Fluid Mechanics

The longest runway at the airport at Los Angeles, at sea level, is 12 091 ft. The longest runway at Denver is 16 000 ft. The longest runway in the world is at Qamdo Bamda Airport in China: 18 045 ft.

Physics for Scientists and Engineers, 10e
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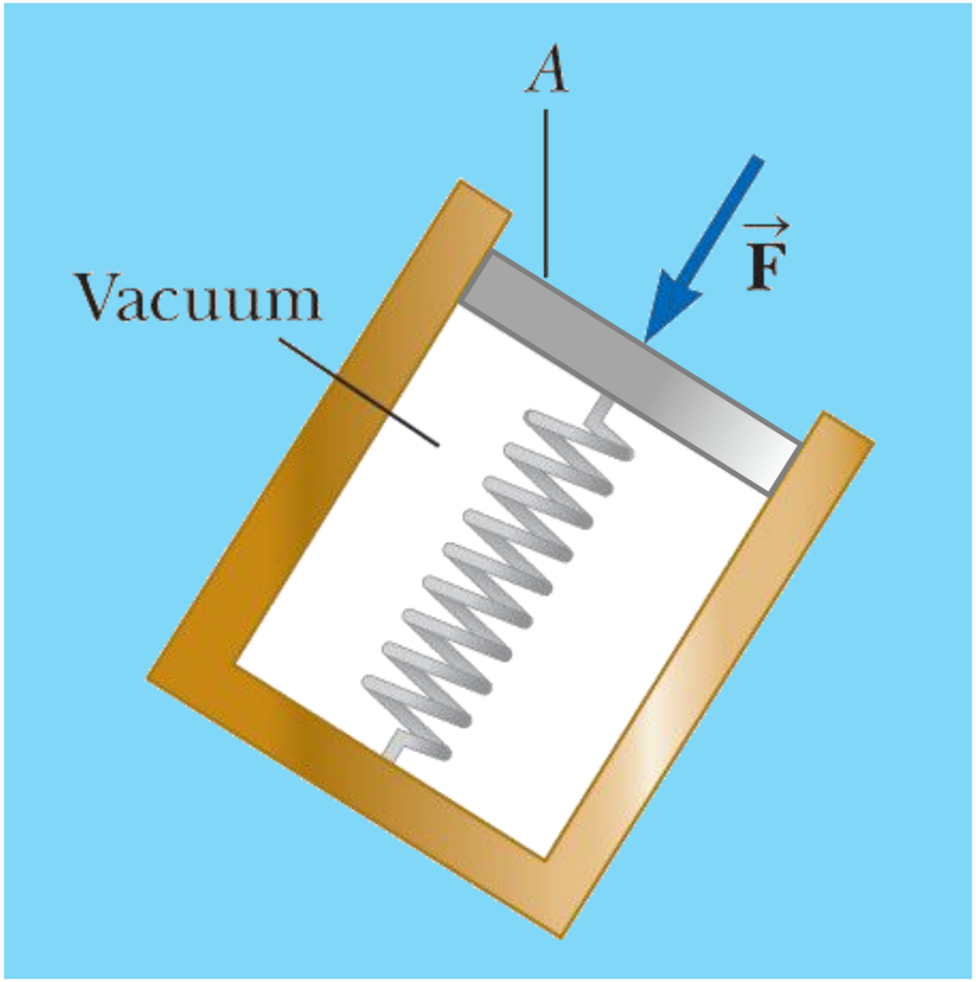
BROOKS/COLE
CENGAGE Learning

Pressure

Pressure P of fluid: ratio of exerted force to area

$$\boxed{P \equiv \frac{F}{A}}$$



$$dF = P dA$$

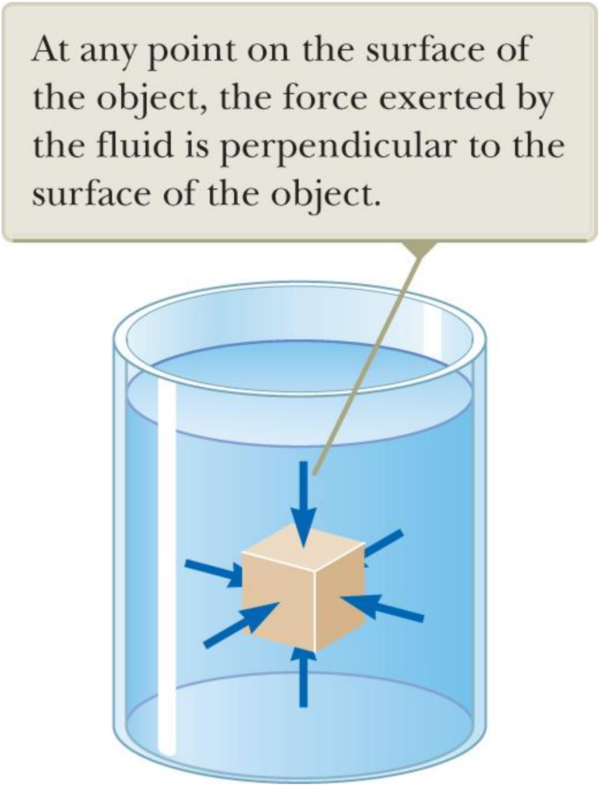
$$F = \int dF = \int P dA$$

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

Pressure

Only stress that can be exerted on object submerged in static fluid:

- One that tends to compress object from all sides
- Force exerted by a static fluid on an object always perpendicular to surfaces of object



Fluids do not sustain

- shearing stresses
- tensile stresses

Heel of shoe, The Water Bed

Quick Quiz 14.1

Suppose you are standing directly behind someone who steps back and accidentally stomps on your foot with the heel of one shoe. Would you be better off if that person were

(a) a large, male professional basketball player wearing sneakers?

(b) a petite woman wearing spike-heeled shoes?

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Example 14.1: The Water Bed

The mattress of a water bed is 2.00 m long by 2.00 m wide and 30.0 cm deep.

(A) Find the weight of the water in the mattress.

$$V = \ell w h$$

$$Mg = (\rho V)g = \rho g \ell w h$$

$$Mg = (1000\ \mathrm{kg/m^3})(9.80\ \mathrm{m/s^2})(2.00\ \mathrm{m})(2.00\ \mathrm{m})(0.300\ \mathrm{m})$$

$$= \boxed{1.18\times 10^4\ \mathrm{N}}$$

Example 14.1:
The Water Bed

(B) Find the pressure exerted by the water bed on the floor when the bed rests in its normal position. Assume the entire lower surface of the bed makes contact with the floor.

$$P = \frac{Mg}{\ell w} = \frac{1.18 \times 10^4 \text{ N}}{4.00 \text{ m}^2} = \boxed{2.94 \times 10^3 \text{ Pa}}$$

Example 14.1:
The Water Bed

What if the water bed is replaced by a 300-lb regular bed that is supported by four legs? Each leg has a circular cross section of radius 2.00 cm. What pressure does this bed exert on the floor?

$$P = \frac{F}{A} = \frac{mg}{4\left(\pi r^2\right)}$$

$$= \frac{300\text{ lb}}{4\pi\left(0.0200\text{ m}\right)^2}\left(\frac{1\text{ N}}{0.225\text{ lb}}\right) = 2.65\times10^5\text{ Pa}$$

Density

$$\rho = M / V$$

TABLE 14.1 Densities of Some Common Substances at Standard Temperature (0°C) and Pressure (Atmospheric)

Substance	ρ (kg/m^3)	Substance	ρ (kg/m^3)
Air	1.29	Iron	7.86×10^3
Air (at 20°C and atmospheric pressure)	1.20	Lead	11.3×10^3
Aluminum	2.70×10^3	Mercury	13.6×10^3
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Fresh water	1.00×10^3	Pine	0.373×10^3
Glycerin	1.26×10^3	Platinum	21.4×10^3
Gold	19.3×10^3	Seawater	1.03×10^3
Helium gas	1.79×10^{-1}	Silver	10.5×10^3
Hydrogen gas	8.99×10^{-2}	Tin	7.30×10^3
Ice	0.917×10^3	Uranium	19.1×10^3

Variation of Pressure with Depth

$$M = \rho V = \rho Ah$$

$$Q = Mg = \rho Ahg$$

The parcel of fluid is in equilibrium, so the net force on it is zero:

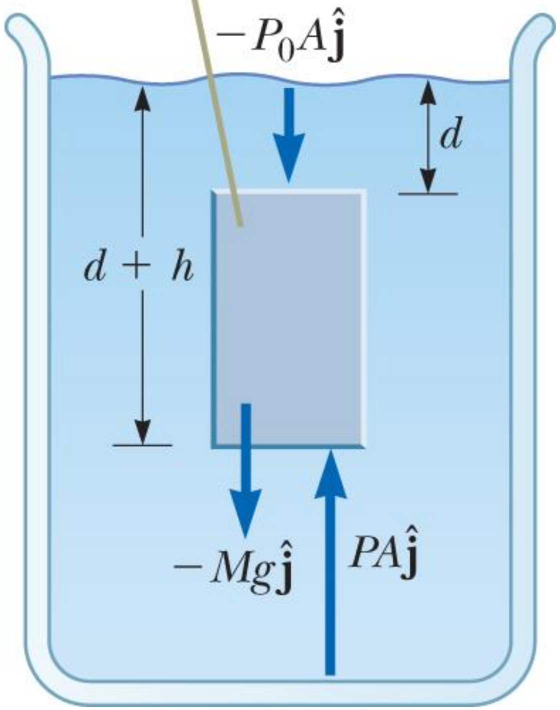
$$\sum \vec{\mathbf{F}} = PA\hat{\mathbf{j}} - P_o A\hat{\mathbf{j}} - Mg\hat{\mathbf{j}} = 0$$

$$PA - P_0 A - \rho Ahg = 0$$

$$\boxed{P = P_0 + \rho gh}$$

hydrostatic pressure = ρgh

A parcel of incompressible fluid in a larger volume of fluid.



Pascal's Law

$$P = P_0 + \rho g h$$

Because the pressure in a fluid depends on depth and on the value of P_0, any increase in pressure at the surface must be transmitted to every other point in the fluid.

A change in the pressure applied to a incompressible fluid is transmitted undiminished to every point of the fluid and to the walls of the container.

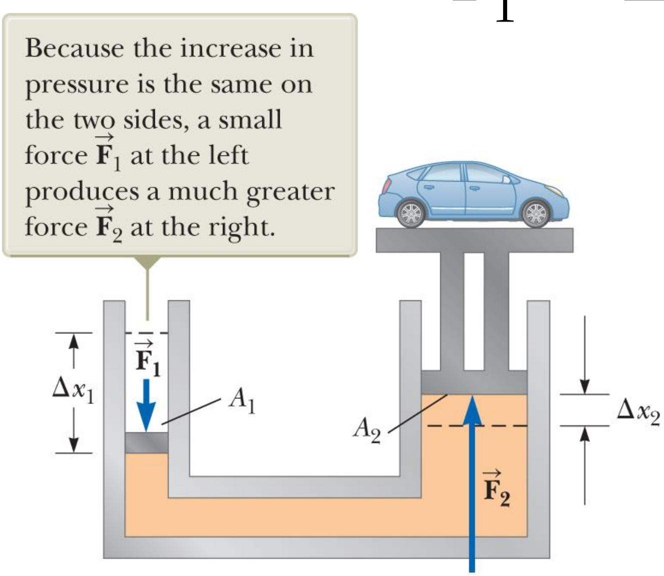
Application of Pascal's Law

Hydraulic lift:

$$P_1 = \frac{F_1}{A_1} = \frac{F_2}{A_2} \Rightarrow \frac{F_2}{F_1} = \frac{A_2}{A_1} \qquad \left(A_1 \Delta x_1 = A_2 \Delta x_2 \Rightarrow \frac{A_2}{A_1} = \frac{\Delta x_1}{\Delta x_2} \right)$$

$$\frac{F_2}{F_1} = \frac{\Delta x_1}{\Delta x_2} \Rightarrow F_1 \Delta x_1 = F_2 \Delta x_2 \Rightarrow W_1 = W_2$$

(energy conservation)



b

Quick Quiz 14.2

The pressure at the bottom of a filled glass of water (ρ = 1 000 kg/m^3) is P. The water is poured out, and the glass is filled with ethyl alcohol (ρ = 806 kg/m^3). What is the pressure at the bottom of the glass?

