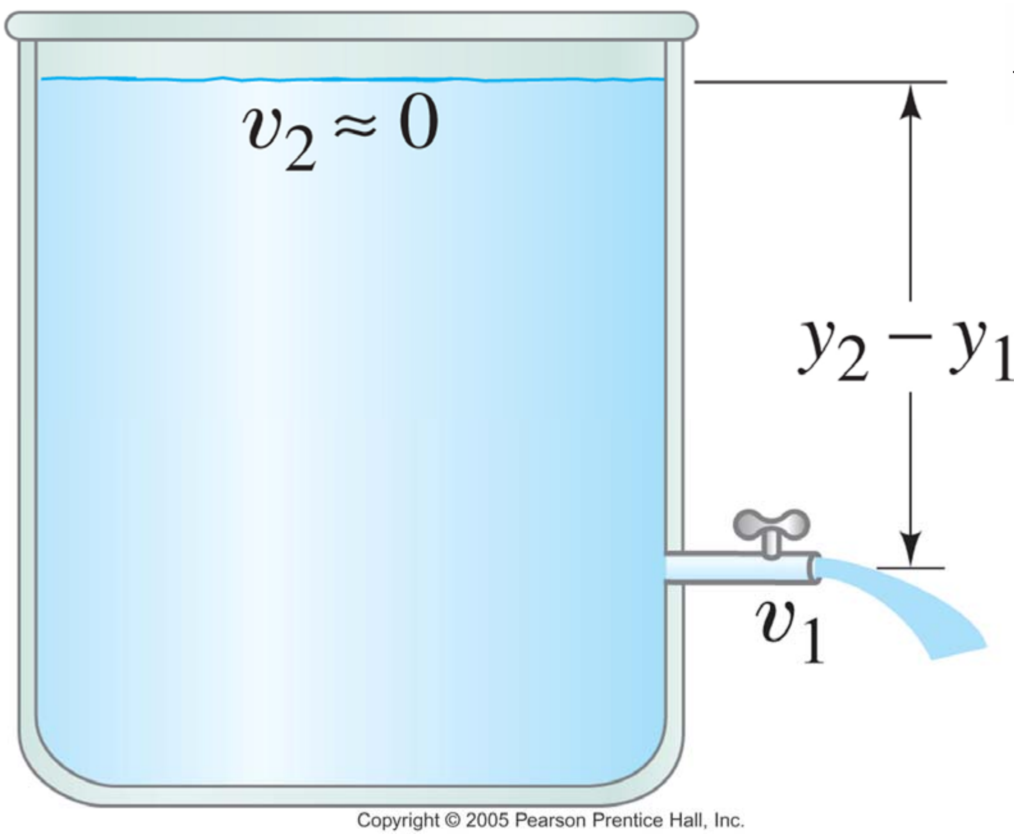
A fluid can also change its **height**. By looking at the work done as it moves, we find:

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

This is **Bernoulli's** equation. One thing it tells us is that as the **speed** goes up, the **pressure** goes down.

10-10 Applications of Bernoulli's Principle: from Torricelli to Airplanes, Baseballs, and TIA

Using Bernoulli's principle, we find that the speed of fluid coming from a **spigot** on an **open** tank is:



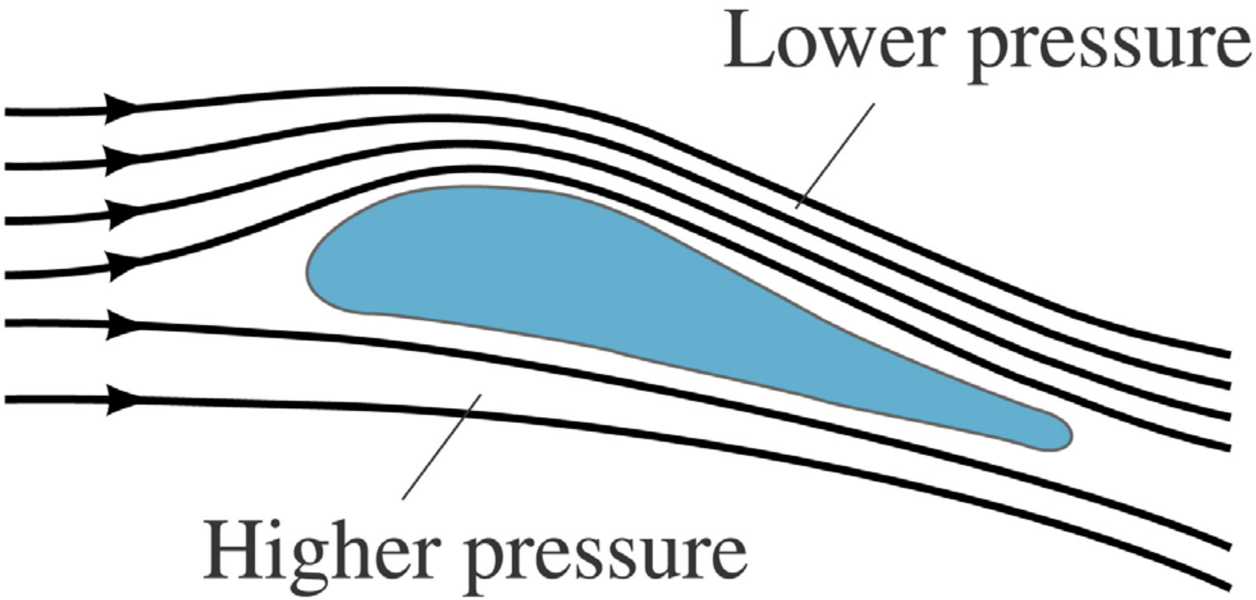
$$v_1 = \sqrt{2g(y_2 - y_1)}$$

(10-6)

