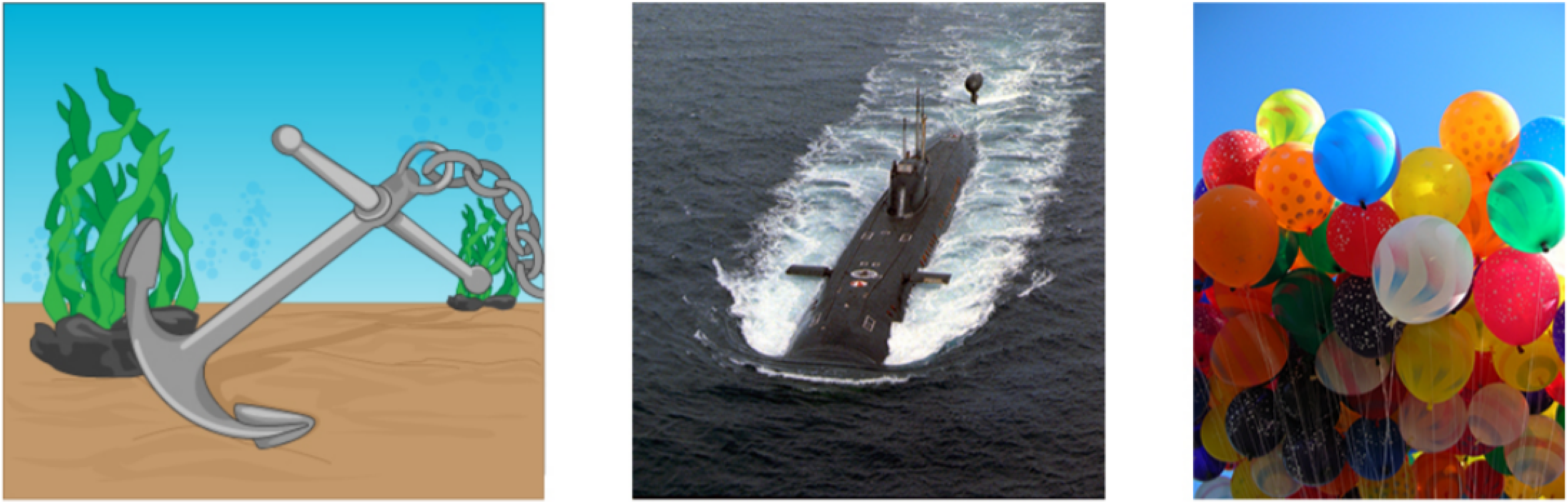
Flotkraftar - buoyant forces

1



(a) (b) (c)

Figure 14.19 (a) Even objects that sink, like this anchor, are partly supported by water when submerged. (b) Submarines have adjustable density (ballast tanks) so that they may float or sink as desired. (c) Helium-filled balloons tug upward on their strings, demonstrating air's buoyant effect. (credit b: modification of work by Allied Navy; credit c: modification of work by "Crystl"/Flickr)

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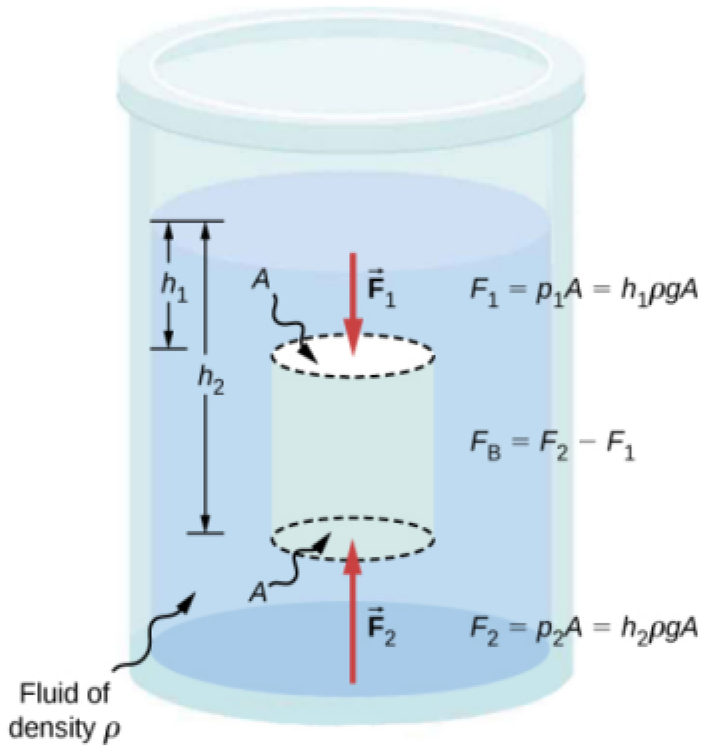
Buoyant Force

The buoyant force is the upward force on any object in any fluid.

2



$$F_B = F_2 - F_1 = h_2 \rho g A - h_1 \rho g A$$

$$= (h_2 - h_1)\rho g A = \rho g \Delta h A = \rho g V$$

$$= w_{fL}$$

Archimedes' Principle

The buoyant force on an object equals the weight of the fluid it displaces. In equation form, **Archimedes' principle** is

$$\boxed{F_B = w_{fl},}$$

where F_B is the buoyant force and w_{fl} is the weight of the fluid displaced by the object.

This principle is named after the Greek mathematician and inventor Archimedes (ca. 287–212 BCE), who stated this principle long before concepts of force were well established.