(a) smaller than P
(b) equal to P
(c) larger than P
(d) indeterminate

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(a) smaller than *P*
(b) equal to *P*
(c) larger than *P*
(d) indeterminate

Example 14.2:
The Car Lift

In a car lift used in a service station, compressed air exerts a force on a small piston that has a circular cross section of radius 5.00 cm. This pressure is transmitted by a liquid to a piston that has a radius of 15.0 cm.

(A) What force must the compressed air exert to lift a car weighing 13 300 N?

$$F_1 = \left(\frac{A_1}{A_2}\right)F_2 = \frac{\pi\left(5.00\times10^{-2}\ \text{m}\right)^2}{\pi\left(15.00\times10^{-2}\ \text{m}\right)^2}\left(1.33\times10^4\ \text{N}\right)$$

$$= \boxed{1.48\times10^3\ \text{N}}$$

Example 14.2: The Car Lift

(B) What air pressure produces this force?

$$P = \frac{F_1}{A_1} = \frac{1.48\times10^3 \text{ N}}{\pi\left(5.00\times10^{-2} \text{ m}\right)^2} = \boxed{1.88\times10^5 \text{ Pa}}$$

Example 14.3:
A Pain in Your Ear

Estimate the force exerted on your eardrum due to the water when you are swimming at the bottom of a pool that is 5.0 m deep.

$$\begin{aligned} P_{\text{bot}} - P_0 &= \rho g h \\ &= \left(1.00\times10^3\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)\left(5.0\ \text{m}\right) \\ &= 4.9\times10^4\ \text{Pa} \end{aligned}$$

$$F = \left(P_{\text{bot}} - P_0\right)A = \left(4.9\times10^4\ \text{Pa}\right)\left(1\times10^{-4}\ \text{m}^2\right) \approx \boxed{5\ \text{N}}$$

Example 14.4:
The Force on a Dam

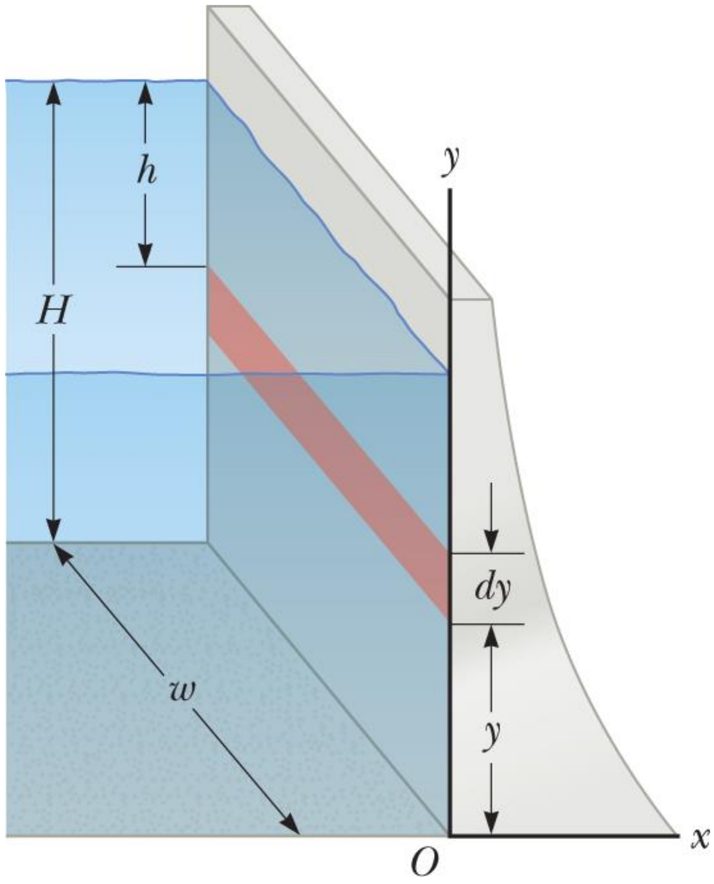
Water is filled to a height H behind a dam of width w. Determine the resultant force exerted by the water on the dam.

$$P = \rho g h = \rho g\left(H - y\right)$$

$$dF = P dA = \rho g\left(H - y\right) w\, dy$$

$$F = \int P\, dA = \int_0^H \rho g\left(H - y\right) w\, dy$$

$$= \boxed{\frac{1}{2}\rho g w H^2}$$



Example 14.4: The Force on a Dam

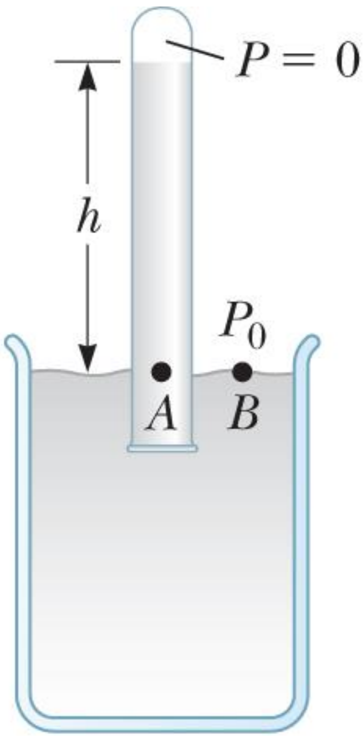
What if you were asked to find this force without using calculus? How could you determine its value?

$$P_{\text{avg}} = \frac{P_{\text{top}} + P_{\text{bottom}}}{2} = \frac{0 + \rho g H}{2} = \frac{1}{2}\rho g H$$

$$F = P_{\text{avg}} A = \left(\frac{1}{2}\rho g H\right)(Hw) = \frac{1}{2}\rho g w H^2$$

Torricelli Experiment - 1643

Barometer, invented by Evangelista Torricelli: long tube closed at one end filled with mercury and then inverted into container of mercury



$$P = P_0 + \rho g h$$

$$P_A = 0 + \rho_{\mathrm{Hg}} g h$$

$$P_B = P_0$$

$$P_A = P_B \Rightarrow$$

$$h = \frac{P_0}{\rho_{\mathrm{Hg}} g} = \frac{1.013\times10^5\ \mathrm{Pa}}{\left(13.6\times10^3\ \mathrm{kg/m^3}\right)\left(9.80\ \mathrm{m/s^2}\right)}$$

$$= 0.760\ \mathrm{m}$$

$$P_0 = 1.013\times10^5\ \mathrm{Pa} = 760\ \mathrm{mmHg} = 1\ \mathrm{atm} = 10.3\ \mathrm{mH_2 0}$$

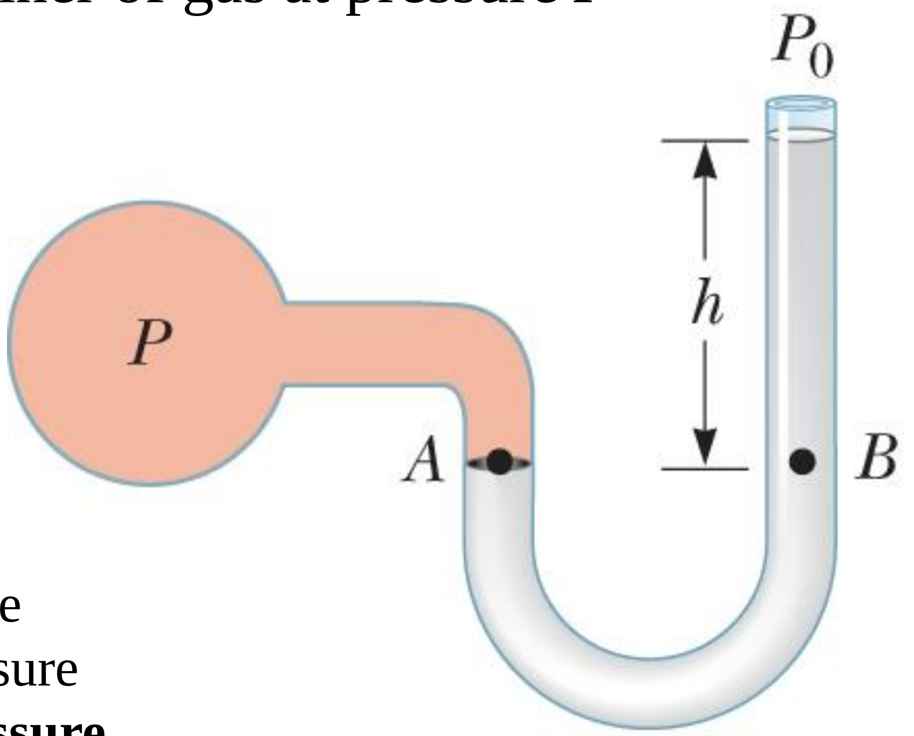
Pressure Measurements

Open-tube manometer:

- Device for measuring excess of gas pressure contained in a vessel
- One end of U-shaped tube containing liquid open to atmosphere
- Other end connected to container of gas at pressure *P*

$$P_A = P$$
$$P_B = P_0 + \rho g h$$

$$P_A = P_B \Rightarrow$$
$$P - P_0 = \rho g h$$



P – absolute pressure

P_0 – referrence pressure

$P - P_0$ – **gauge pressure**

Column of fluid

Quick Quiz 14.3

Several common barometers are built, with a variety of fluids. For which of the following fluids will the column of fluid in the barometer be
the highest?

(a) mercury
(b) water
(c) ethyl alcohol
(d) benzene

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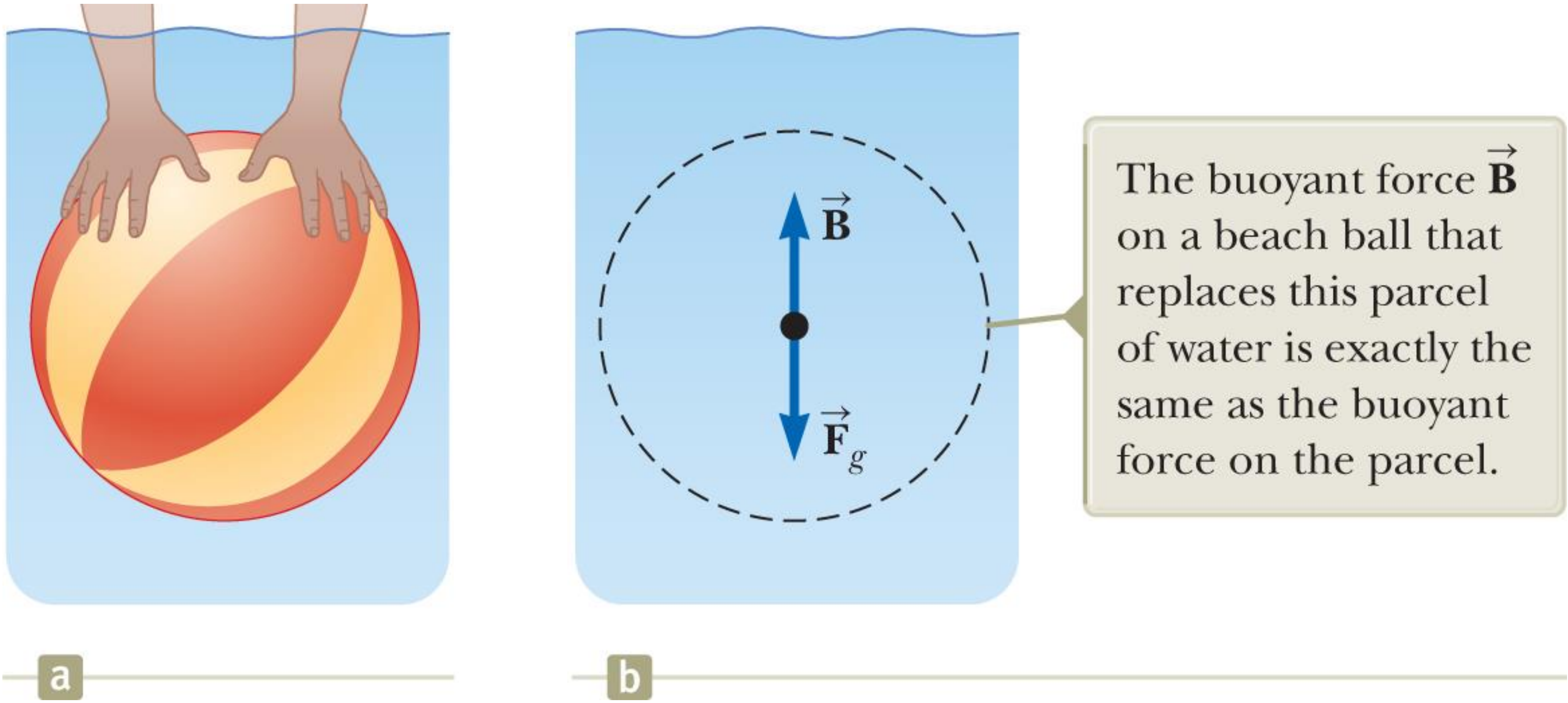
Buoyant Forces and Archimedes's Principle



Magnitude of the buoyant force on an object always equals the weight of the fluid displaced by the object.