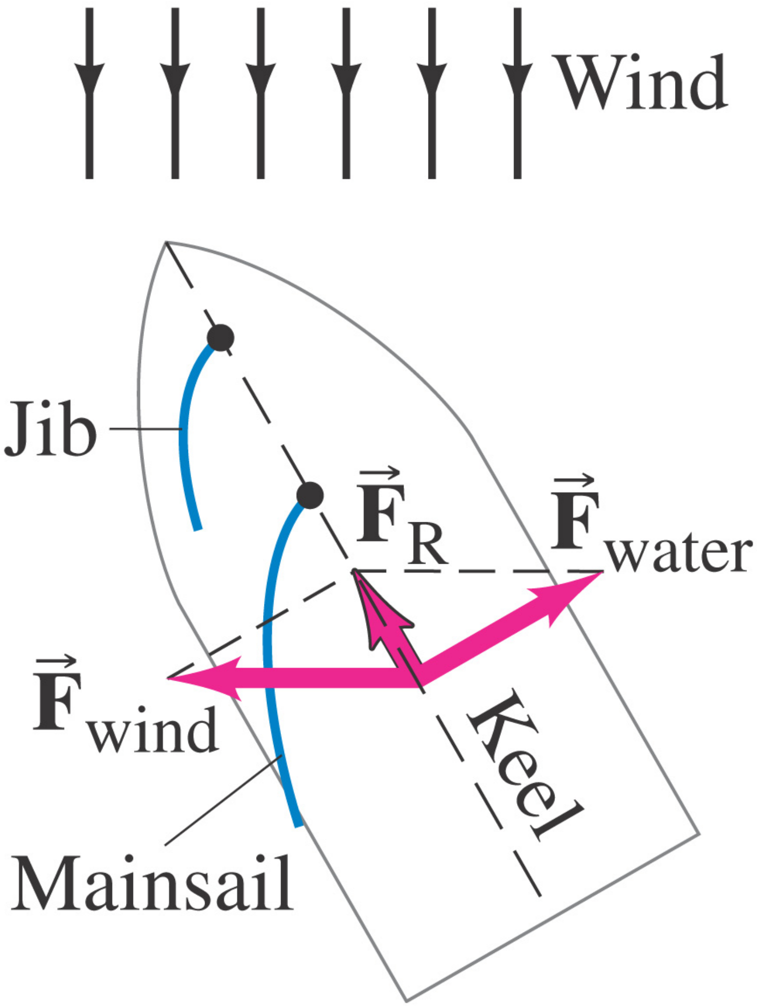
This is called **Torricelli's** theorem.

10-10 Applications of Bernoulli's Principle: from Torricelli to Airplanes, Baseballs, and TIA

Lift on an airplane **wing** is due to the different air **speeds** and **pressures** on the two surfaces of the wing.

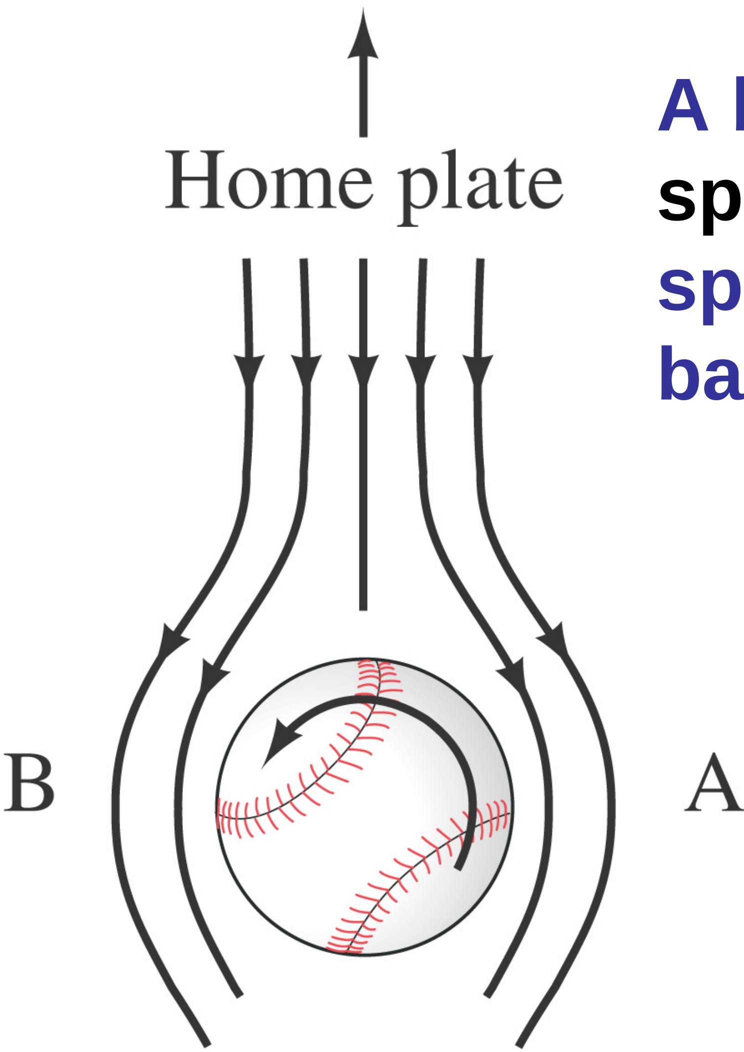


10-10 Applications of Bernoulli's Principle: from Torricelli to Airplanes, Baseballs, and TIA