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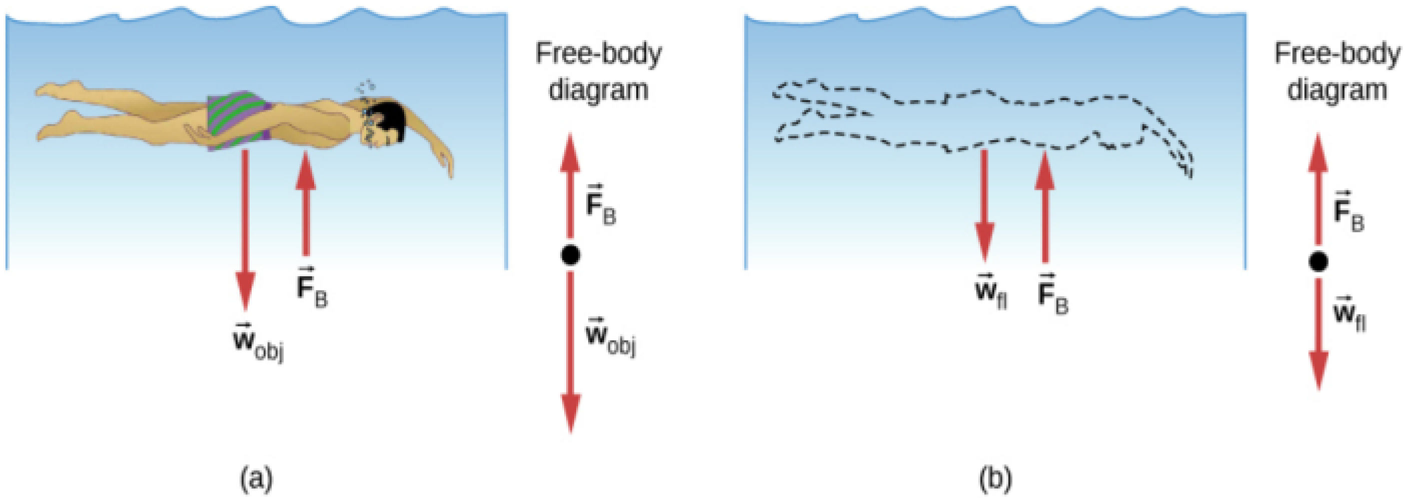

Figure 14.21 (a) An object submerged in a fluid experiences a buoyant force F_B. If F_B is greater than the weight of the object, the object

Vökvaaflfræði - fluid dynamics

Jafnt eða lagskipt flæði

Iðuflæði

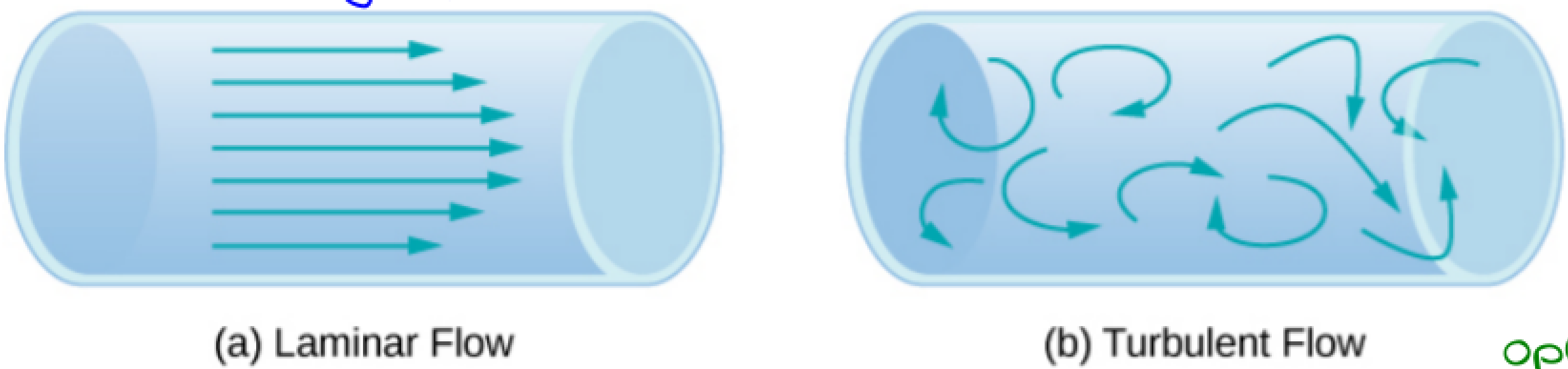

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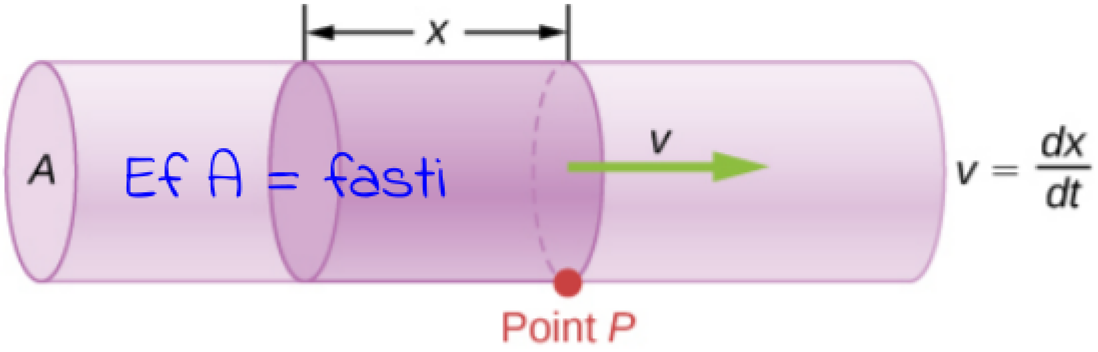
Figure 14.25 (a) Laminar flow can be thought of as layers of fluid moving in parallel, regular paths. (b) In turbulent flow, regions of fluid move in irregular, colliding paths, resulting in mixing and swirling.

