ENVE2061
Basic Fluid Mechanics

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Fall 2023, Marmara University

Practice Problems

- Dimensions & Dimensional Homogeneity
- System of Units
- Measures of Fluid Mass & Weight: Density, Specific Weight, Specific Gravity
- Viscosity of Fluids

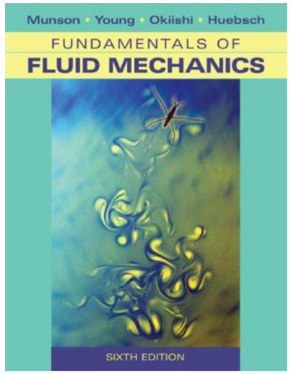
1.13 A formula to estimate the volume rate of flow, Q, flowing over a dam of length, B, is given by the equation

$$Q = 3.09\, BH^{3/2}$$

where H is the depth of the water above the top of the dam (called the head). This formula gives Q in ft^3/s when B and H are in feet. Is the constant, 3.09, dimensionless? Would this equation be valid if units other than feet and seconds were used?

Dimensions & dimensional homogeneity

System of Units



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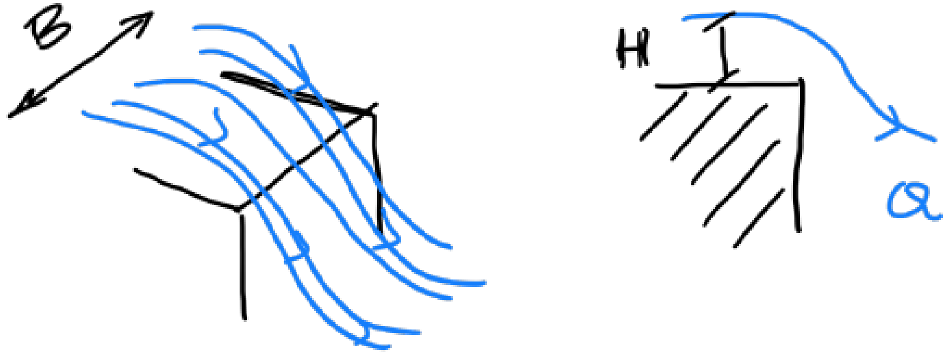
$$Q = 3.09\ B\ H^{3/2}$$



Q: volume rate of flow, ft^3/sec

B: length of dam, ft

H: depth of water above the top of the dam, ft

Is constant, 3.09, dimensionless?

Would this equation be valid if units other than feet & seconds were used?

$$\frac{\text{ft}^3}{\text{sec}} = 3.09\ \text{ft}\ (\text{ft})^{\frac{3}{2}}$$

$$\frac{\text{ft}^3}{\text{sec}} = 3.09\ \text{ft}^{(1+\frac{3}{2}) = \frac{5}{2}}$$

$$Q = 3.09\ B\ H^{3/2}$$

$$\frac{ft^3}{sec} = 3.09\ ft\ (ft)^{\frac{3}{2}}$$

$$\frac{ft^3}{sec} = 3.09\ ft^{\left(1+\frac{3}{2}\right)=\frac{5}{2}}$$

Q: volume rate of flow, ft^3/sec

B: length of dam, ft

H: depth of water above the top of the dam, ft

$$\frac{\frac{ft^3}{sec}}{ft^{5/2}} = 3.09 \text{ (units)}$$

$$\frac{ft^{3-\frac{5}{2}}}{se} = \frac{ft^{1/2}}{sec}$$

constant 3.09 is not dimensionless.

$$3.09\ \frac{ft^{1/2}}{sec}$$

So the equation $Q = 3.09\, B\, H^{3/2}$ is a restricted equation.

It should be used in BG unit system.

1.15 Make use of Table 1.3 to express the following quantities in SI units: **(a)** 10.2 in./min, **(b)** 4.81 slugs, **(c)** 3.02 lb, **(d)** 73.1 ft/s^2, **(e)** 0.0234 $lb \cdot s/ft^2$.