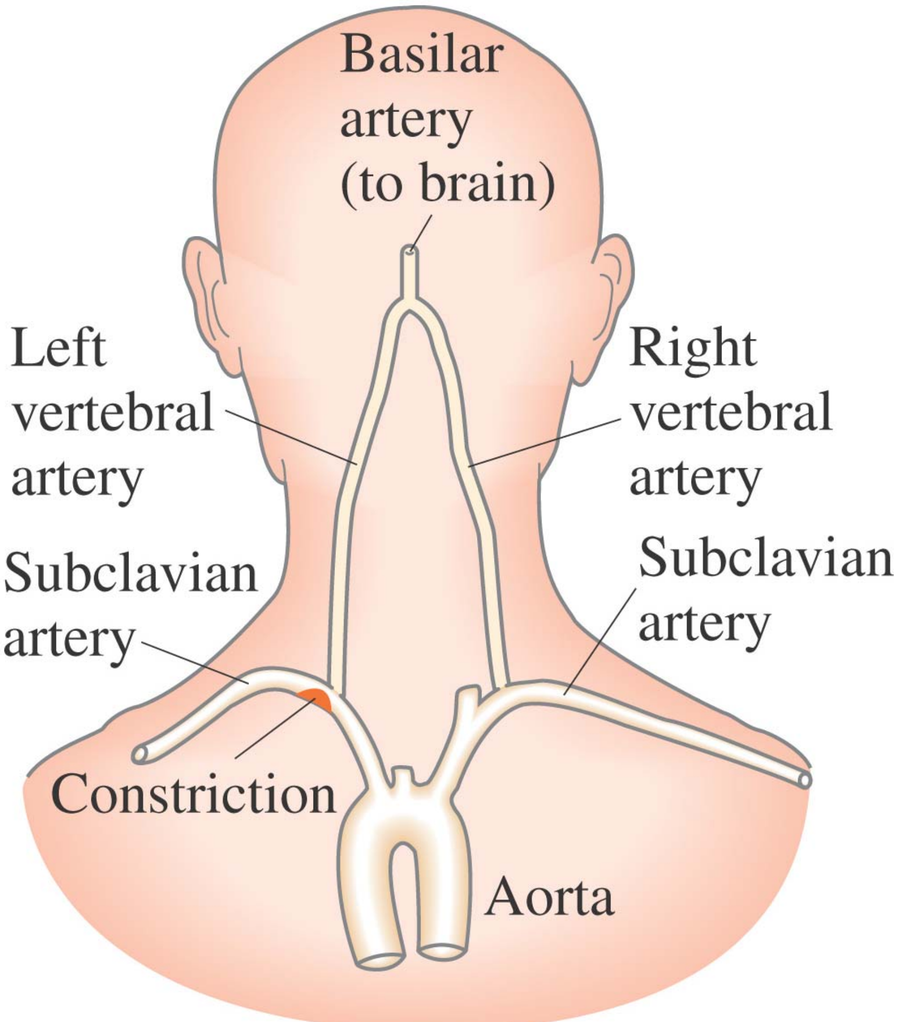
A **sailboat** can move **against** the wind, using the pressure **differences** on each side of the sail, and using the **keel** to keep from going sideways.

10-10 Applications of Bernoulli's Principle: from Torricelli to Airplanes, Baseballs, and TIA



A ball's path will **curve** due to its **spin**, which results in the air speeds on the two sides of the ball not being equal.

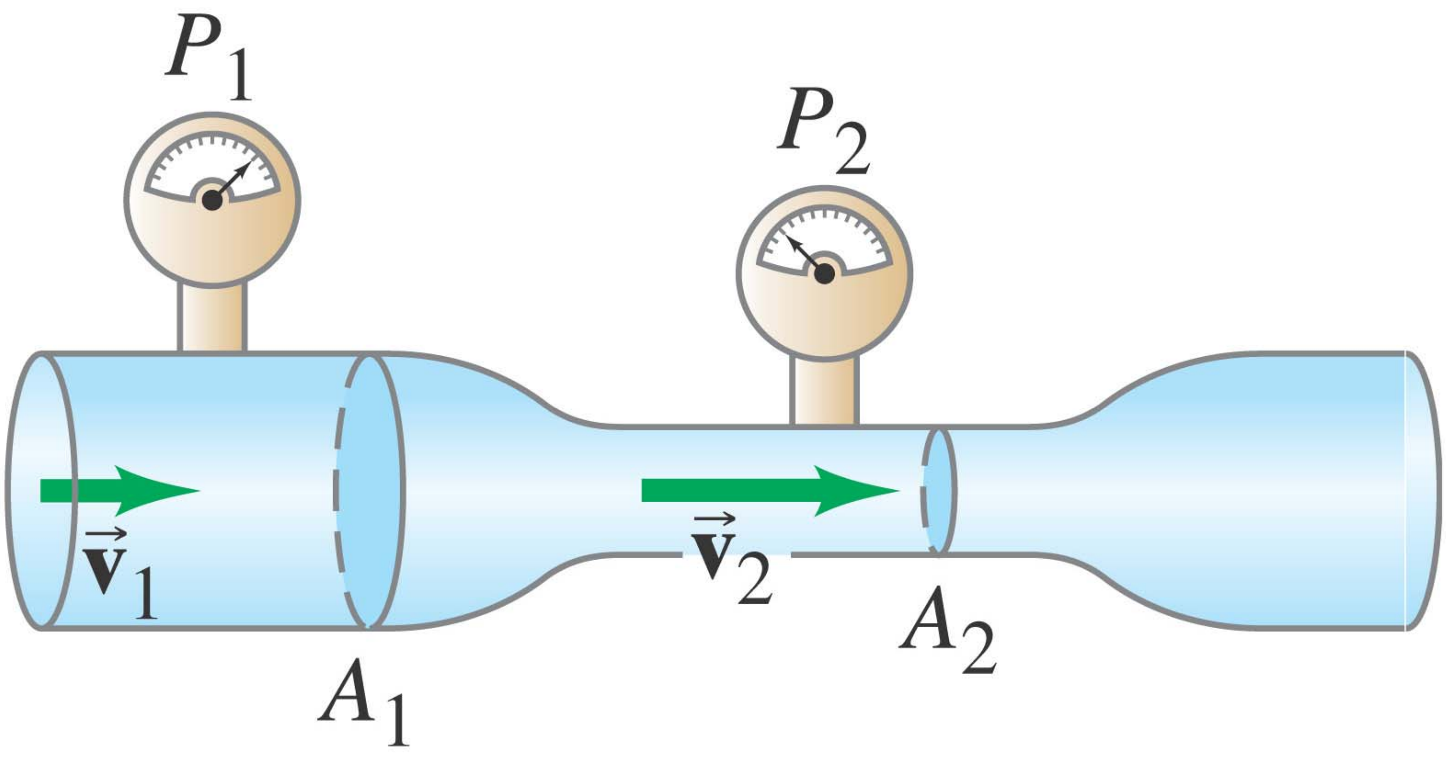
10-10 Applications of Bernoulli's Principle: from Torricelli to Airplanes, Baseballs, and TIA



A person with **constricted** arteries will find that they may experience a temporary lack of blood to the brain (**TIA**) as blood speeds up to get past the **constriction**, thereby **reducing** the pressure.