$$\boxed{Q = \frac{dV}{dt} = \frac{d}{dt}(Ax) = A\frac{dx}{dt} = Av.}$$



Ef A = fasti

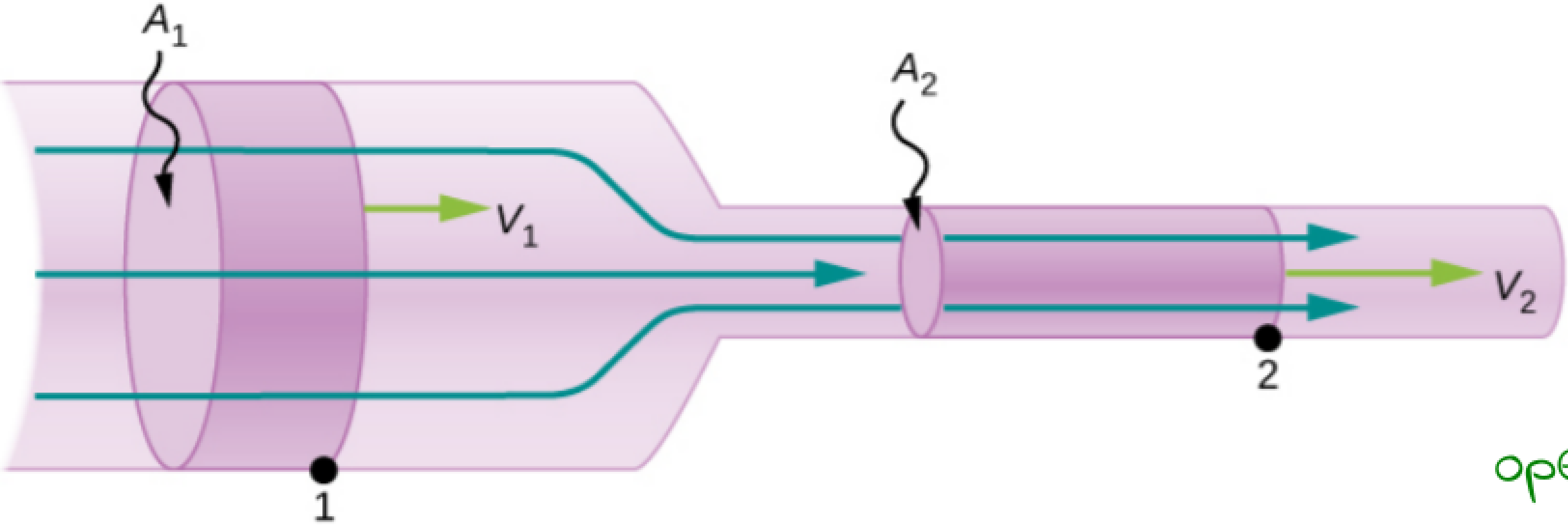
$$Q = \frac{dV}{dt} = \frac{d}{dt}(Ax) = A\frac{dx}{dt} = Av$$

Flæði $\boxed{Q = \frac{dV}{dt}}$

$$[Q] = \frac{L^3}{T}$$

Eining: m^3/s

ósampþjappanlegur vökvi - incompressible fluid



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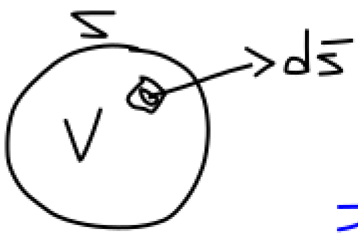
$$Q_1 = Q_2$$

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

Sértilfelli af samfelldni jöfnunni

$$\frac{\partial \rho}{\partial t} + \bar{\nabla} \cdot \bar{J} = 0$$

$$\frac{\partial}{\partial t} M_V + \oint_S \bar{J} \cdot d\bar{s} = 0$$



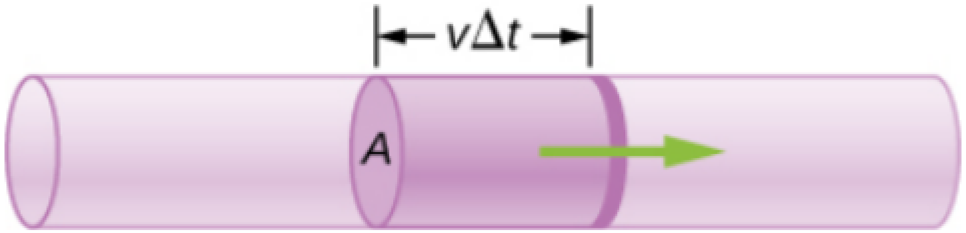
straumþéttleiki

$$\bar{J} = \rho \bar{v}$$

Nett flæði "efnis" inn í V verður til að massinn þar breytist, varðveislulögmál

$$M_V = \int_V \rho \, dv'$$

Varðveisla massa



$$m = \rho V = \rho A x$$ ef ρ er fasti

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$$\frac{dm}{dt} = \frac{d}{dt}(\rho A x) = \rho A \frac{dx}{dt} = \rho A v$$

Massinn út úr einhverju rúmmáli verður að vera jafn massanum inn (sístætt ástand). Ef þéttleikinn í þverskurði gæti breyst:

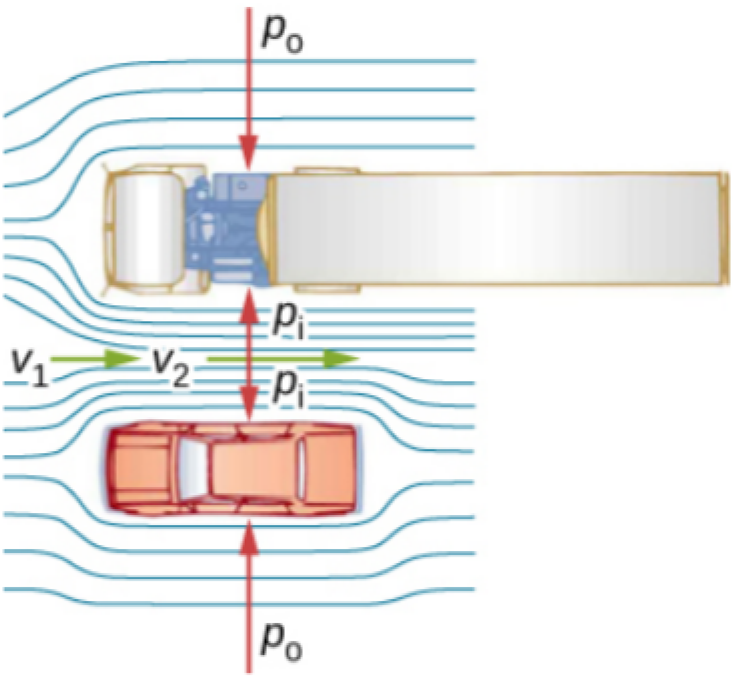
$$\left(\frac{dm}{dt}\right)_1 = \left(\frac{dm}{dt}\right)_2 \rightarrow \boxed{\rho_1 A_1 v_1 = \rho_2 A_2 v_2}$$

Ef vökvinn er ósamþjappanlegur $\quad A_1 v_1 = A_2 v_2$

Jafna Bernoullis

Þurfum að huga að orkuvarðveislu í flæði. Athugum ósamþjappanlegan vökva án flæðisviðnáms

Hversdagsleg reynsla



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Í engum hliðarvind er eins og kraftur myndist á litla bílinn þegar hinn fer framhjá. Krafturinn er að stóra bílnum og við eigum eftir að tengja hann við hraðabreytingu loftsins milli bílanna

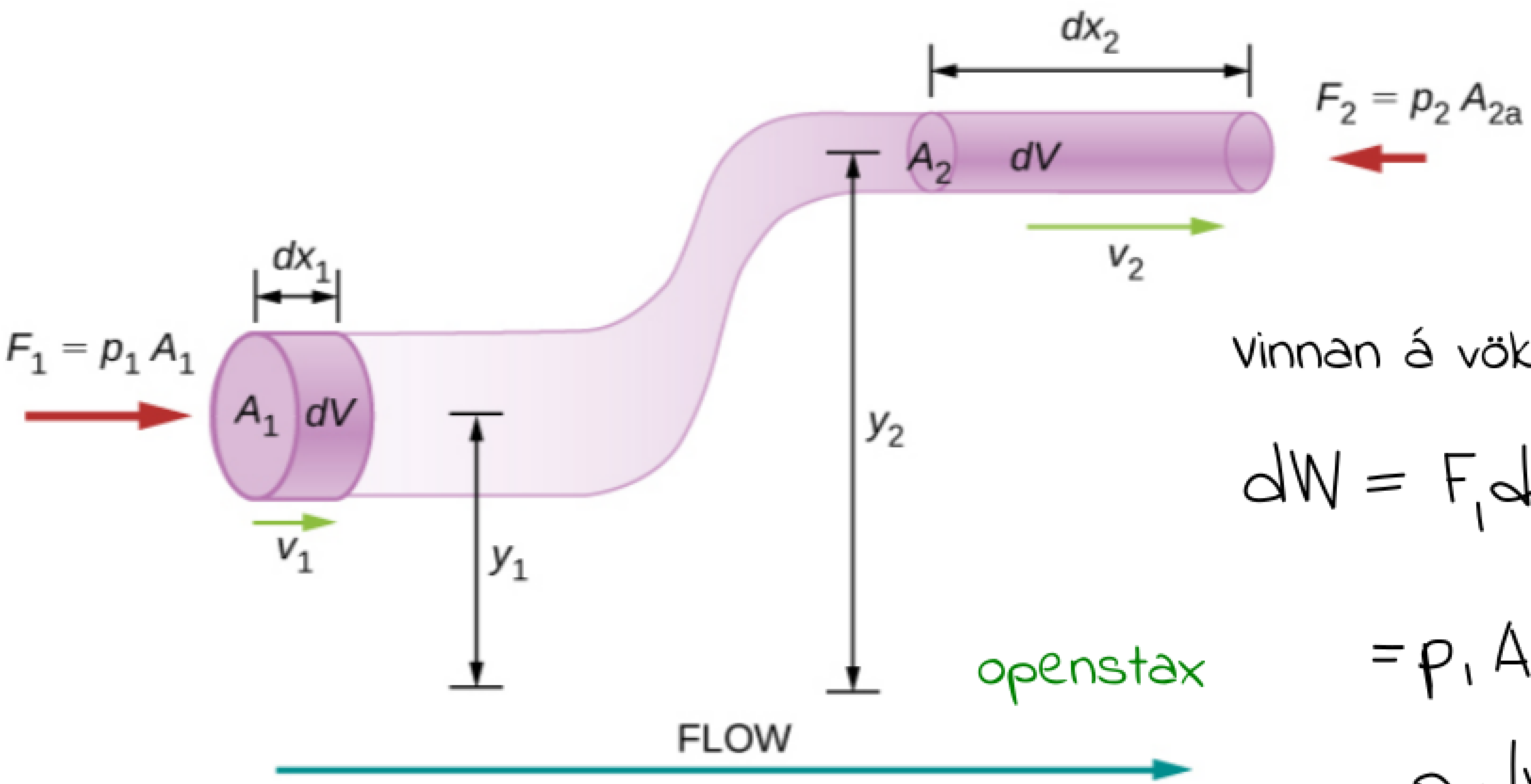

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Figure 14.30 The geometry used for the derivation of Bernoulli's equation.