System of Units

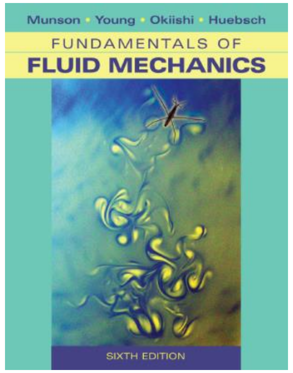


TABLE 1.3

Conversion Factors from BG and EE Units to SI Units[a]

	To Convert from	to	Multiply by
Acceleration	ft/s^2	m/s^2	3.048 E − 1
Area	ft^2	m^2	9.290 E − 2
Density	lbm/ft^3	kg/m^3	1.602 E + 1
	$slugs/ft^3$	kg/m^3	5.154 E + 2
Energy	Btu	J	1.055 E + 3
	$ft \cdot lb$	J	1.356
Force	lb	N	4.448
Length	ft	m	3.048 E − 1
	in.	m	2.540 E − 2
	mile	m	1.609 E + 3
Mass	lbm	kg	4.536 E − 1
	slug	kg	1.459 E + 1
Power	$ft \cdot lb/s$	W	1.356
	hp	W	7.457 E + 2
Pressure	in. Hg (60 °F)	N/m^2	3.377 E + 3
	lb/ft^2 (psf)	N/m^2	4.788 E + 1
	$lb/in.^2$ (psi)	N/m^2	6.895 E + 3
Specific weight	lb/ft^3	N/m^3	1.571 E + 2
Temperature	°F	°C	$T_C = (5/9)(T_F - 32°)$
	°R	K	5.556 E − 1
Velocity	ft/s	m/s	3.048 E − 1
	mi/hr (mph)	m/s	4.470 E − 1
Viscosity (dynamic)	$lb \cdot s/ft^2$	$N \cdot s/m^2$	4.788 E + 1
Viscosity (kinematic)	ft^2/s	m^2/s	9.290 E − 2
Volume flowrate	ft^3/s	m^3/s	2.832 E − 2
	gal/min (gpm)	m^3/s	6.309 E − 5

[a]If more than four-place accuracy is desired, refer to Appendix E.

1.15 Make use of Table 1.3 to express the following quantities in SI units: **(a)** 10.2 in./min, **(b)** 4.81 slugs, **(c)** 3.02 lb, **(d)** 73.1 ft/s^2, **(e)** 0.0234 lb · s/ft^2.

$$10.2\ \frac{\text{in}}{\text{min}} \longrightarrow \text{SI units } \left[\frac{L}{T}\right]$$

meter /second

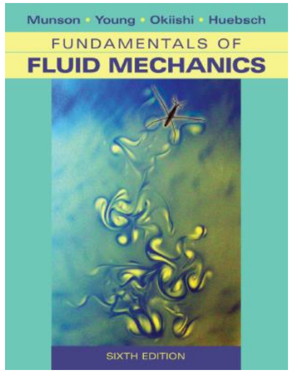
$1 \text{ in} = 2.54 \text{ cm}$

$1 \text{ min} = 60 \text{ sec}$

$100 \text{ cm} = 1 \text{ m}$

$$10.2\ \frac{\cancel{\text{in}}}{\cancel{\text{min}}} \times \frac{1\cancel{\text{min}}}{60\text{sec}} \times \frac{2.54\cancel{\text{cm}}}{1\cancel{\text{in}}} \times \frac{1\text{m}}{100\cancel{\text{cm}}}$$

$$\boxed{10.2\ \frac{\text{in}}{\text{min}} = 0.043\ \frac{\text{m}}{\text{sec}}}$$