Buoyant Forces and Archimedes's Principle

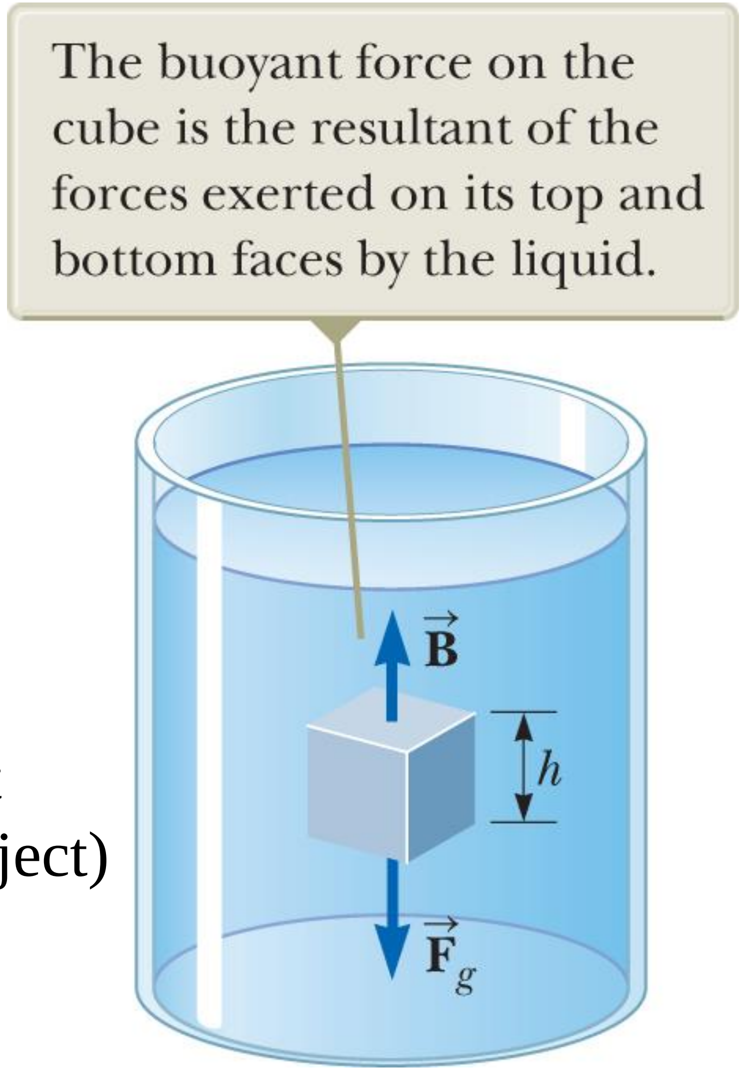
$$B = F_{\text{bot}} - F_{\text{top}} = \left(P_{\text{bot}} - P_{\text{top}}\right)A$$

$$= \left(\rho_{\text{fluid}} g h\right)A$$

$$\boxed{B = \rho_{\text{fluid}} g V_{\text{disp}}}$$

V_{disp} – volume of fluid displaced by object
(same volume as submerged portion of object)

$$B = M_{\text{disp fluid}}\, g$$



Buoyant Forces and Fish

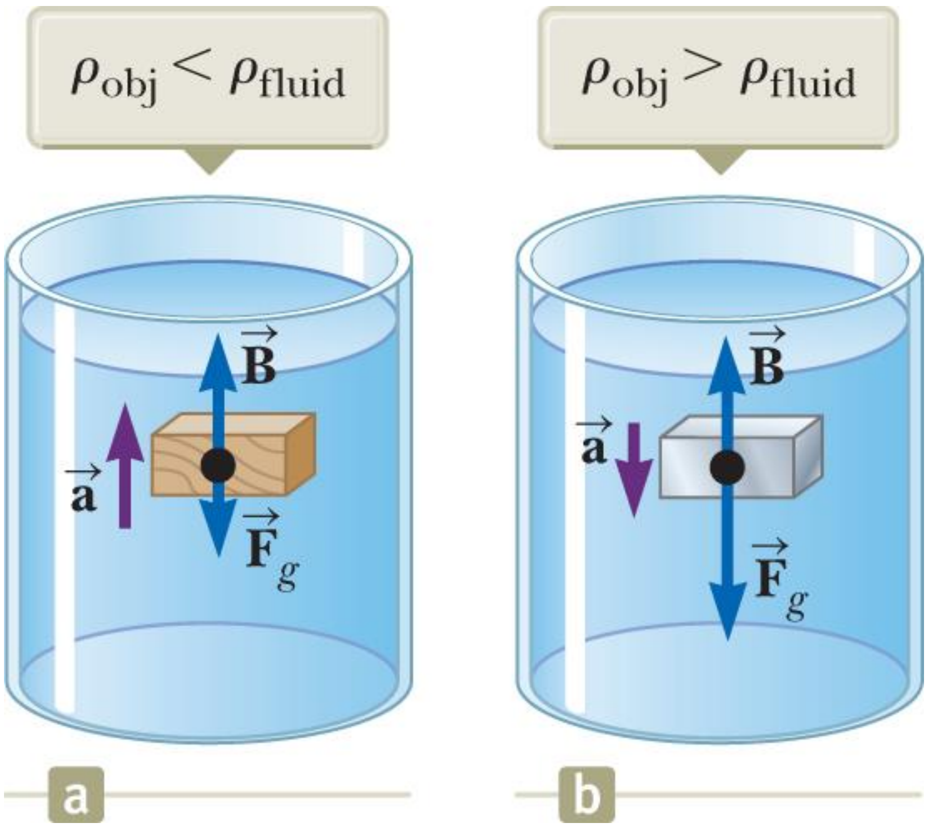
Under normal conditions: weight of a fish slightly greater than buoyant force on fish

$\Longrightarrow$ fish would sink if it did not have some mechanism for adjusting buoyant force

Fish internally regulates size of its air-filled swim bladder to increase its volume and magnitude of buoyant force acting on it

$\Longrightarrow$ Fish is able to swim to various depths

Totally Submerged Object



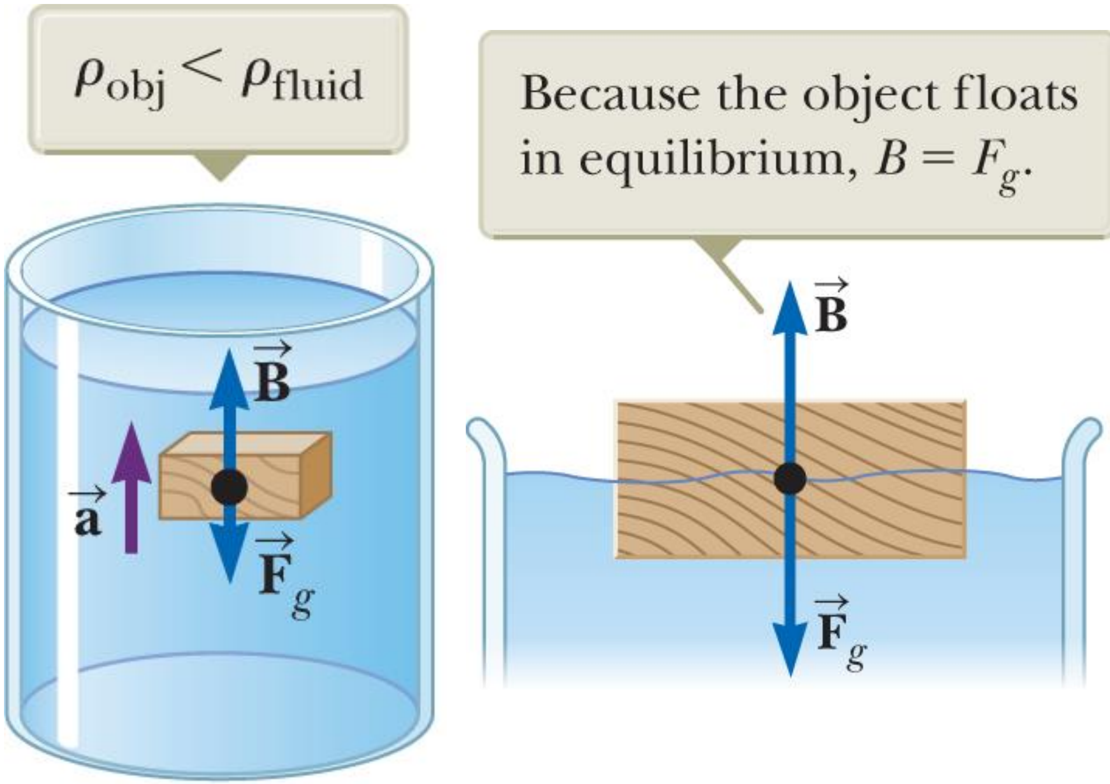
$$B = \rho_{\text{fluid}} g V_{\text{disp}}$$

$$F_g = Mg = \rho_{\text{obj}} g V_{\text{obj}}$$

$$V_{disp} = V_{\text{obj}} \Rightarrow$$

$$B - F_g = \left(\rho_{\text{fluid}} - \rho_{\text{obj}}\right) g V_{\text{obj}}$$

Floating Object



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

$$F_g = Mg = \rho_{obj} g V_{obj}$$

$$F_g = B$$

$$\frac{V_{disp}}{V_{obj}} = \frac{\rho_{obj}}{\rho_{fluid}} \Leftarrow \quad \rho_{fluid} g V_{disp} = \rho_{fluid} g V_{obj}$$

Treasure chest, Eureka!, A Titanic Surprise

Quick Quiz 14.4

You are shipwrecked and floating in the middle of the ocean on a raft. Your cargo on the raft includes a treasure chest full of gold that you found before your ship sank, and the raft is just barely afloat. To keep you floating as high as possible in the water, what should you do? (Assume throwing the treasure chest overboard is not an option you wish to consider.)

(a) Leave the treasure chest on top of the raft.
(b) Secure the treasure chest to the underside of the raft.
(c) Hang the treasure chest in the water with a rope attached to the raft.

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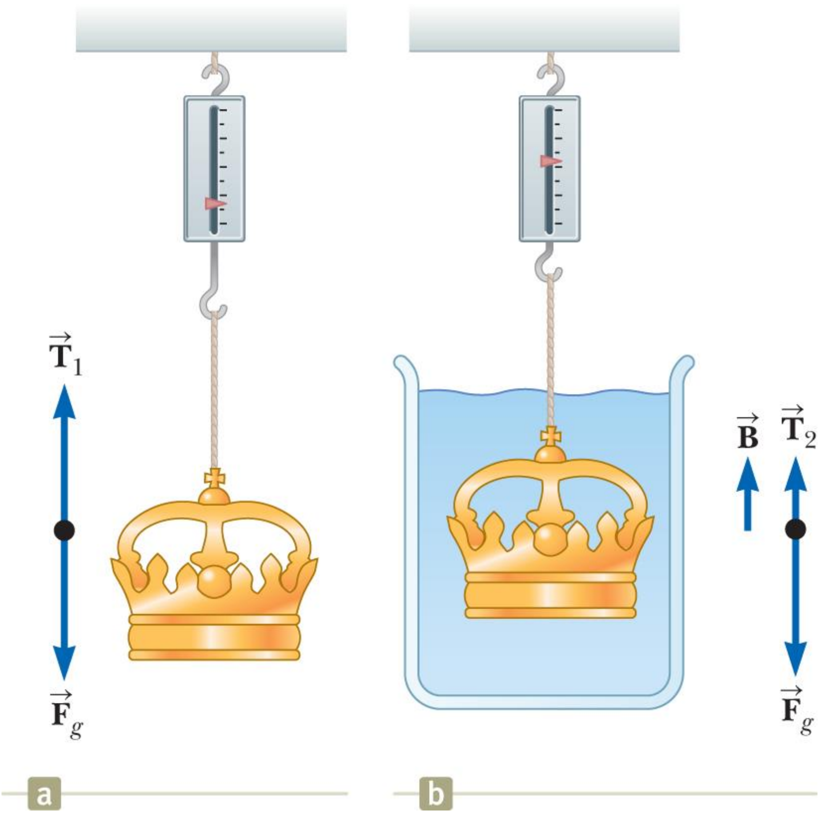
Example 14.5: Eureka!