Vinnan á vökvann

$$dW = F_1 dx_1 - F_2 dx_2$$

$$= p_1 A_1 dx_1 - p_2 A_2 dx_2$$

$$= p_1 dV - p_2 dV$$

$$= (p_1 - p_2) dV$$

Vinnan breytir hreyfiorku vökvans

$$dK = \frac{1}{2} m_2 v_2^2 - \frac{1}{2} m_1 v_2^2 = \frac{1}{2} \rho dV (v_2^2 - v_1^2)$$

notuðum varðveislu massa

breytingin í stöðuorku er

$$dU = mgy_2 - mgy_1 = \rho dV g (y_2 - y_1)$$

$$dW = dK + dU$$

$$\rightarrow \quad \overbrace{(p_1 - p_2)\,dV}^{dW} = \frac{1}{2}\rho\, dV\,(v_2^2 - v_1^2) + \rho\, dV\, g\,(y_2 - y_1)$$

$$\rightarrow \quad (p_1 - p_2) = \frac{1}{2}\rho\,(v_2^2 - v_1^2) + \rho g\,(y_2 - y_1)$$

$$\rightarrow \quad p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$\rightarrow \quad \boxed{p + \frac{1}{2}\rho v^2 + \rho g h = \text{Fasti}}$$

Jafna Bernoullis

Sértilfelli fyrir jöfnu Bernoullis

Vökvi án flæðis

$$v_1 = v_2 = 0$$

$$P_1 + \rho g h_1 = P_2 + \rho g h_2$$

$$\rightarrow \boxed{P_2 = P_1 + \rho g h_1 \quad \text{ef } h_2 = 0}$$

Enginn hæðarmunur, lögmál Bernoullis

$$h_1 = h_2$$

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

Munum, ósamþjappanlegur vökvi og ekkert viðnám við flæðinu

Notkun

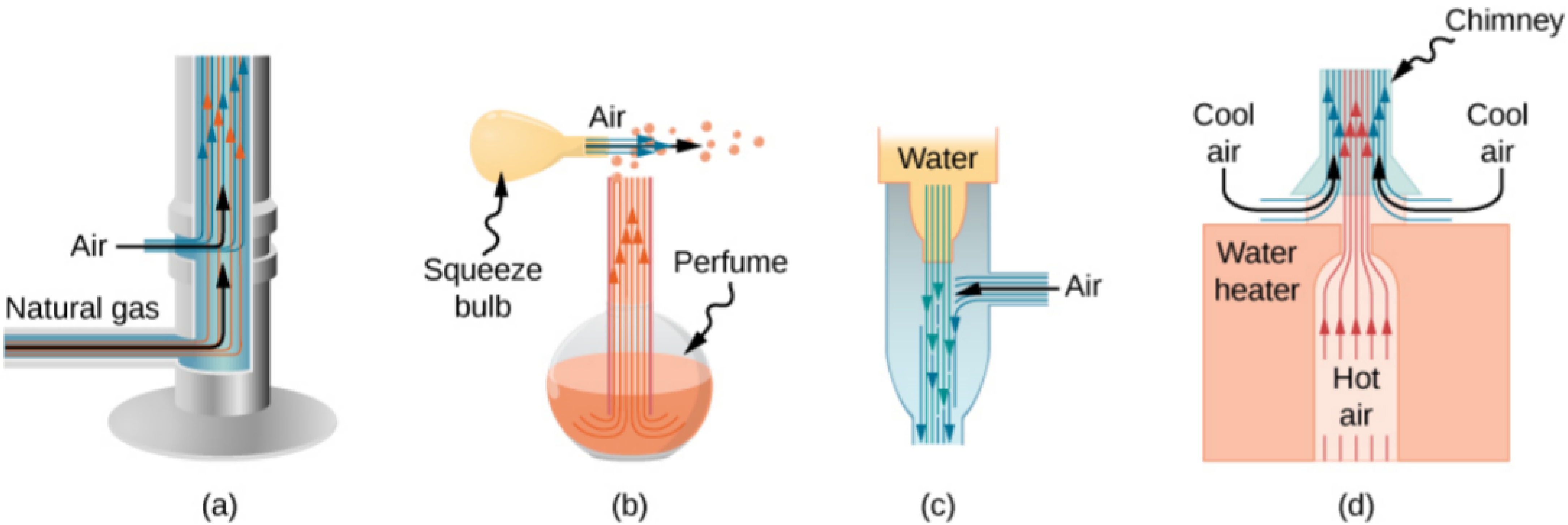

Figure 14.31 Entrainment devices use increased fluid speed to create low pressures, which then entrain one fluid into another. (a) A Bunsen burner uses an adjustable gas nozzle, entraining air for proper combustion. (b) An atomizer uses a squeeze bulb to create a jet of air that entrains drops of perfume. Paint sprayers and carburetors use very similar techniques to move their respective liquids. (c) A common aspirator uses a high-speed stream of water to create a region of lower pressure. Aspirators may be used as suction pumps in dental and surgical situations or for draining a flooded basement or producing a reduced pressure in a vessel. (d) The chimney of a water heater is designed to entrain air into the pipe leading through the ceiling.