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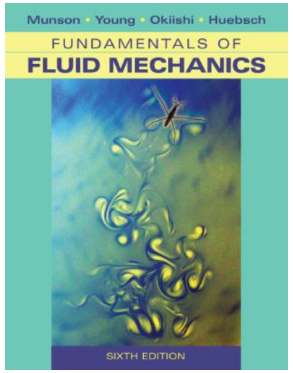
4.81 slugs $\longrightarrow$ SI units [M]

kilogram

1 slug = 14.594 kg

$$4.81 \cancel{\text{slug}} \times \frac{14.594 \text{ kg}}{1 \cancel{\text{slug}}}$$

$$\boxed{4.81 \text{ slug} = 70.2 \text{ kg}}$$



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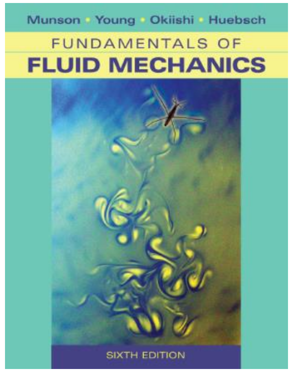
3.02 lb $\longrightarrow$ SI units [F]

Newton

$1 \text{ lb} = 4.4482$

$$3.02 \, \cancel{\text{lb}} \times \frac{4.4482}{1 \, \cancel{\text{lb}}}$$

$$\boxed{3.02 \text{ lb} = 13.434 \text{ N}}$$



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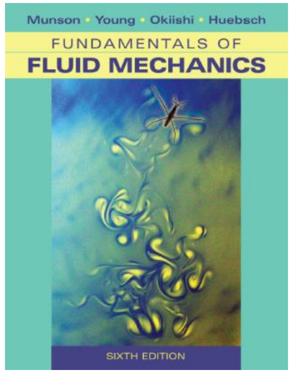
$$73.1 \ ft/s^2 \longrightarrow SI \ units \ \left[\frac{L}{T^2}\right]$$

meter / second^2

$$1 \ ft = 0.3048 \ m$$

$$73.1 \ \frac{\cancel{ft}}{s^2} * \frac{0.3048 \ m}{1 \ \cancel{ft}}$$

$$\boxed{73.1 \ ft/s^2 = 22.28 \ m/s^2}$$



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$$0.0234 \ \frac{\text{lb}\cdot\text{s}}{\text{ft}^2} \longrightarrow \text{SI units} \quad \left[\frac{F\cdot T}{L^2}\right]$$

$$\frac{\text{Newton}\cdot\text{second}}{\text{meter}^2}$$

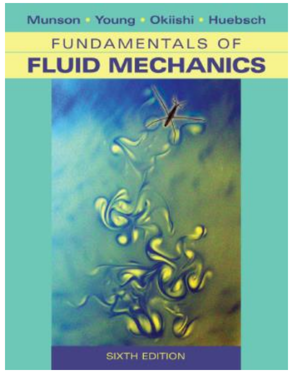
Pa·s : viscosity unit

$$1 \text{ lb} = 4.4482 \text{ N}$$
$$1 \text{ ft} = 0.3048 \text{ m}$$

$$F = ma$$
$$N = kg\,\frac{m}{s^2}$$
$$\frac{kg\,\frac{m}{s^2}\; s}{m^2} = \frac{kg}{m\cdot s}$$

$$0.0234 \ \frac{\cancel{\text{lb}}\cdot\text{s}}{\cancel{\text{ft}^2}} * \frac{4.4482\,\text{N}}{1\ \cancel{\text{lb}}} * \left[\frac{1\ \cancel{\text{ft}}}{0.3048\,\text{m}}\right]^{\cancel{2}}$$

$$\boxed{0.0234 \ \frac{\text{lb}\cdot\text{s}}{\text{ft}^2} = 1.12 \ \text{Pa}\cdot\text{s} = 1.12 \ \frac{kg}{m\cdot s}}$$



1.16 Make use of Table 1.4 to express the following quantities in BG units: **(a)** 14.2 km, **(b)** 8.14 N/m^3, **(c)** 1.61 kg/m^3, **(d)** 0.0320 N $\cdot$ m/s, **(e)** 5.67 mm/hr.