Archimedes supposedly was asked to determine whether a crown made for the king consisted of pure gold. According to legend, he solved this problem by weighing the crown first in air and then in water. Suppose the scale read 7.84 N when the crown was in air and 6.84 N when it was in water. What should Archimedes have told the king?



Example 14.5: Eureka!

$$T_2 = F_g - B \qquad \sum F = B + T_2 - F_g = 0$$

$$B = F_g - T_2 = m_c g - T_2$$

$$B = \rho_w g V_{\text{disp}} = \rho_w g V_c$$

$$\rho_c = \frac{m_c}{V_c} = \frac{m_c g}{V_c g} = \frac{m_c g}{\left(B / \rho_w\right)} = \frac{m_c g \rho_w}{B} = \frac{m_c g \rho_w}{F_g - T_2} = \frac{m_c g \rho_w}{m_c g - T_2}$$

$$\rho_c = \frac{\left(7.84\ \text{N}\right)\left(1000\ \text{kg/m}^3\right)}{7.84\ \text{N} - 6.84\ \text{N}} = 7.84 \times 10^3\ \text{kg/m}^3$$

Example 14.5: Eureka!

TABLE 14.1 Densities of Some Common Substances at Standard Temperature (0°C) and Pressure (Atmospheric)

Substance	ρ (kg/m^3)	Substance	ρ (kg/m^3)
Air	1.29	Iron	7.86×10^3
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Glycerin	1.26×10^3	Platinum	21.4×10^3
Gold	$\boxed{19.3 \times 10^3}$	Seawater	1.03×10^3
Helium gas	1.79×10^{-1}	Silver	10.5×10^3
Hydrogen gas	8.99×10^{-2}	Tin	7.30×10^3
Ice	0.917×10^3	Uranium	19.1×10^3

Example 14.5: Eureka!

Suppose the crown has the same weight but is indeed pure gold and not hollow. What would the scale reading be when the crown is immersed in water?

$$B = \rho_w g V_w = \rho_w g V_c = \rho_w g \left(\frac{m_c}{\rho_c} \right) = \rho_w \left(\frac{m_c g}{\rho_c} \right)$$

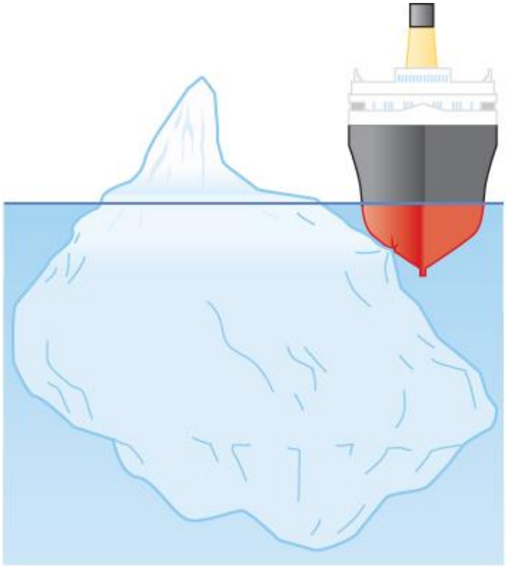
$$B = \left(1.00 \times 10^3 \text{ kg/m}^3 \right) \frac{7.84 \text{ N}}{19.3 \times 10^3 \text{ kg/m}^3} = 0.406 \text{ N}$$

$$T_2 = m_c g - B = 7.84 \text{ N} - 0.406 \text{ N} = 7.43 \text{ N}$$

Example 14.6: A Titanic Surprise

An iceberg floating in seawater is extremely dangerous because most of the ice is below the surface. This hidden ice can damage a ship that is still a considerable distance from the visible ice. What fraction of the iceberg lies below the water level?

a



b

Example 14.6:
A Titanic Surprise

TABLE 14.1 Densities of Some Common Substances at Standard Temperature (0°C) and Pressure (Atmospheric)

Substance	ρ (kg/m^3)	Substance	ρ (kg/m^3)
Air	1.29	Iron	7.86×10^3
Air (at 20°C and atmospheric pressure)	1.20	Lead	11.3×10^3
		Mercury	13.6×10^3
Aluminum	2.70×10^3	Nitrogen gas	1.25
Benzene	0.879×10^3	Oak	0.710×10^3
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Hydrogen gas	8.99×10^{-2}	Uranium	19.1×10^3
Ice	0.917×10^3		

$$f = \frac{V_{\text{disp}}}{V_{\text{ice}}} = \frac{\rho_{\text{ice}}}{\rho_{\text{seawater}}} = \frac{917 \text{ kg/m}^3}{1030 \text{ kg/m}^3} = \boxed{0.890 \text{ or } 89.0\%}$$

Fluid Dynamics

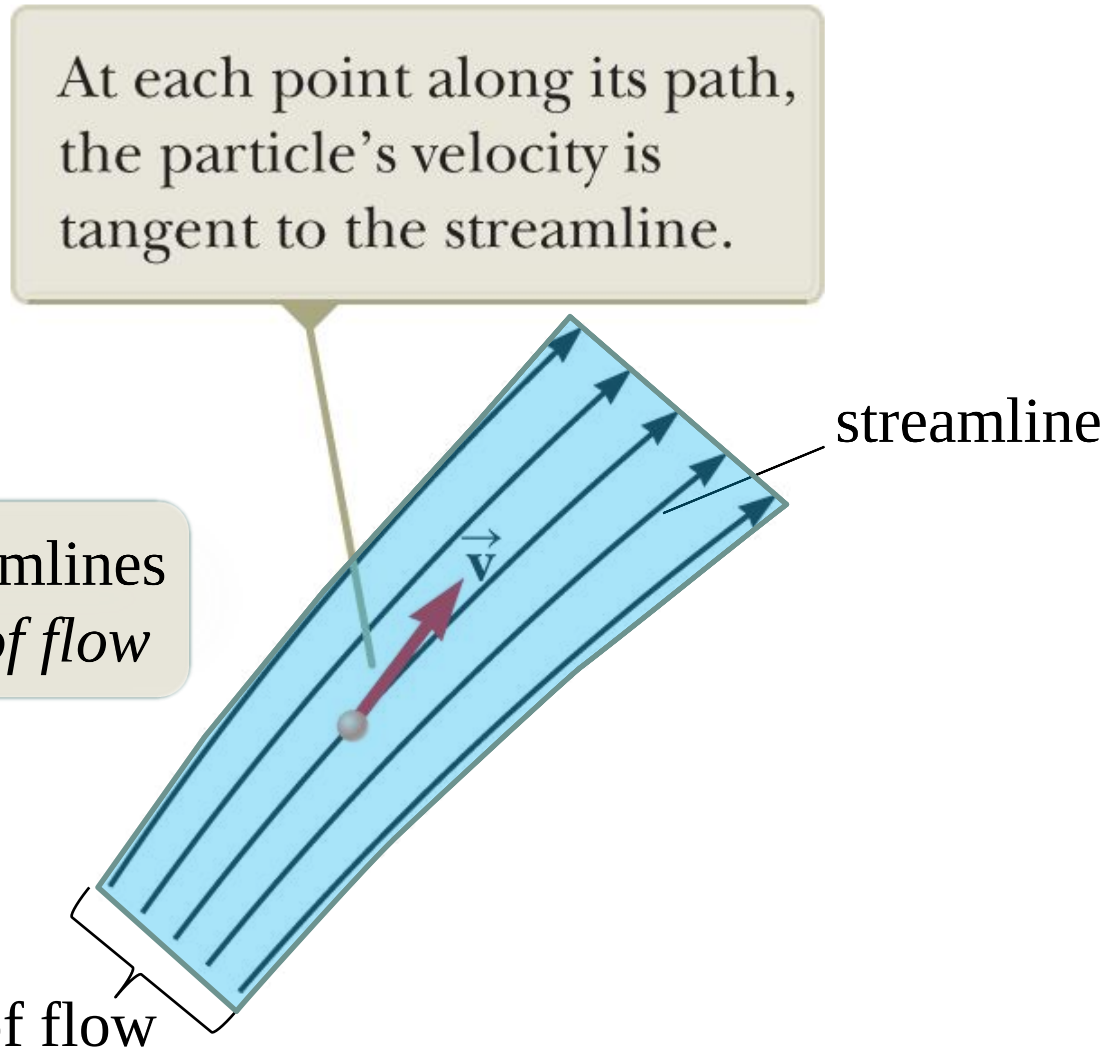
Laminar flow:
each particle of fluid follows smooth path, constant in time

Turbulent flow:
irregular unpredictable flow characterized by small whirlpool-like regions

Ideal Fluid Flow Assumptions

1. **The fluid is nonviscous**
   - In nonviscous fluid, internal friction neglected
   - Object moving through fluid experiences no viscous force
2. **The flow is laminar**
   - All particles passing through point have same velocity and follow same path
3. **The fluid is incompressible**
   - Density of an incompressible fluid same throughout fluid
4. **The flow is irrotational**
   - Fluid has no angular momentum about any point
   - If small paddle wheel placed anywhere in fluid does not rotate about wheel's center of mass

Streamlines



Set of streamlines form *tube of flow*

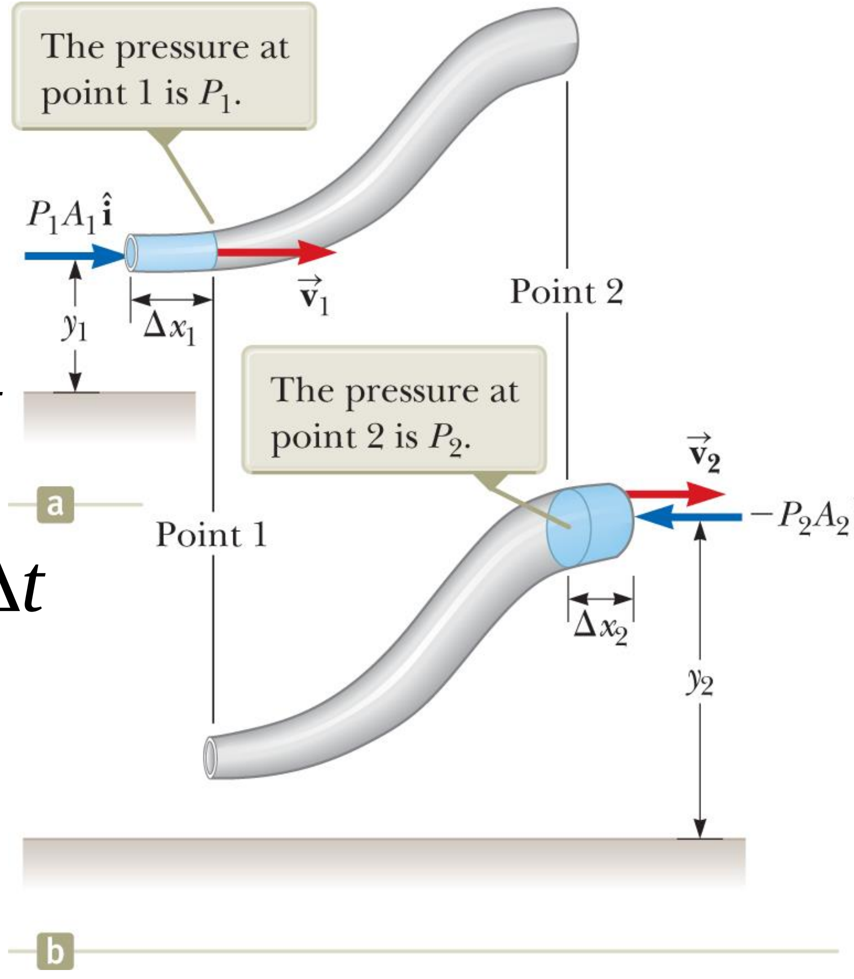
Continuity Equation for Fluids

$$m_1 = \rho V = \rho A_1 \Delta x_1 = \rho A_1 v_1 \Delta t$$

$$m_2 = \rho V = \rho A_2 \Delta x_2 = \rho A_2 v_2 \Delta t$$

$$m_1 = m_2 \quad \text{or} \quad \rho A_1 v_1 \Delta t = \rho A_2 v_2 \Delta t$$

$$\boxed{A_1 v_1 = A_2 v_2 = \text{constant}}$$



Continuity Equation for Fluids

Watering a Garden

Example 14.7: Watering a Garden

A gardener uses a water hose to fill a 30.0-L bucket. The gardener notes that it takes 1.00 min to fill the bucket. A nozzle with an opening of cross-sectional area 0.500 cm^2 is then attached to the hose. The nozzle is held so that water is projected horizontally from a point 1.00 m above the ground. Over what horizontal distance can the water be projected?