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Hraðamæling

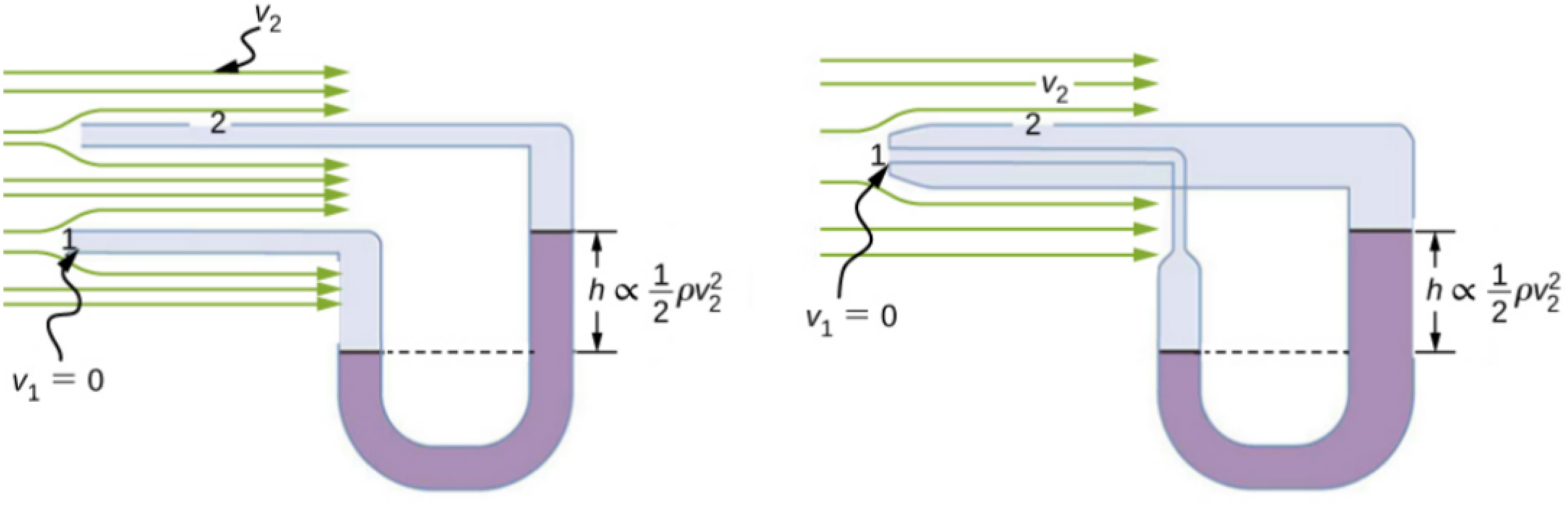

Figure 14.32 Measurement of fluid speed based on Bernoulli's principle. (a) A manometer is connected to two tubes that are close together and small enough not to disturb the flow. Tube 1 is open at the end facing the flow. A dead spot having zero speed is created there. Tube 2 has an opening on the side, so the fluid has a speed v across the opening; thus, pressure there drops. The difference in pressure at the manometer is $\frac{1}{2}\rho v_2^2$, so h is proportional to $\frac{1}{2}\rho v_2^2$. (b) This type of velocity measuring device is a Prandtl tube, also known as a pitot tube.

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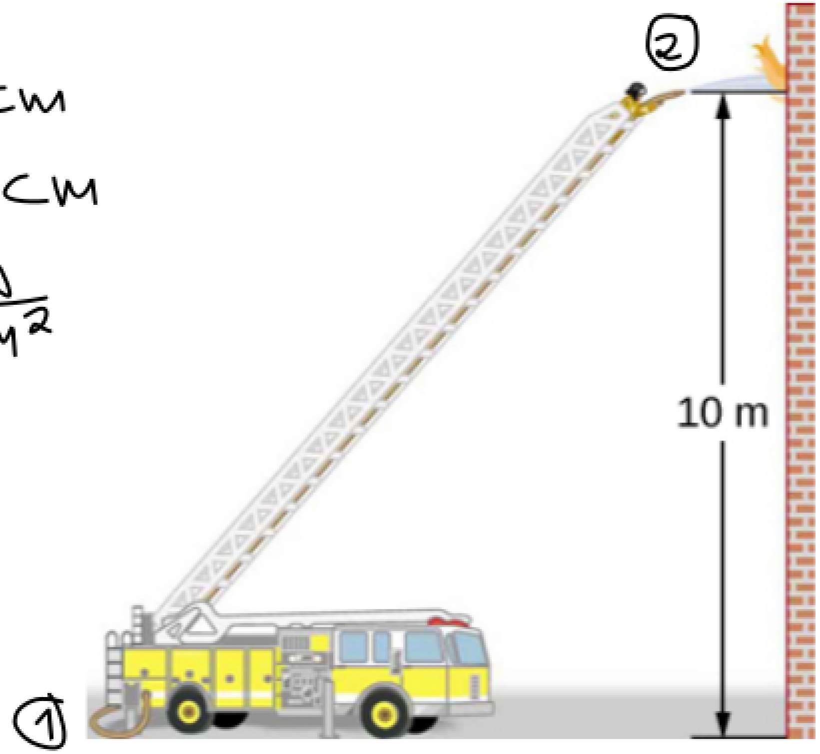
Ex. 14.7

Slanga $d = 6{,}40$ cm

Stútur $d_N = 3{,}00$ cm

$P_1 = 1{,}62 \cdot 10^6 \ \frac{N}{m^2}$

$Q = 40 \ l/s$



$h_2 = 10$ m

$h_1 = 0$

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Figure 14.33 Pressure in the nozzle of this fire hose is less than at ground level for two reasons: The water has to go uphill to get to the nozzle, and speed increases in the nozzle. In spite of its lowered pressure, the water can exert a large force on anything it strikes by virtue of its kinetic energy. Pressure in the water stream becomes equal to atmospheric pressure once it emerges into the air.