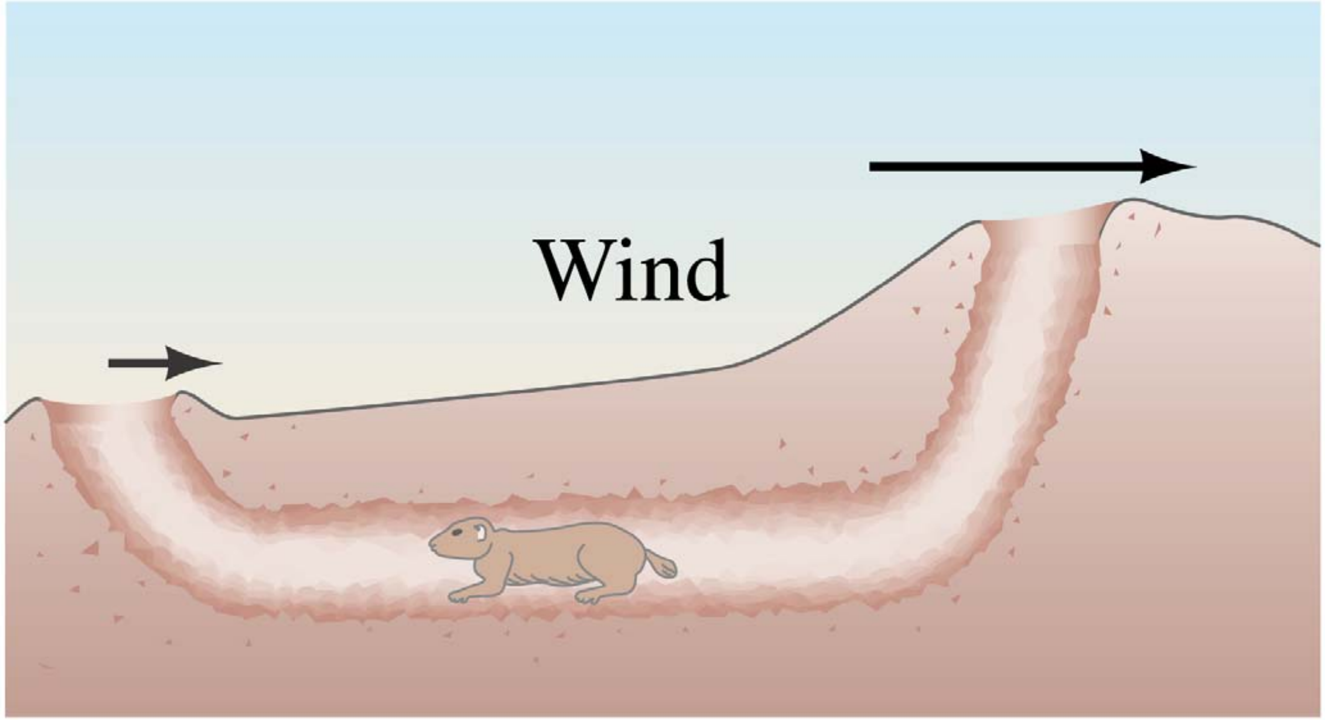
10-10 Applications of Bernoulli's Principle: from Torricelli to Airplanes, Baseballs, and TIA

A **venturi meter** can be used to measure fluid flow by measuring **pressure** differences.



10-10 Applications of Bernoulli's Principle: from Torricelli to Airplanes, Baseballs, and TIA

Air flow across the top helps smoke go up a **chimney**, and air flow over multiple openings can provide the needed **circulation** in underground burrows.



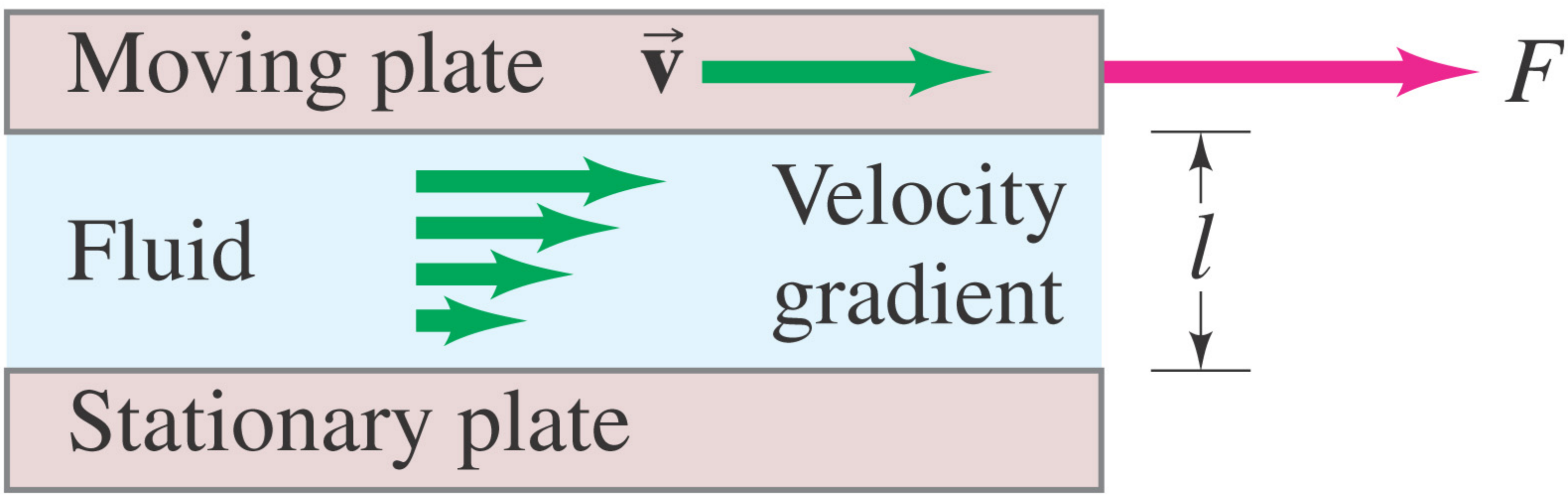
10-11 Viscosity

Real fluids have some **internal friction**, called **viscosity**.