Example 14.7:
Watering a Garden

$$I_V = A_1 v_1 \quad \Rightarrow v_1 = I_V / A_1 \qquad v_2 = v_{xi} = \frac{A_1}{A_2}\left(\frac{I_V}{A_1}\right) = \frac{I_V}{A_2}$$

$$y_f = y_i + v_{yi}t - \frac{1}{2}gt^2 \qquad \Rightarrow y_f = 0 + 0 - \frac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{-2y_f}{g}}$$

$$x_f = x_i + v_{xi}t = 0 + v_2 t = v_2 t$$

$$x_f = \frac{I_V}{A_2}\sqrt{\frac{-2y_f}{g}}$$

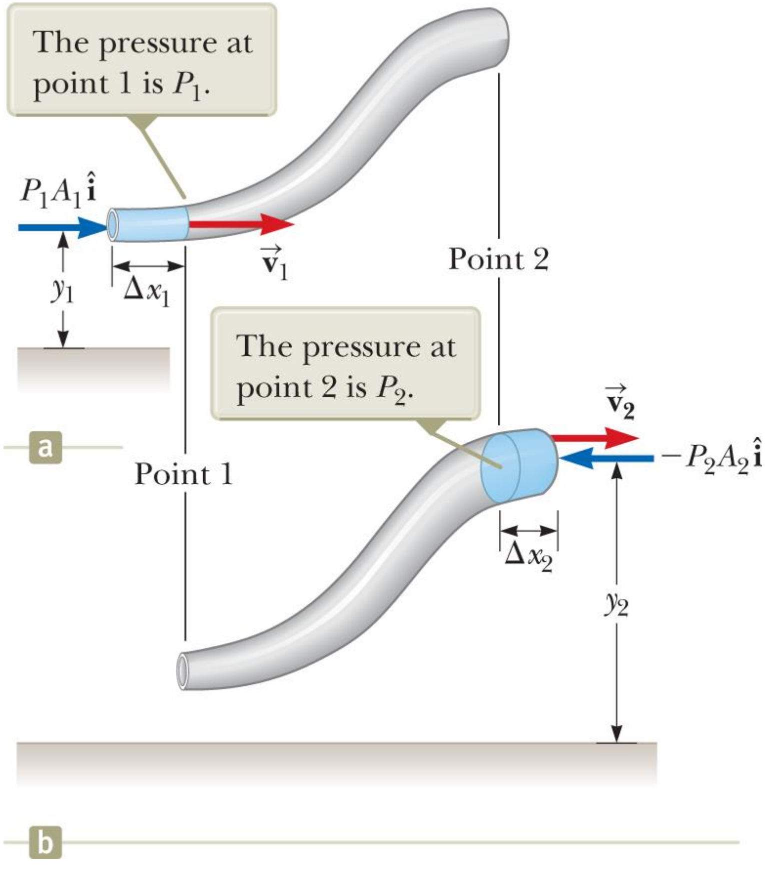
$$x_f = \frac{30.0\ \mathrm{L/min}}{0.500\ \mathrm{cm}^2}\sqrt{\frac{-2(-1.00\ \mathrm{m})}{9.80\ \mathrm{m/s}^2}}\left(\frac{10^3\ \mathrm{cm}^3}{1\ \mathrm{L}}\right)\left(\frac{1\ \mathrm{min}}{60\ \mathrm{s}}\right) = 452\ \mathrm{cm}$$

Bernoulli's Equation (1738)

$$W_1 = F_1 \Delta x_1 = P_1 A_1 \Delta x_1 = P_1 V$$

$$W_2 = -P_2 A_2 \Delta x_2 = -P_2 V$$

$$W = (P_1 - P_2) V$$



Total Energy Conservation:

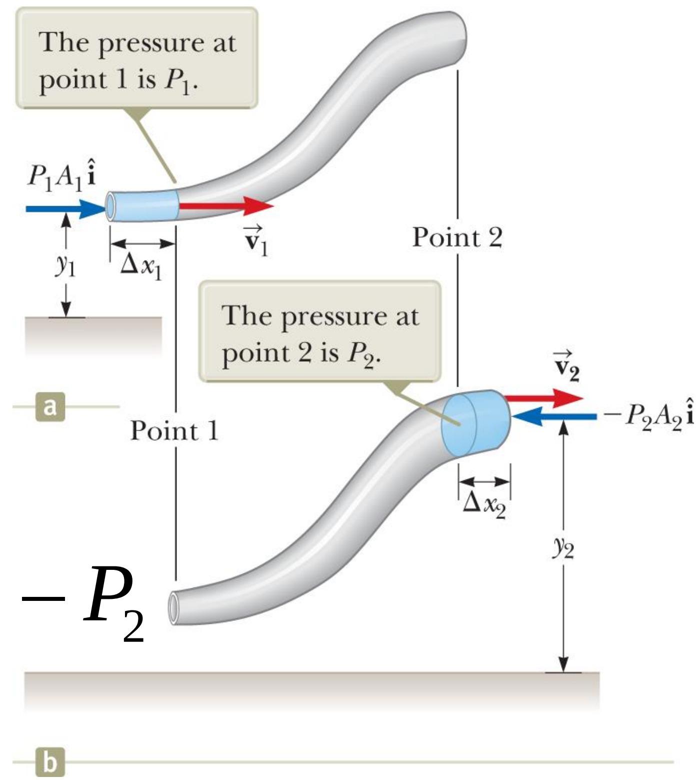
$$\Delta K + \Delta U_g = W$$

$$\Delta K = \left(\frac{1}{2} m v_2^{\ 2} + K_{gray} \right) - \left(\frac{1}{2} m v_1^{\ 2} + K_{gray} \right) = \frac{1}{2} m v_2^{\ 2} - \frac{1}{2} m v_1^{\ 2}$$

Bernoulli's Equation

$$\Delta U_g = \left(mgy_2 + U_{gray}\right) - \left(mgy_1 + U_{gray}\right)$$
$$= mgy_2 - mgy_1$$

$$\left(\frac{1}{2}mv_2 - \frac{1}{2}mv_1^{\;2}\right) + \left(mgy_2 - mgy_1\right)$$
$$= \left(P_1 - P_2\right)V$$



$$\frac{1}{2}\rho v_2^{\;2} - \frac{1}{2}\rho v_1^{\;2} + \rho g y_2 - \rho g y_1 = P_1 - P_2$$

$$P_1 + \frac{1}{2}\rho v_1^{\;2} + \rho g y_1 = P_2 + \frac{1}{2}v_2^{\;2} + \rho g y_2$$

Bernoulli's Equation

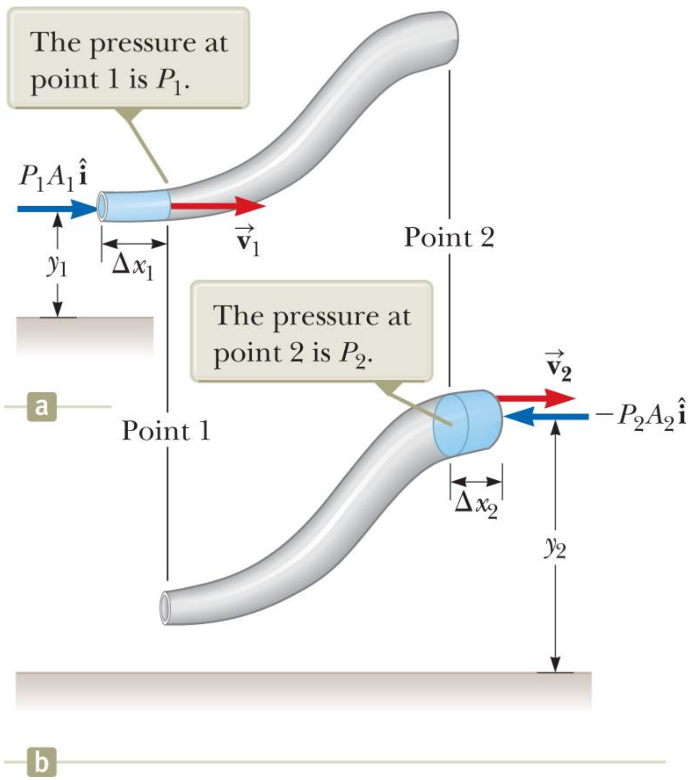
Energy per unit volume is constant:

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

Pressure energy

Kinetic Energy per unit volume

Potential Energy per unit volume



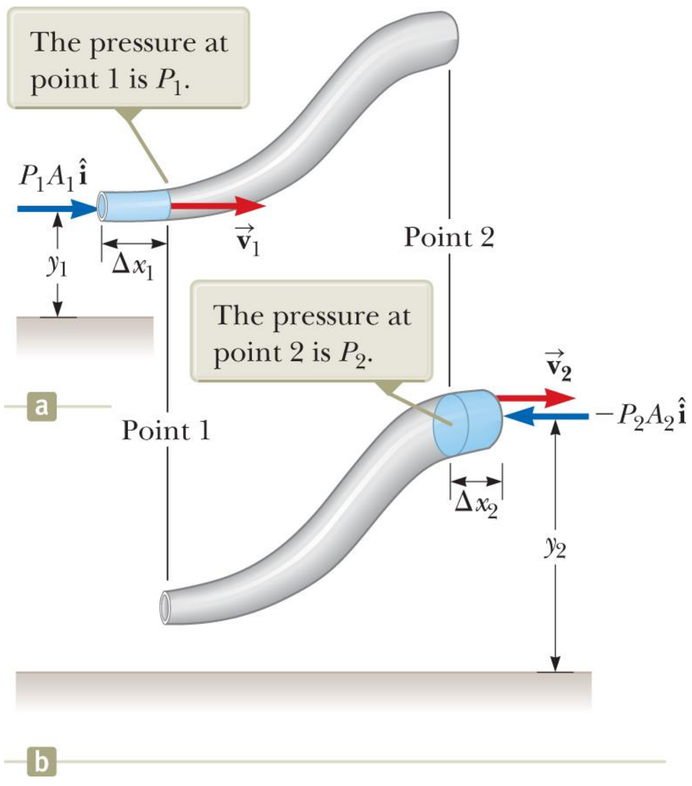
$$P = \frac{F}{A} \Rightarrow \text{Pa} = \frac{\text{N}}{\text{m}^2} = \frac{\text{N}\cdot\text{m}}{\text{m}^3} = \frac{\text{J}}{\text{m}^3} \Rightarrow P = \frac{E}{V}$$

Hydrostatic pressure

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

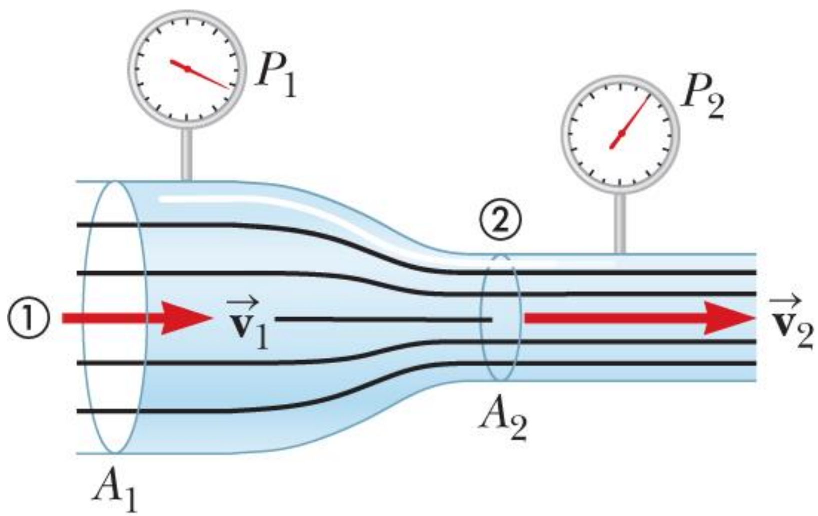
For fluid at rest:

$$P_1 = P_2 + \rho g\left(y_2 - y_1\right) = P_2 + \rho g h$$



Example 14.8: The Venturi Tube

The horizontal constricted pipe illustrated in the figure, known as a *Venturi tube*, can be used to measure the flow speed of an incompressible fluid. Determine the flow speed at point 2 of the figure on the left if the pressure difference $P_1 - P_2$ is known.



a

b

Example 14.8: The Venturi Tube

Bernoulli's equation:

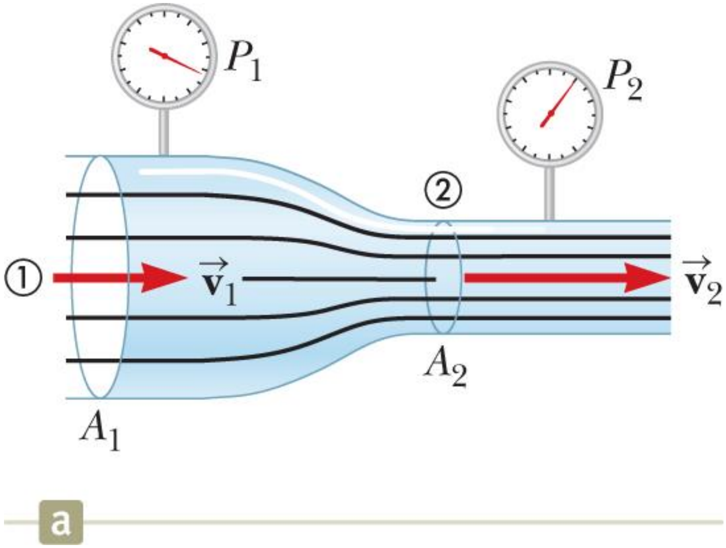
$$P_1 + \frac{1}{2}\rho v_1^{\,2} = P_2 + \frac{1}{2}\rho v_2^{\,2}$$

Equation of continuity:

$$v_1 = \frac{A_2}{A_1} v_2$$

$$P_1 + \frac{1}{2}\rho\left(\frac{A_2}{A_1}\right)^2 v_2^{\,2} = P_2 + \frac{1}{2}\rho v_2^{\,2}$$

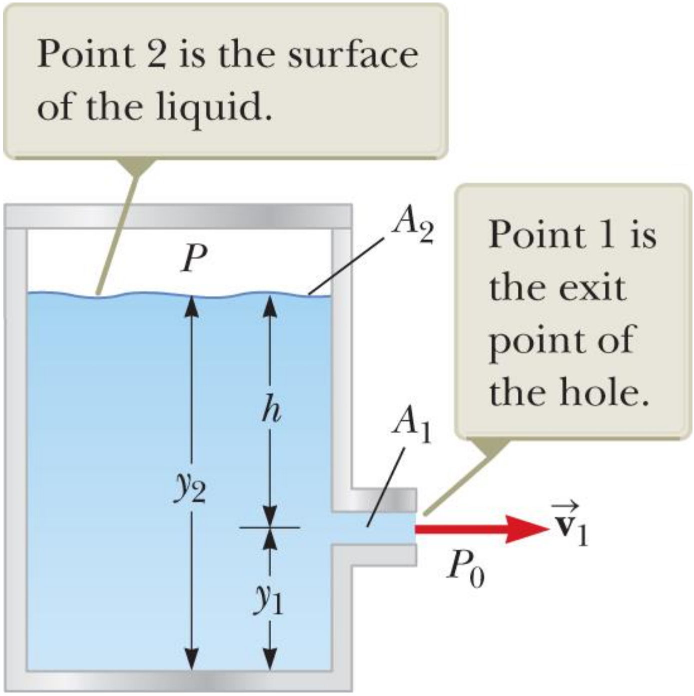
$$v_2 = A_1\sqrt{\frac{2(P_1 - P_2)}{\rho\left(A_1^{\,2} - A_2^{\,2}\right)}}$$



Example 14.9: Torricelli's Law

An enclosed tank containing a liquid of density ρ has a hole in its side at a distance y_1 from the tank's bottom. The hole is open to the atmosphere, and its diameter is much smaller than the diameter of the tank.

The air above the liquid is maintained at a pressure *P*. Determine the speed of the liquid as it leaves the hole when the liquid's level is a distance *h* above the hole.

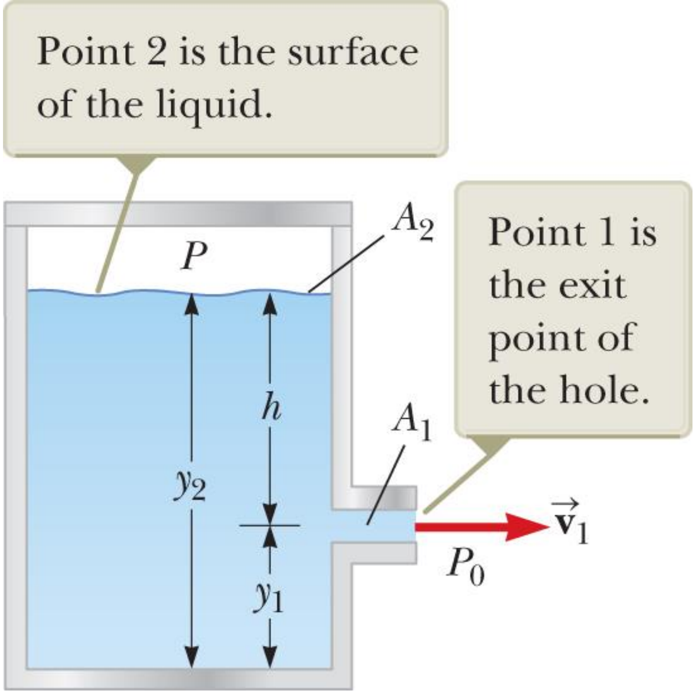


Example 14.9: Torricelli's Law

$$P_0 + \frac{1}{2}\rho v_1^{\,2} + \rho g y_1 = P + \rho g y_2$$

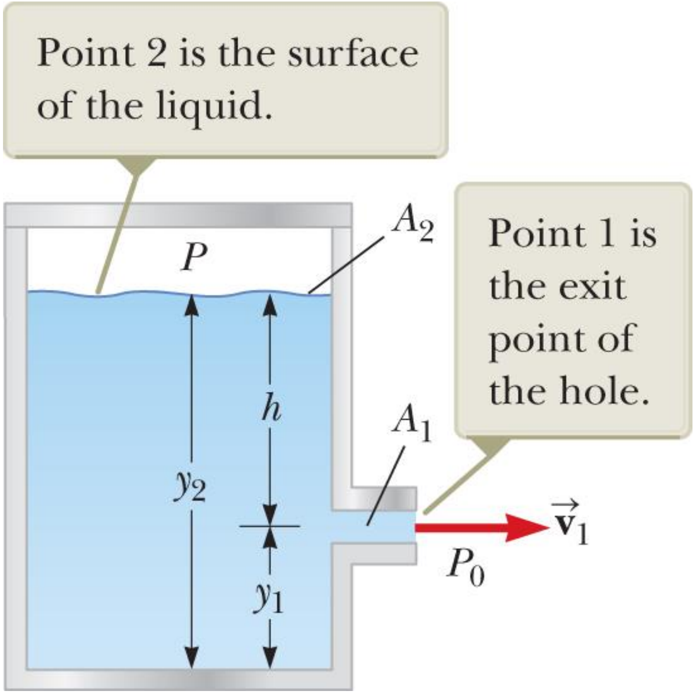
$$v_1 = \sqrt{\frac{2(P - P_0)}{\rho} + 2gh}$$

$$v_1 = \sqrt{2gh}$$



Example 14.9: Torricelli's Law

What if the position of the hole could be adjusted vertically? If the top of the tank is open to the atmosphere and sitting on a table, what position of the hole would cause the water to land on the table at the farthest distance from the tank?



Example 14.9: Torricelli's Law

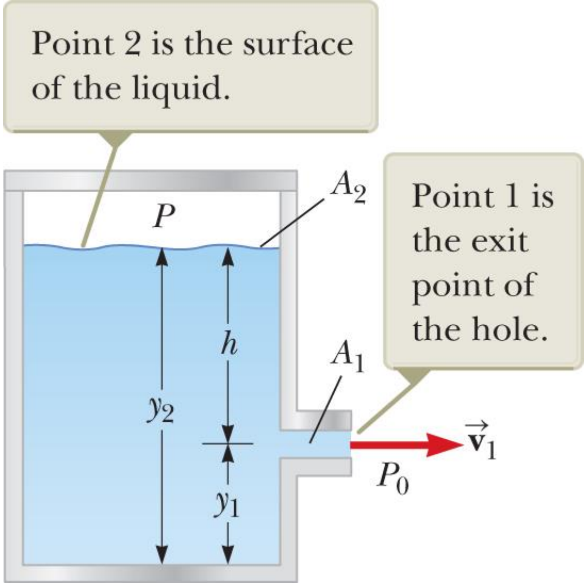
$$y_f = y_i + v_{yi}t - \frac{1}{2}gt^2 \Rightarrow 0 = y_1 + 0 - \frac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{2y_1}{g}}$$

$$x_f = x_i + v_{xi}t = 0 + \sqrt{2g\left(y_2 - y_1\right)}\sqrt{\frac{2y_1}{g}} = 2\sqrt{\left(y_2 y_1 - y_1^{\,2}\right)}$$

$$\frac{dx_f}{dy_1} = \frac{1}{2}(2)\left(y_2 y_1 - y_1^{\,2}\right)^{-1/2}\left(y_2 - 2y_1\right)$$