$$P_1 + \frac{1}{2}\rho v_1^2 + \underbrace{\rho g h_1}_{=0,\ h_1 = 0} = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

$$v_1 = \frac{Q_1}{A_1} = \frac{Q}{\pi\left(\frac{d}{2}\right)^2} = \frac{40\cdot10^{-3}\ m^3/s}{\pi\cdot(3{,}2\cdot10^{-2}\ m)^2} = \underline{12{,}4\ m/s}$$

$$v_2 = \frac{Q_2}{A_2} = \frac{Q}{\pi\left(\frac{d_N}{2}\right)^2} = \underline{56{,}6\ m/s}$$

$$p_2 = p_1 + \frac{1}{2}\rho\left[v_1^2 - v_2^2\right] - \rho g h_2$$

$$= p_1 + \frac{\rho Q^2 8}{\pi^2}\left[\frac{1}{d^4} - \frac{1}{d_N^4}\right] - \rho g h_2$$

$$= 1{,}62\cdot10^6\,\frac{N}{m^2} + \frac{\left(1000\,\frac{kg}{m^3}\right)8\left(40\cdot10^{-3}\ m^3/s\right)^2}{\pi^2}\left[\frac{1}{(3{,}2\cdot10^{-2}\ m)^4} - \frac{1}{(1{,}5\cdot10^{-2}\ m)^4}\right]$$

$$-1000\,\frac{kg}{m^3}\ 9{,}81\,m/s^2\cdot10\ m \ \hat{=}\ \underline{\underline{0}}$$

Seigla og iðustreymi

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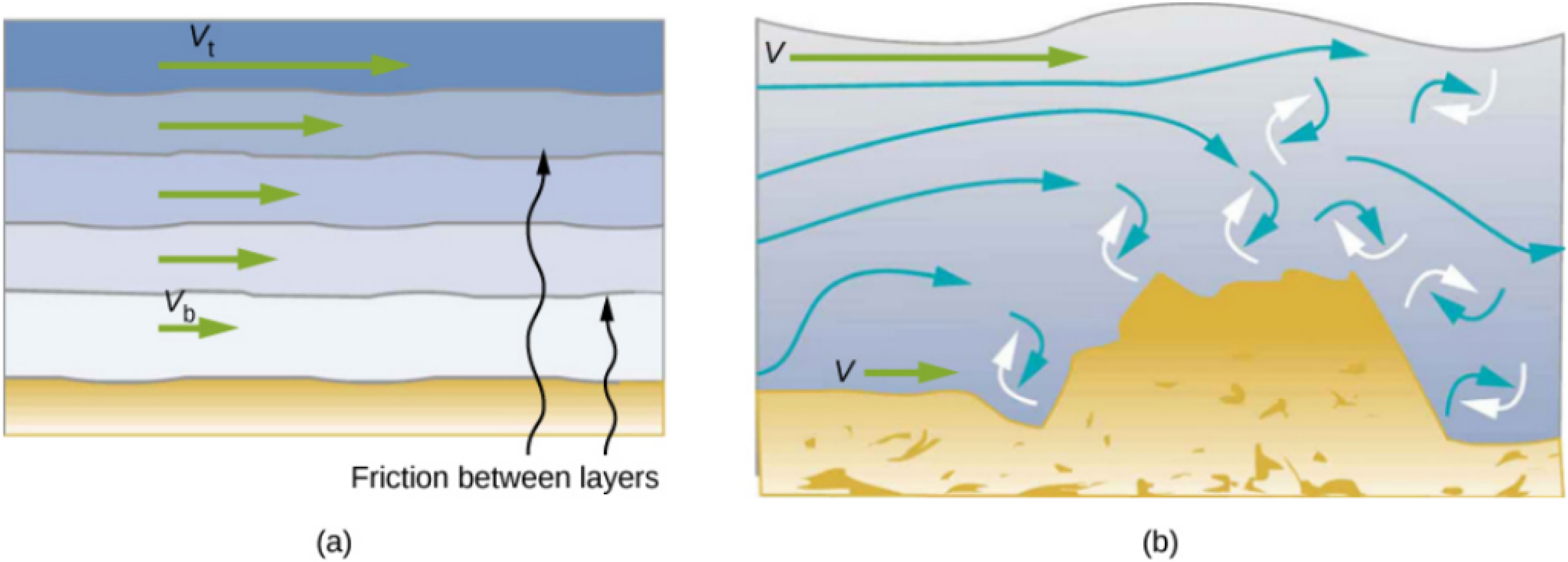
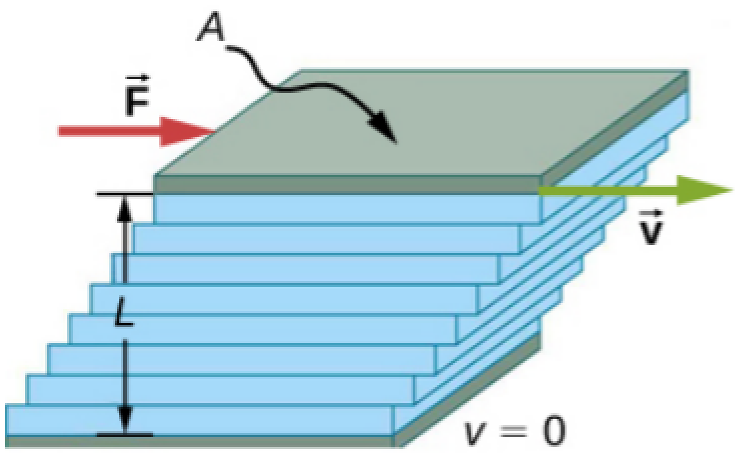


Figure 14.34 (a) Laminar flow occurs in layers without mixing. Notice that viscosity causes drag between layers as well as with the fixed surface. The speed near the bottom of the flow (v_b) is less than speed near the top (v_t) because in this case, the surface of the containing vessel is at the bottom. (b) An obstruction in the vessel causes turbulent flow. Turbulent flow mixes the fluid. There is more interaction, greater heating, and more resistance than in laminar flow.