The **viscosity** can be measured; it is found from the relation

$$F = \eta A \frac{v}{l} \qquad (10\text{-}8)$$

where η is the **coefficient of viscosity**.



10-12 Flow in Tubes; Poiseuille's Equation, Blood Flow

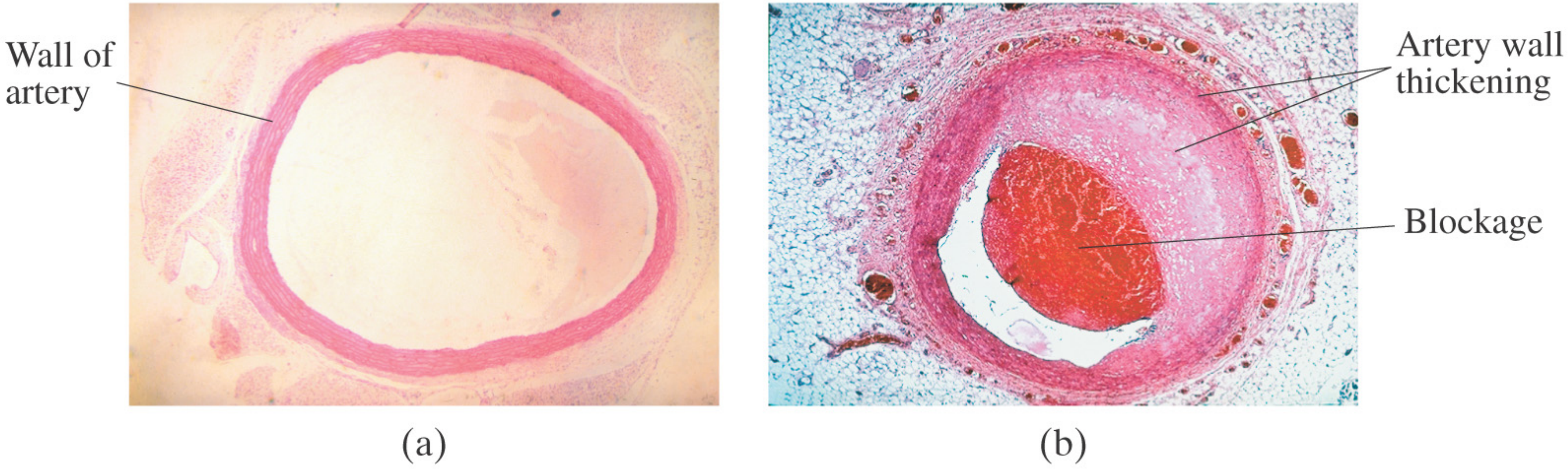
The **rate of flow** in a fluid in a round tube depends on the **viscosity** of the fluid, the **pressure** difference, and the **dimensions** of the tube.

The volume flow rate is proportional to the **pressure difference**, inversely proportional to the **length** of the tube and to the **pressure difference**, and proportional to the **fourth** power of the radius of the tube.

10-12 Flow in Tubes; Poiseuille's Equation, Blood Flow

This has consequences for blood flow – if the radius of the artery is **half** what it should be, the pressure has to increase by a factor of **16** to keep the same flow.

Usually the **heart** cannot work that hard, but **blood pressure** goes up as it tries.

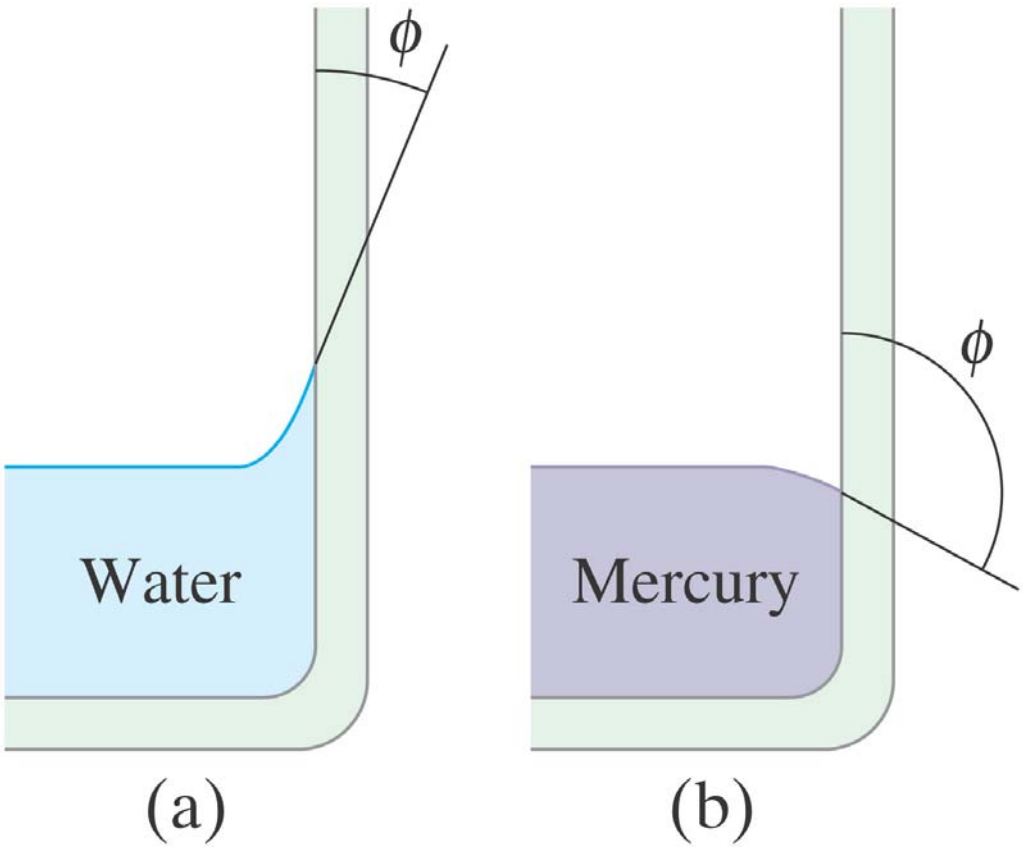


10-13 Surface Tension and Capillarity

The **surface** of a liquid at rest is not perfectly flat; it **curves** either up or down at the **walls** of the container. This is the result of **surface tension**, which makes the surface behave somewhat elastically.