System of Units

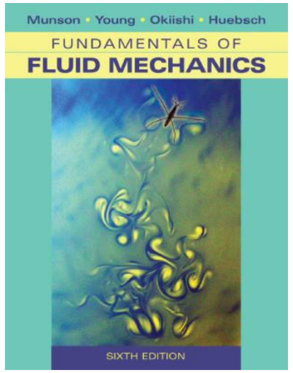


TABLE 1.4

Conversion Factors from SI Units to BG and EE Units[a]

	To Convert from	to	Multiply by
Acceleration	m/s^2	ft/s^2	3.281
Area	m^2	ft^2	1.076 E + 1
Density	kg/m^3	lbm/ft^3	6.243 E − 2
	kg/m^3	slugs/ft^3	1.940 E − 3
Energy	J	Btu	9.478 E − 4
	J	ft $\cdot$ lb	7.376 E − 1
Force	N	lb	2.248 E − 1
Length	m	ft	3.281
	m	in.	3.937 E + 1
	m	mile	6.214 E − 4
Mass	kg	lbm	2.205
	kg	slug	6.852 E − 2
Power	W	ft $\cdot$ lb/s	7.376 E − 1
	W	hp	1.341 E − 3
Pressure	N/m^2	in. Hg (60 °F)	2.961 E − 4
	N/m^2	lb/ft^2 (psf)	2.089 E − 2
	N/m^2	lb/in.^{2} (psi)	1.450 E − 4
Specific weight	N/m^3	lb/ft^3	6.366 E − 3
Temperature	°C	°F	$T_F = 1.8\, T_C + 32°$
	K	°R	1.800
Velocity	m/s	ft/s	3.281
	m/s	mi/hr (mph)	2.237
Viscosity (dynamic)	N $\cdot$ s/m^2	lb $\cdot$ s/ft^2	2.089 E − 2
Viscosity (kinematic)	m^2/s	ft^2/s	1.076 E + 1
Volume flowrate	m^3/s	ft^3/s	3.531 E + 1
	m^3/s	gal/min (gpm)	1.585 E + 4

[a] If more than four-place accuracy is desired, refer to Appendix E.

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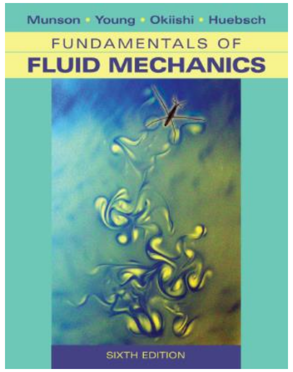
$14.2 \text{ km} \longrightarrow$ BG units $[L]$ ft

$$1 \text{ ft} = 0.3048 \text{ m}$$

$$14.2 \, \cancel{\text{km}} * \frac{1000 \, \cancel{\text{m}}}{1 \, \cancel{\text{km}}} * \frac{1 \text{ ft}}{0.3048 \, \cancel{\text{m}}}$$

$$\boxed{14.2 \text{ km} = 46{,}587.9 \text{ ft}}$$



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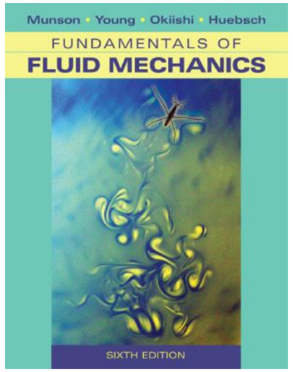
$8.14 \frac{N}{m^3} \longrightarrow$ BG units $\left[\frac{F}{L^3}\right]$ $\quad \frac{lb}{ft^3}$

1 lb = 4.4482 N

1 ft = 0.3048 m

$$8.14 \frac{\cancel{N}}{\cancel{m^3}} \times \frac{1\ lb}{4.4482\ \cancel{N}} * \left[\frac{0.3048\ \cancel{m}}{1\ ft^3}\right]^{\cancel{3}}$$

$$\boxed{8.14 \frac{N}{m^3} = 0.0518 \frac{lb}{ft^3}}$$



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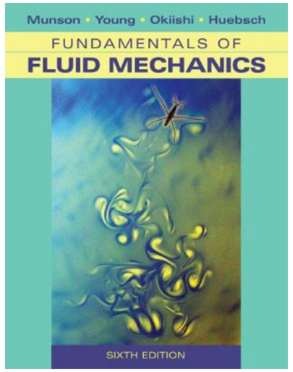
$$1.61 \frac{kg}{m^3} \longrightarrow \text{BG units} \quad \left[\frac{M}{L^3}\right] \qquad \frac{slugs}{ft^3}$$