$$= 0$$

$$y_1 = \frac{1}{2}y_2$$



Flow of Viscous Fluids in Pipes

$$\Delta P = I_V R$$

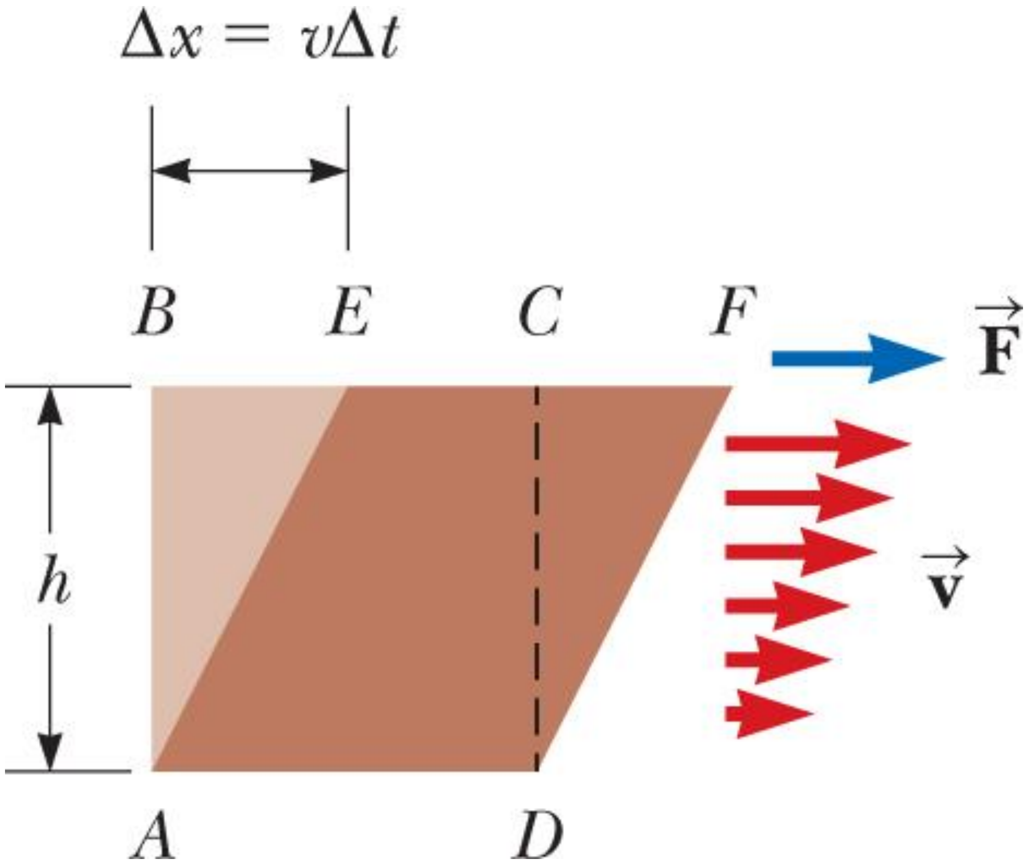
compare to: $\Delta V = IR$

$$F = SA\frac{\Delta x}{h}$$

$$F \propto A\frac{\Delta x}{h}$$

$$F \propto A\frac{v}{h}$$

$$F = \eta A\frac{v}{h}$$



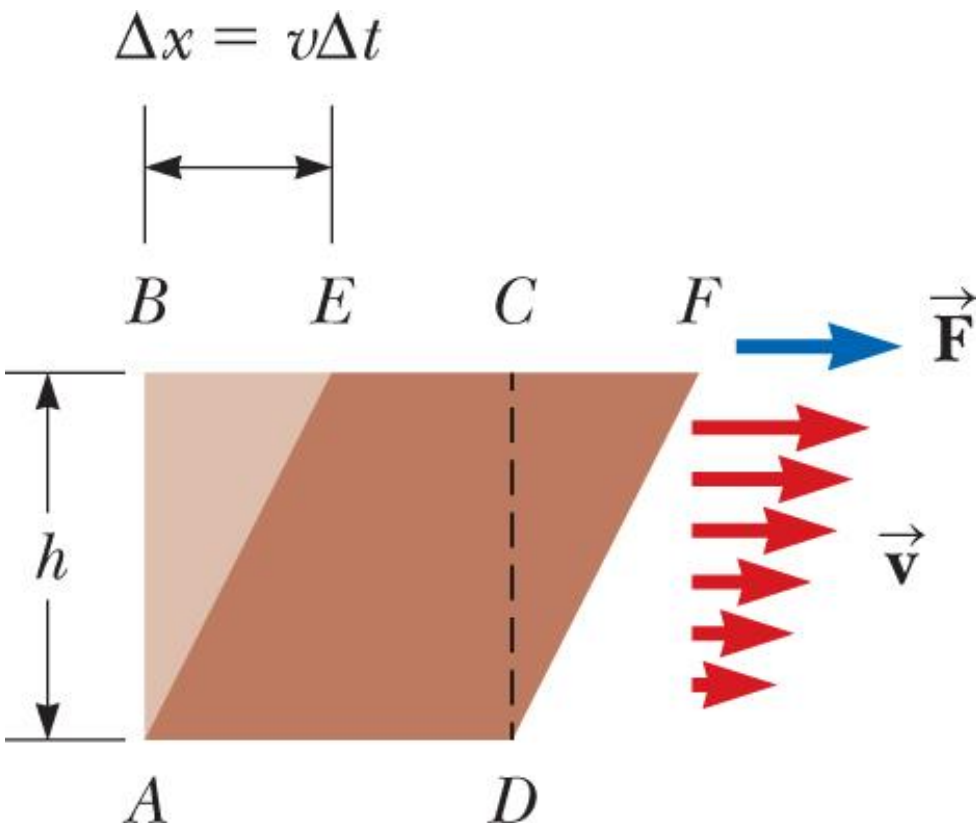
Viscosities of Fluids

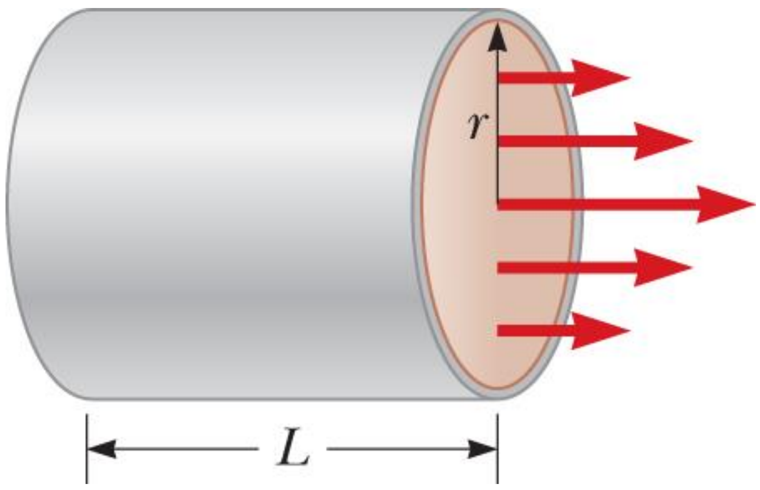
TABLE 14.2 Viscosities of Various Fluids[a]

Fluid	Viscosity (mPa · s)
Air	0.018
Helium	0.020
Liquid nitrogen (−196°C)	0.158
Acetone	0.306
Water	0.894
Ethanol	1.07
Blood (37.0°C)	2.70
Olive oil	81
Motor oil (SAE 40, 20°C)	319
Corn syrup	1 381
Glycerin	1 500
Honey[b]	2 000–10 000
Peanut butter	250 000

[a]All values at 25.0°C unless noted otherwise.
[b]Value depends on moisture content.

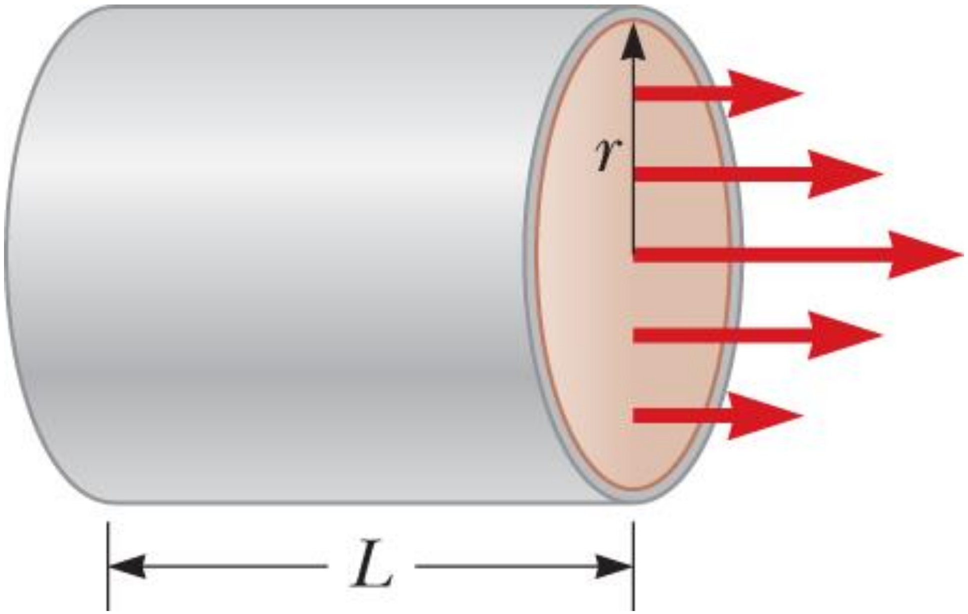
Flow of Viscous Fluids in Pipes





Flow of Viscous Fluids in Pipes

$$R = \frac{8\eta L}{\pi r^4}$$

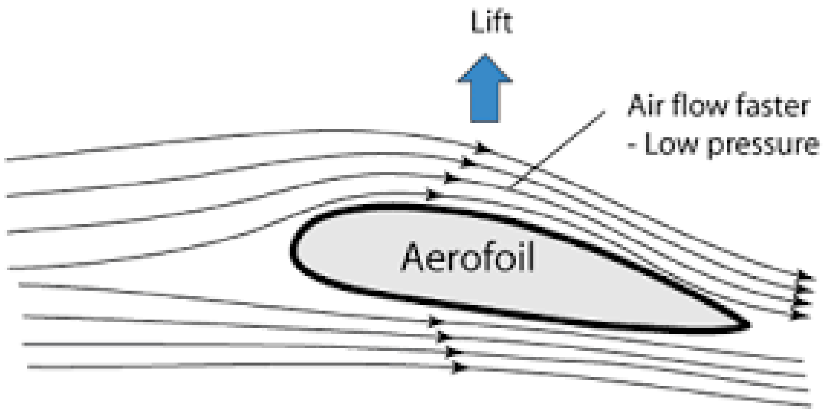


$$\Delta P = I_V R$$

$$\boxed{\Delta P = \frac{8\eta L}{\pi r^4} I_V}$$ Poiseuille's Law

(Hagen-Poiseuille equation)

Runway length

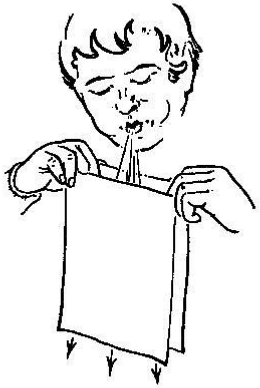


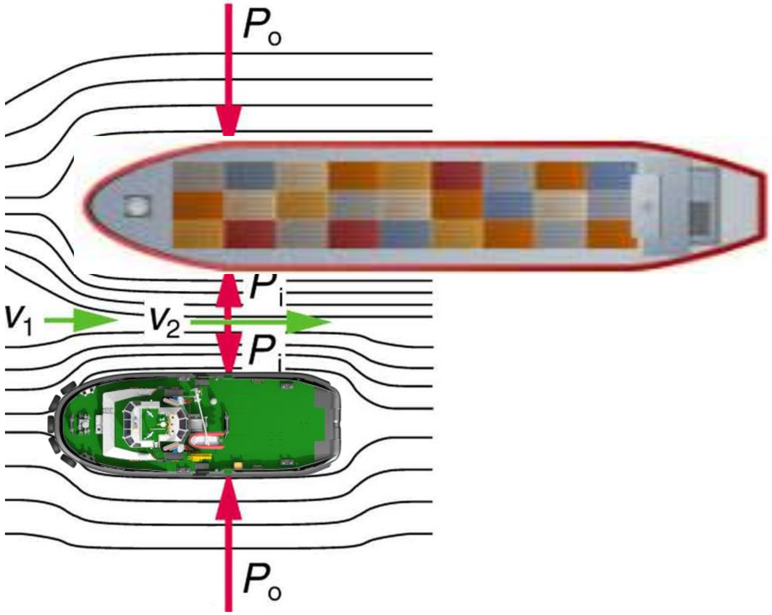
$$P_1 + \frac{1}{2}\rho v_1{}^2 = P_2 + \frac{1}{2}\rho v_2{}^2$$

$$F = (P_1 - P_2)A = \frac{1}{2}\rho\left(v_2{}^2 - v_1{}^2\right)A$$

Lift force and pressure difference between top and bottom of wing (Bernoulli effect) depend on density of air surrounding wings $\Rightarrow$ at the air of lower density the drag force is smaller

Attraction





Quick Quiz 14.5

You observe two helium balloons floating next to each other at the ends of strings secured to a table. The facing surfaces of the balloons are separated by 1 to 2 cm. You blow through the small space between the balloons. What happens to the balloons?

(a) They move toward each other.
(b) They move away from each other.
(c) They are unaffected.

Quick Quiz 14.5

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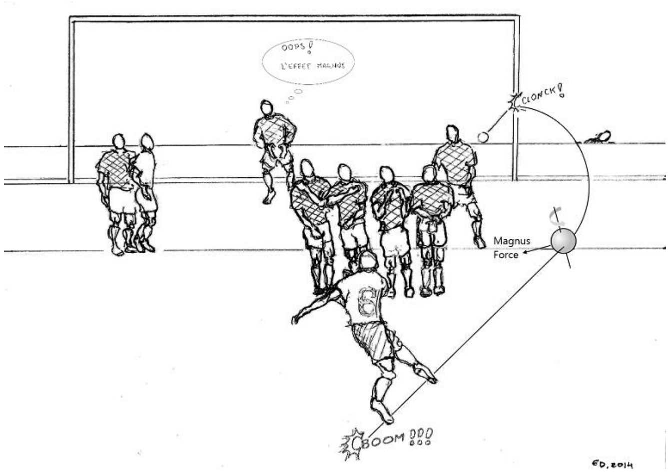
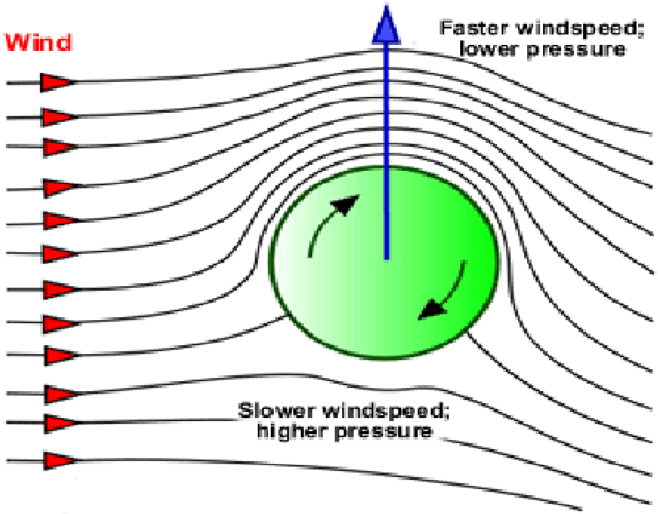
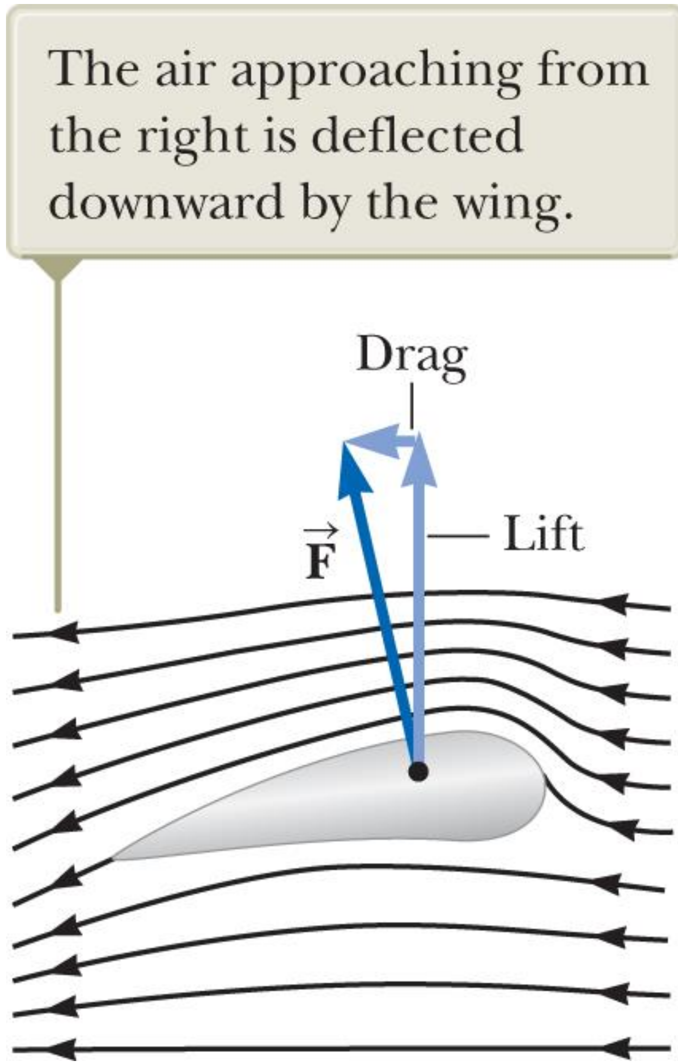
Magnus effect