10-13 Surface Tension and Capillarity

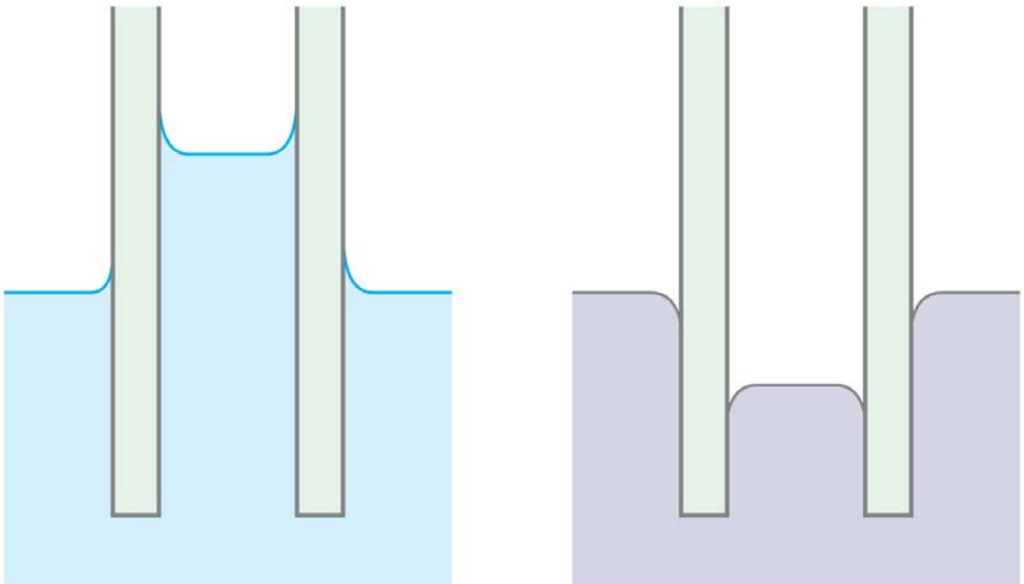
Soap and **detergents** lower the surface tension of water. This allows the water to penetrate materials more easily.



Water molecules are more strongly attracted to **glass** than they are to each other; just the opposite is true for **mercury**.

10-13 Surface Tension and Capillarity

If a **narrow** tube is placed in a fluid, the fluid will exhibit **capillarity**.