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Seigja

$$F = \eta \frac{vA}{L}$$

$$\rightarrow \eta = \frac{FL}{vA}$$

$$[\eta] = \frac{M}{TL}$$

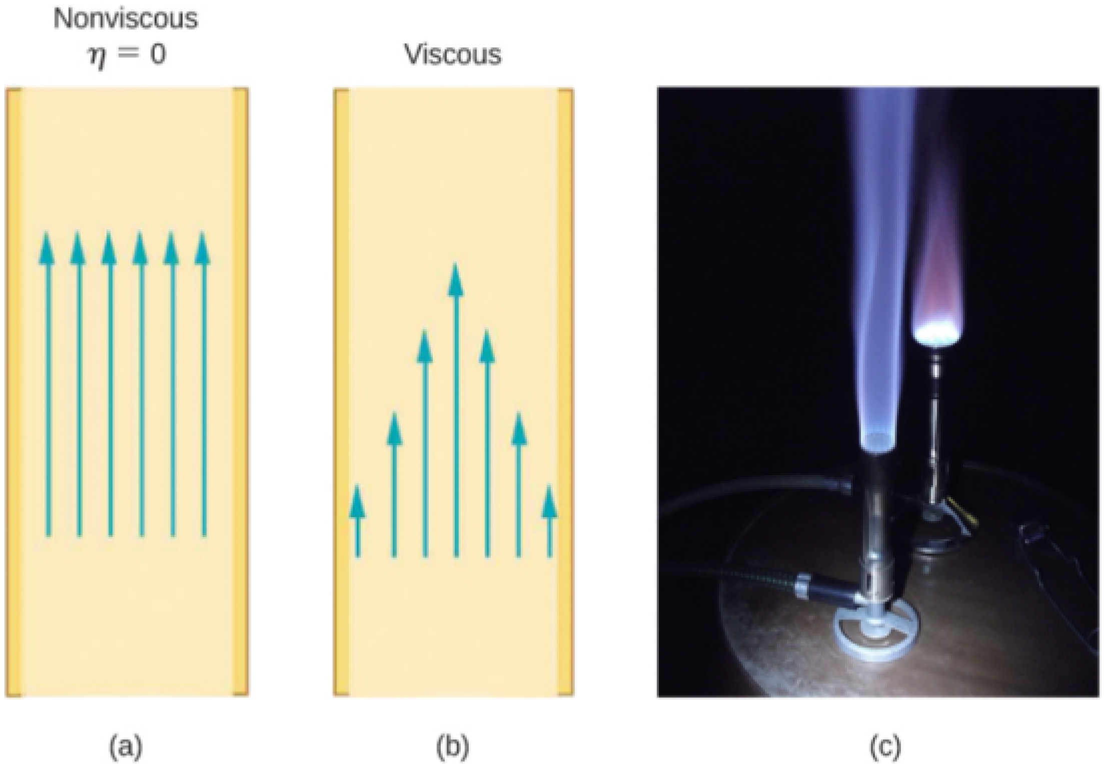
Eining $Pa \cdot s$

Fluid	Temperature (°C)	Viscosity $\eta \times 10^3$
Blood plasma	20	1.810
	37	1.257
Ethyl alcohol	20	1.20
Methanol	20	0.584
Oil (heavy machine)	20	660
Oil (motor, SAE 10)	30	200
Oil (olive)	20	138
Glycerin	20	1500
Honey	20	2000–10000
Maple syrup	20	2000–3000
Milk	20	3.0
Oil (corn)	20	65

Table 14.4 Coefficients of Viscosity of Various Fluids

Fluid	Temperature (°C)	Viscosity $\eta \times 10^3$
Air	0	0.0171
	20	0.0181
	40	0.0190
	100	0.0218
Ammonia	20	0.00974
Carbon dioxide	20	0.0147
Helium	20	0.0196
Hydrogen	0	0.0090
Mercury	20	0.0450
Oxygen	20	0.0203
Steam	100	0.0130
Liquid water	0	1.792
	20	1.002
	37	0.6947
	40	0.653
	100	0.282
Whole blood	20	3.015
	37	2.084

Lögmál Poiseuille



$$\boxed{Q = \frac{(P_2 - P_1)\pi r^4}{8\eta l}}$$

Lárétt flæði

$$\boxed{QR = P_2 - P_1}$$

R: viðnám við flæði

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

lengd rörs: l

geisli rörs: r

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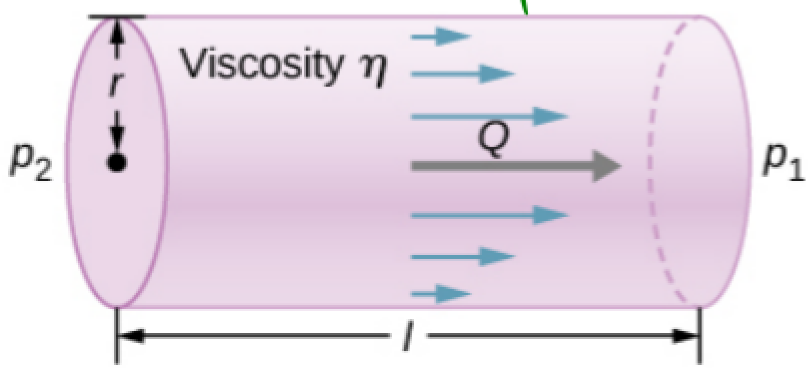

Reynoldstala fyrir flæði um rör

"Mæling" á iðustreymi, eða iðumyndun

$$\boxed{N_R = \frac{2\rho v r}{\eta}}$$

$$[N_R] = 1$$

víddarlaus fasti

Fyrir NR > 3000 er streymið orðið iðustreymi, fyrir 2000 < NR < 3000 er flæðið orðið óreiðukennt, ringlað streymi