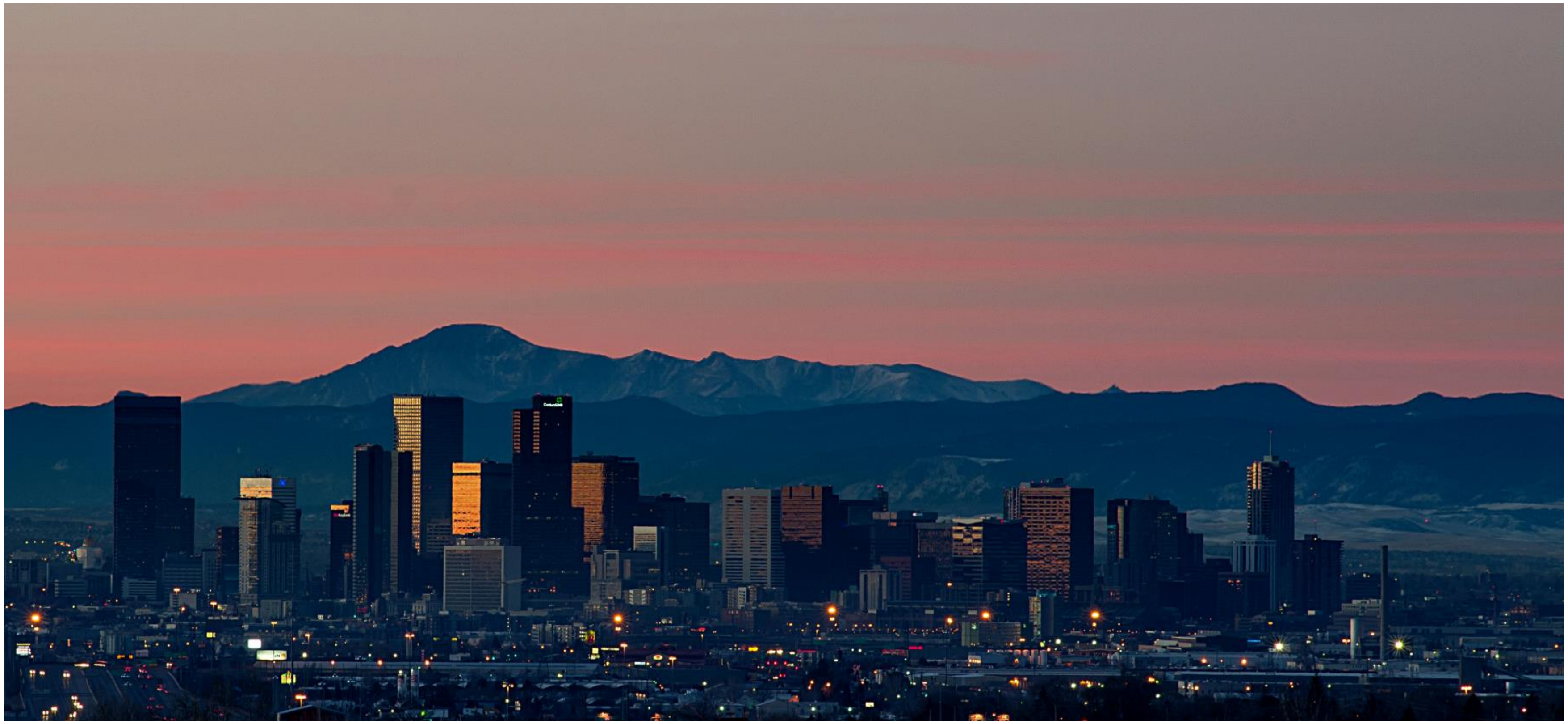




Other Applications of Fluid Dynamics



Other Applications of Fluid Dynamics

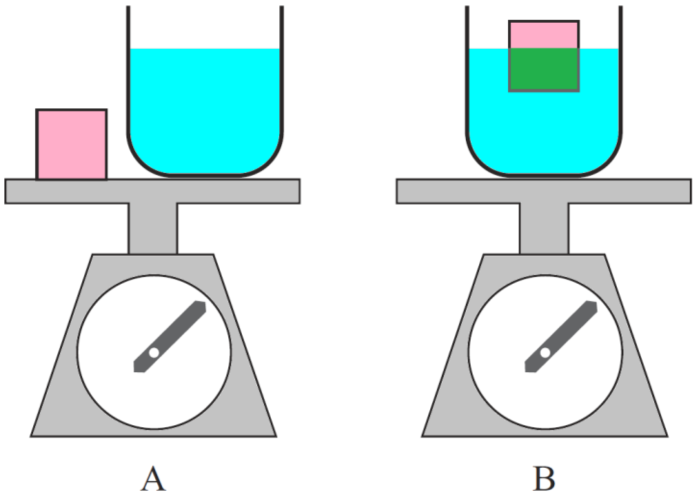


Other Applications of Fluid Dynamics

Assessing to Learn

A block and a beaker of water are placed side-by-side on a scale (case A). The block is then placed into the beaker of water, where it floats (case B). How do the two scale readings compare?

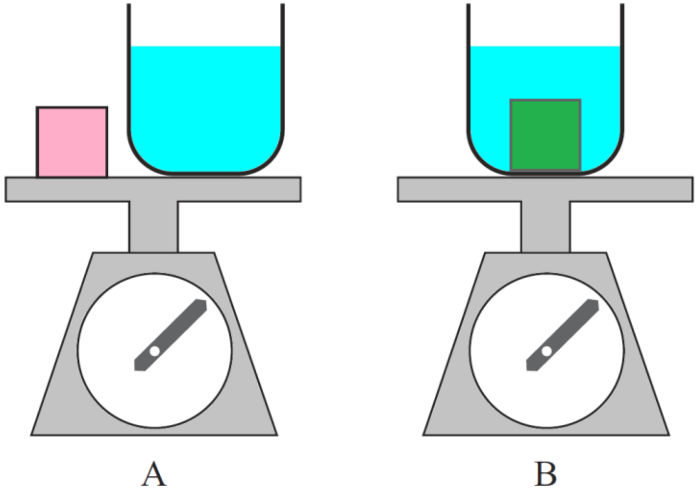
1. Scale A reads more than scale B.
2. Scale A reads the same as scale B.
3. Scale A reads less than scale B.
4. Not enough information.



Assessing to Learn

A block and a beaker of water are placed side-by-side on a scale (case A). The block is then placed into the beaker of water, where it sinks (case B). How do the two scale readings compare?

1. Scale A reads more than scale B.
2. Scale A reads the same as scale B.
3. Scale A reads less than scale B.
4. Not enough information.



Assessing to Learn

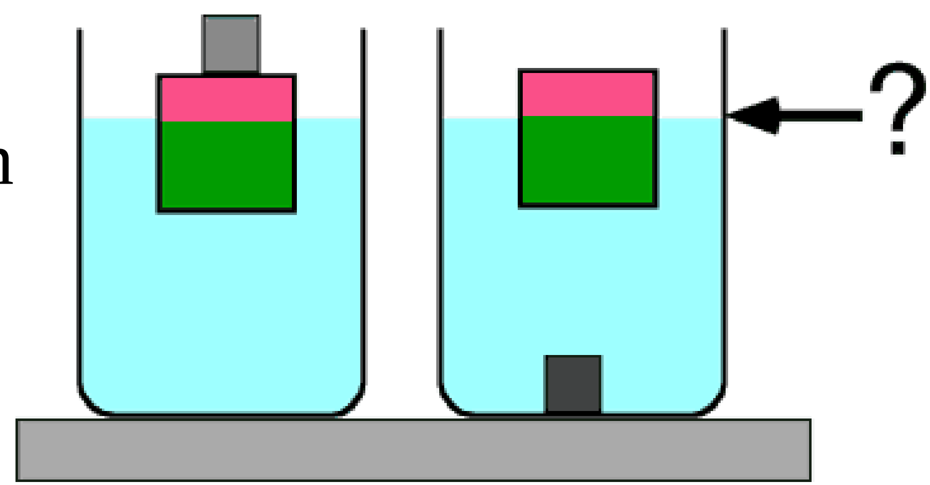
Two blocks, A and B, have the same size and shape. Block A floats in water, but block B sinks in water. Which block has the larger buoyant force on it?

1. Block A has the larger buoyant force on it.
2. Block B has the larger buoyant force on it.
3. Neither; they have the same buoyant force on them.
4. Impossible to determine from the given information.

Assessing to Learn

A metal block sits on top of a floating wooden block. If the metal block is placed on the bottom of the beaker, what happens to the **level of water** in the beaker?

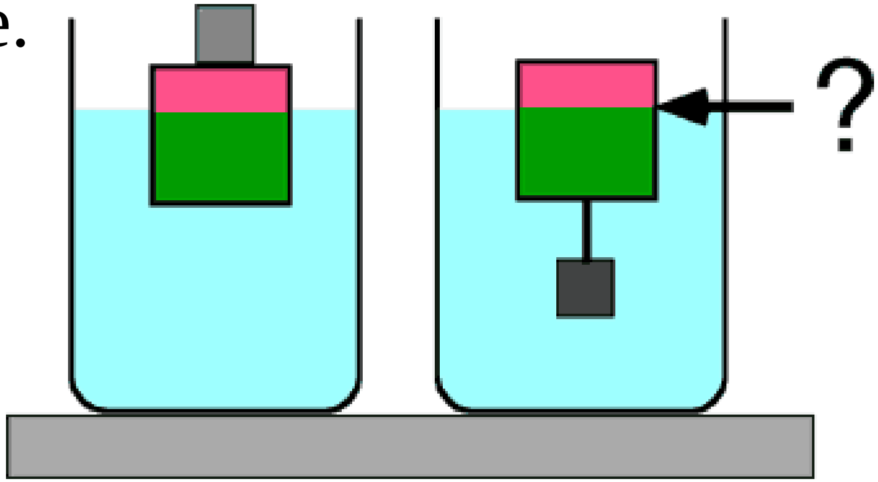
1. The level decreases.
2. The level stays the same.
3. The level increases.
4. Not enough information



Assessing to Learn

A metal block sits on top of a floating wooden block. If the metal block is suspended from the bottom of the wooden block, what happens to the **volume of the wooden block** that is submerged in the water?

1. The volume decreases.
2. The volume stays the same.
3. The volume increases.
4. Not enough information.



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