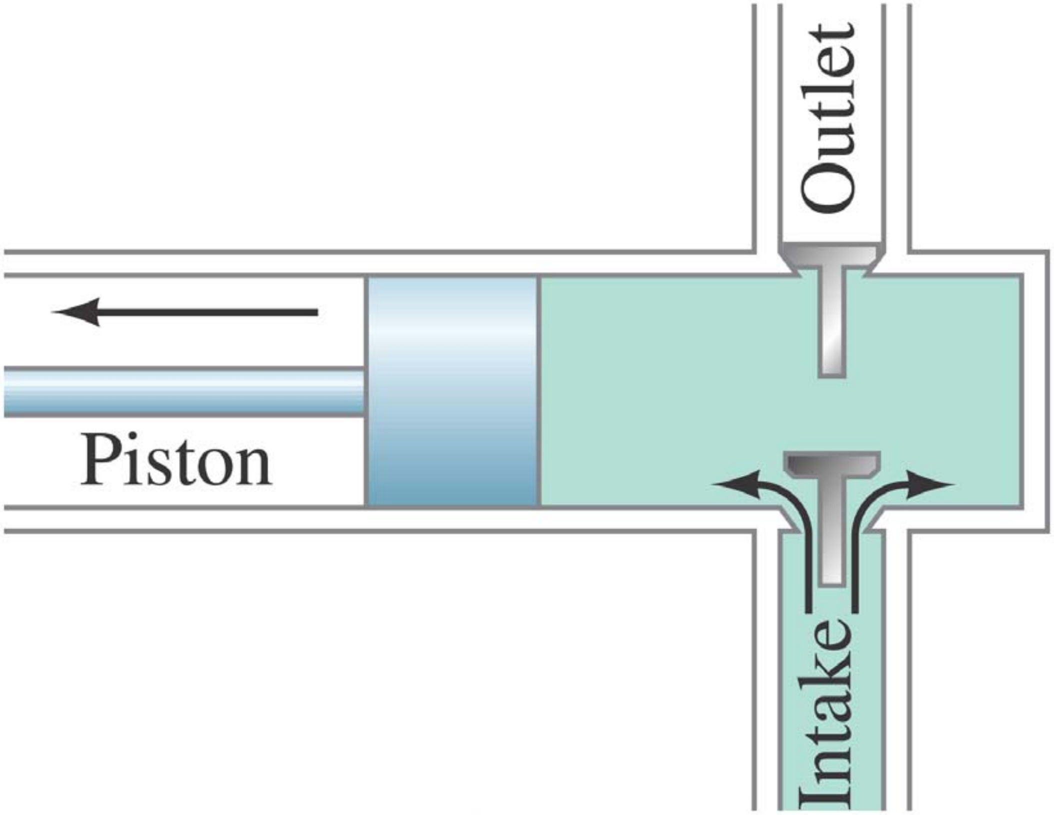


(a) Glass tube in water

(b) Glass tube in mercury

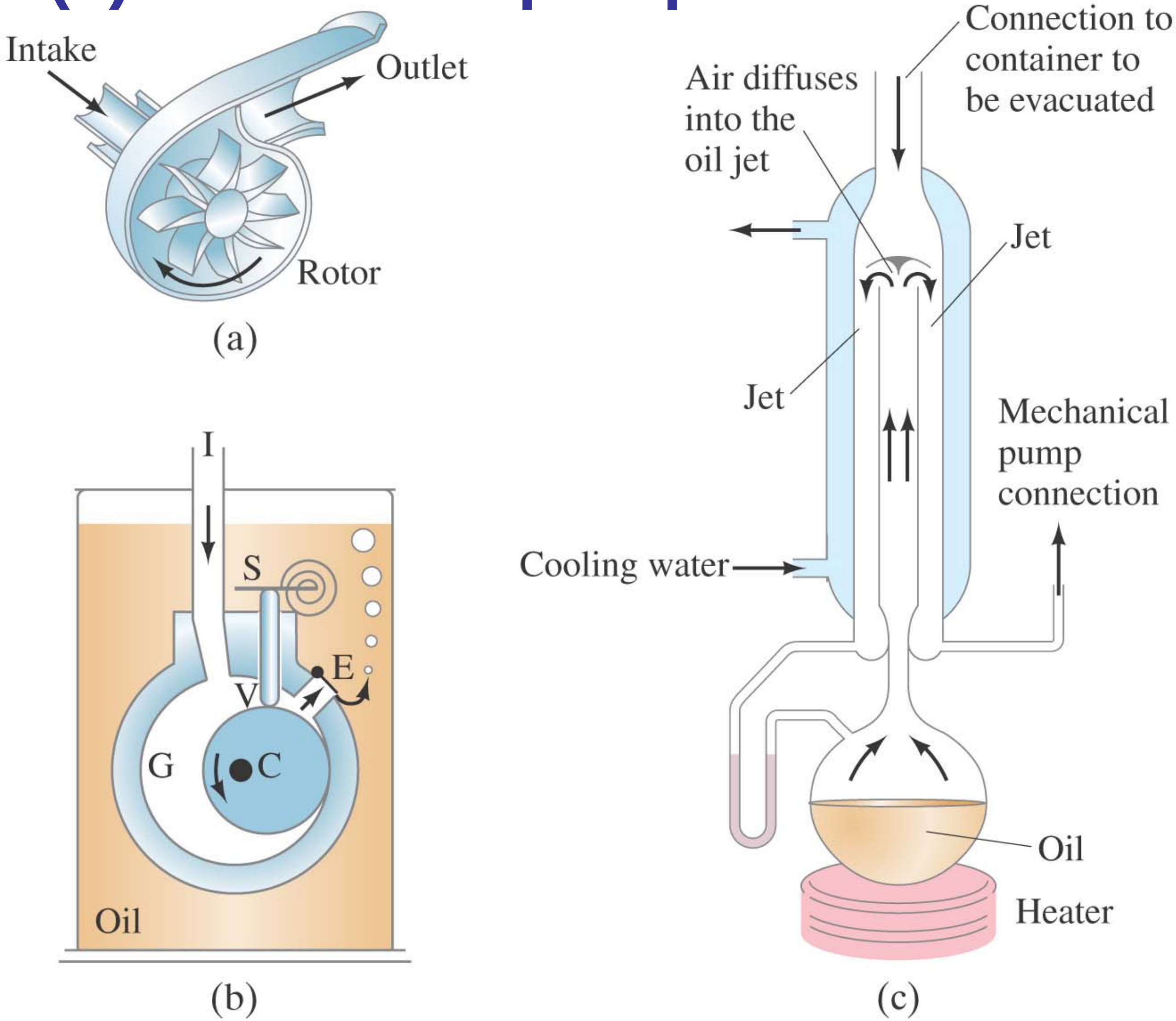
10-14 Pumps, and the Heart

This is a simple **reciprocating** pump. If it is to be used as a **vacuum** pump, the vessel is connected to the **intake**; if it is to be used as a **pressure** pump, the vessel is connected to the **outlet**.