$$1 \text{ slug} = 14.594 \text{ kg}$$

$$1 \text{ ft} = 0.3048 \text{ m}$$

$$1.61 \frac{\cancel{kg}}{\cancel{m^3}} * \frac{1 \text{ slug}}{14.594 \cancel{kg}} * \left[\frac{0.3048 \cancel{m}}{1 ft}\right]^{\cancel{3}}$$

$$\boxed{1.61 \frac{kg}{m^3} = 0.00312 \frac{slugs}{ft^3}}$$



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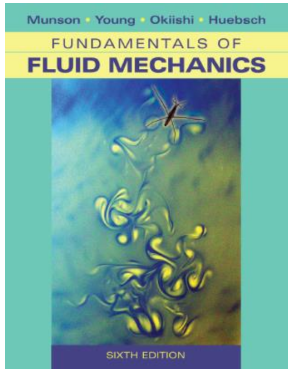
$$0.0320 \ \frac{N.m}{s} \longrightarrow \text{BG units} \ \left[\frac{F.L}{T}\right] \quad \frac{lb \cdot ft}{sec}$$

$$1 \ lb = 4.4482 \ N$$

$$1 \ ft = 0.3048 \ m$$

$$0.0320 \ \frac{\cancel{N}.\cancel{m}}{s} \times \frac{1 \ lb}{4.4482 \ \cancel{N}} * \frac{1 \ ft}{0.3048 \ \cancel{m}}$$

$$\boxed{0.0320 \ \frac{N.m}{s} = 0.0236 \ \frac{lb.ft}{s}}$$



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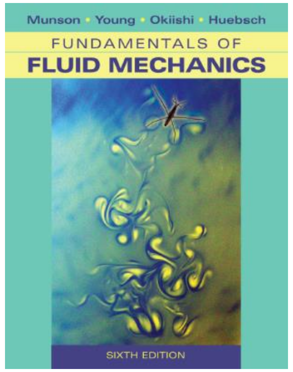
$$5.67 \ \frac{mm}{hr} \longrightarrow \text{BG units} \ \left[\frac{L}{T}\right] \quad \frac{ft}{sec}$$

$$1 \ ft = 0.3048 \ m$$

$$1 \ m = 1000 \ mm$$

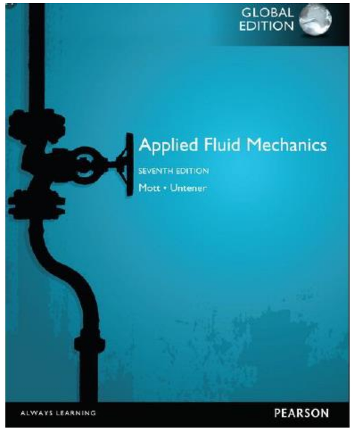
$$5.67 \ \frac{\cancel{mm}}{\cancel{hr}} * \frac{1 \cancel{m}}{1000 \cancel{mm}} * \frac{1 \ ft}{0.3048 \cancel{m}} * \frac{1 \cancel{hr}}{60 \cancel{min}} * \frac{1 \cancel{min}}{60 \ sec}$$

$$\boxed{5.67 \ \frac{mm}{hr} = 5.17 * 10^{-6} \ \frac{ft}{s}}$$



1.75 A cylindrical can 150 mm in diameter is filled to a depth of 100 mm with a fuel oil. The oil has a mass 1.56 kg. Calculate its density, specific weight, and specific gravity.