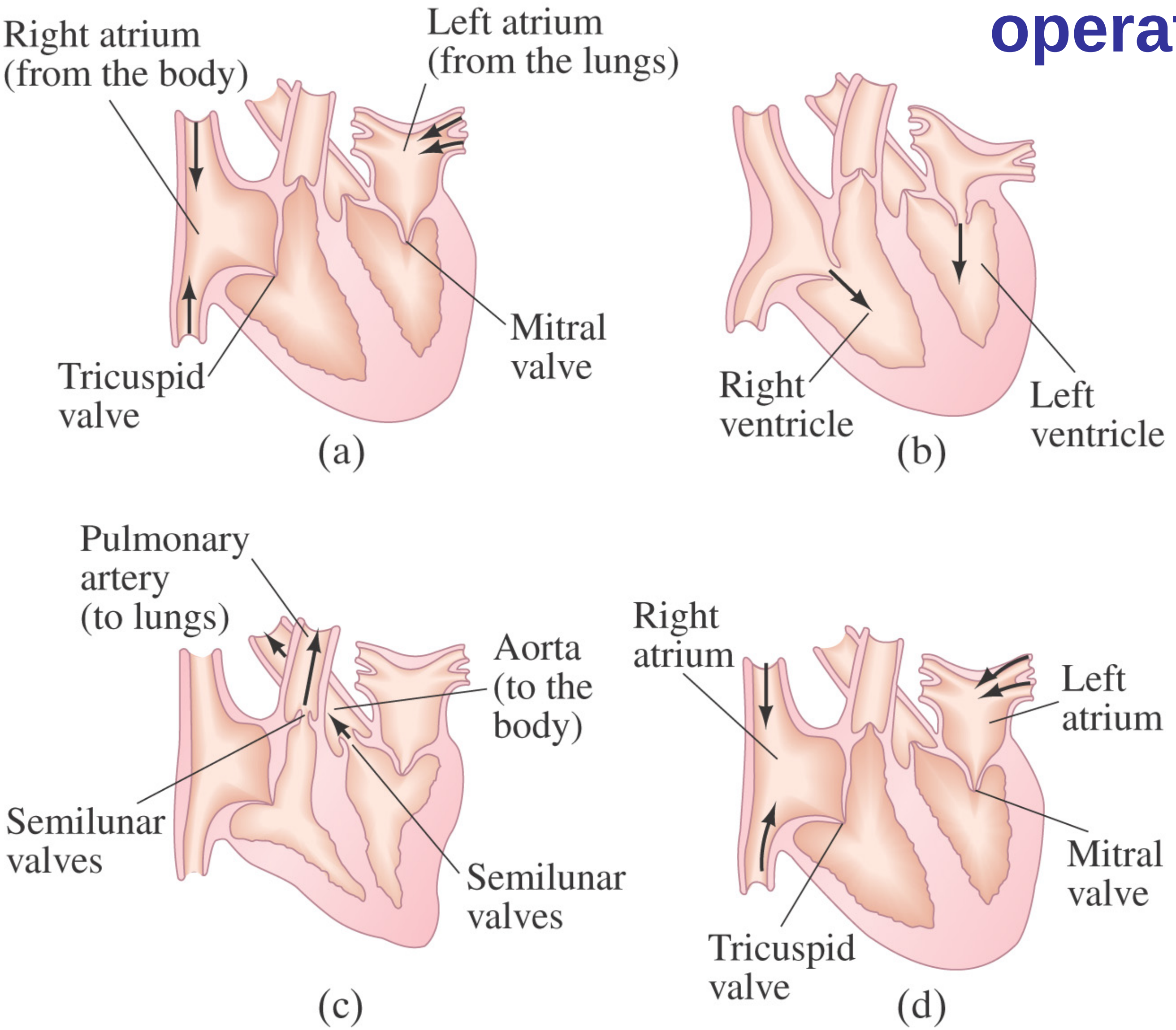
10-14 Pumps, and the Heart

(a) is a centrifugal pump; (b) a rotary oil-seal pump; (c) a diffusion pump



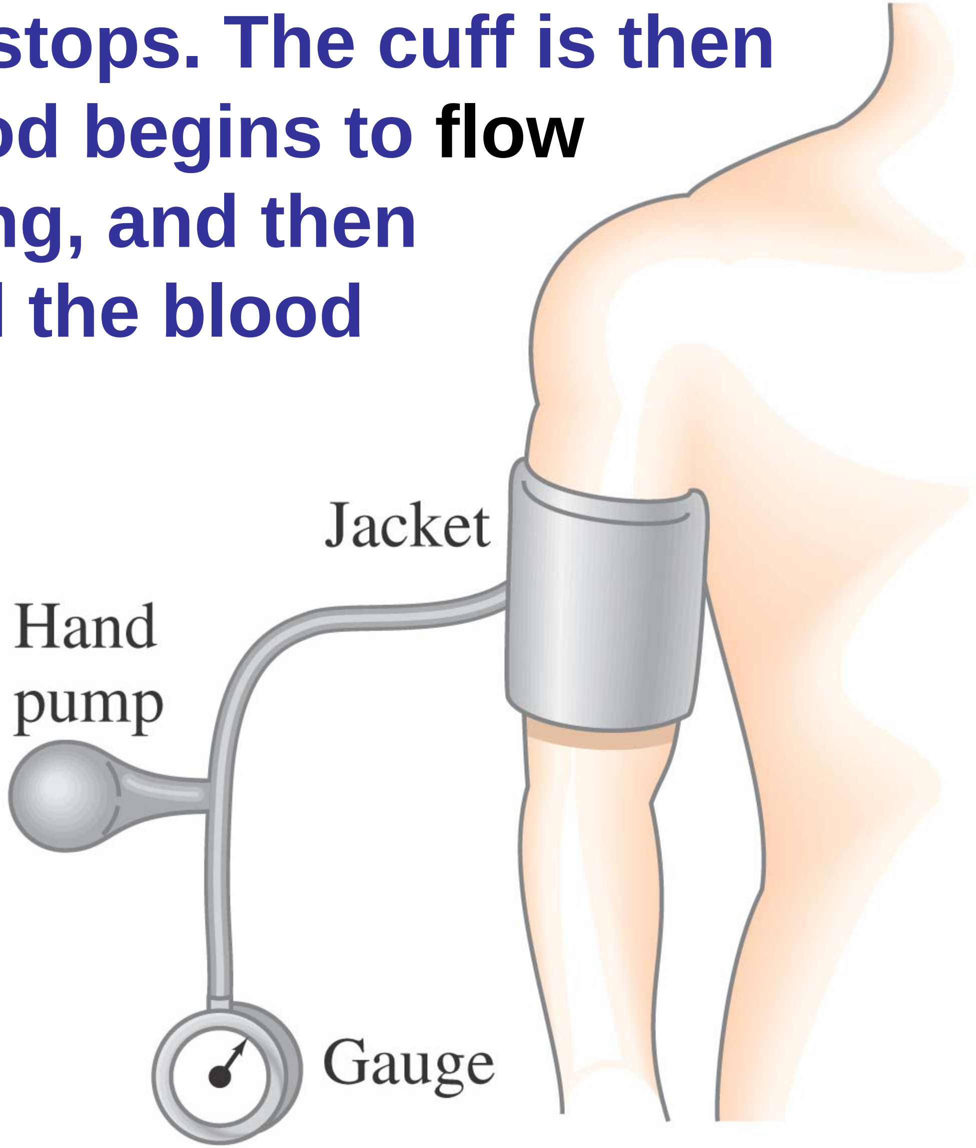
10-14 Pumps, and the Heart

The **heart** of a human, or any other animal, also operates as a **pump**.



10-14 Pumps, and the Heart

In order to measure **blood pressure**, a cuff is **inflated** until blood flow stops. The cuff is then deflated slowly until blood begins to **flow** while the heart is pumping, and then deflated some more until the blood flows **freely**.



Summary of Chapter 10

- Phases of matter: solid, liquid, gas.
- Liquids and gases are called fluids.
- Density is mass per unit volume.
- Specific gravity is the ratio of the density of the material to that of water.
- Pressure is force per unit area.
- Pressure at a depth h is $\rho g h$.
- External pressure applied to a confined fluid is transmitted throughout the fluid.

Summary of Chapter 10

- Atmospheric pressure is measured with a barometer.
- Gauge pressure is the total pressure minus the atmospheric pressure.
- An object submerged partly or wholly in a fluid is buoyed up by a force equal to the weight of the fluid it displaces.
- Fluid flow can be laminar or turbulent.
- The product of the cross-sectional area and the speed is constant for horizontal flow.

Summary of Chapter 10

- Where the velocity of a fluid is high, the pressure is low, and vice versa.
- Viscosity is an internal frictional force within fluids.
- Liquid surfaces hold together as if under tension.