Measures of Fluid Mass & Weight: Density, Specific Weight, Specific Gravity



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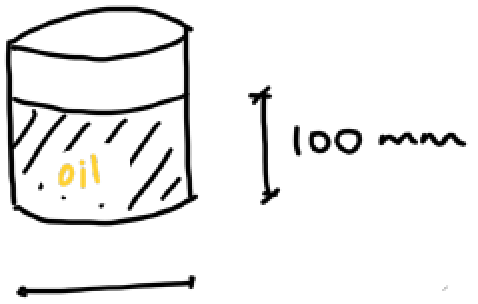


$D = 150\ mm$

$m = 1.56\ kg$

$\rho_{oil} = ?$

$SG_{oil} = ?$

$\gamma_{oil} = ?$

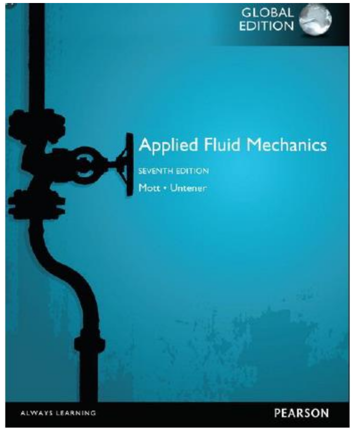
$$\text{volume} = \frac{\pi D^2}{4} * h$$

$$150\ \cancel{mm} * \frac{1m}{1000\ \cancel{mm}} = 0.15\ m$$

$$100\ \cancel{mm} * \frac{1m}{1000\ \cancel{mm}} = 0.10\ m$$

$$\forall = \frac{\pi (0.15)^2}{4} * 0.10$$

$$\forall = 0.00177\ m^3$$



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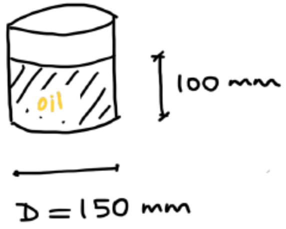


$m = 1.56\ kg$

$\rho_{oil} = ?$

$SG_{oil} = ?$

$\gamma_{oil} = ?$

$$\text{volume} = \frac{\pi D^2}{4} * h$$

$$150\ \cancel{mm} * \frac{1\ m}{1000\ \cancel{mm}} = 0.15\ m$$

$$100\ \cancel{mm} * \frac{1\ m}{1000\ \cancel{mm}} = 0.10\ m$$

$$\forall = \frac{\pi (0.15)^2}{4} * 0.10$$

$$\forall = 0.00177\ m^3$$

$$\rho_{oil} = \frac{m_{oil}}{\forall_{oil}} = \frac{1.56\ kg}{0.00177\ m^3}$$

$$\rho_{oil} = 882.8\ kg/m^3$$

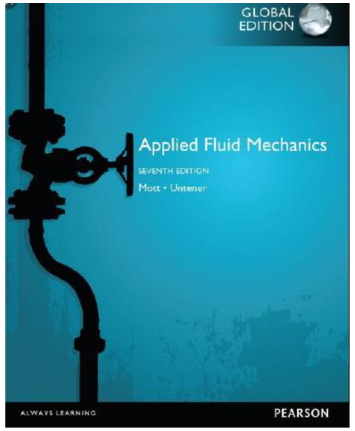
$$SG_{oil} = \frac{\rho_{oil}}{\rho_{H_2O}} = \frac{882.8}{1000}$$

$$SG_{oil} = 0.883$$

$$\gamma_{oil} = \frac{W_{oil}}{\forall_{oil}} = \frac{\overbrace{m_{oil}}\, g}{\underbrace{\forall_{oil}}_{\rho_{oil}}} = \rho_{oil}\, g$$

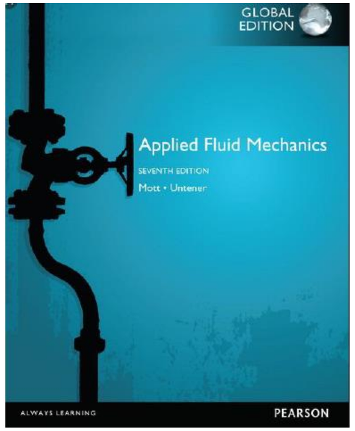
$$\gamma_{oil} = 882.8 * 9.81$$

$$\gamma_{oil} = 8660\ N/m^3$$



1.77 The fuel tank of an automobile holds 0.095 m^3. If it is full of gasoline having a specific gravity of 0.68, calculate the weight of the gasoline.

Measures of Fluid Mass & Weight: Density, Specific Weight, Specific Gravity



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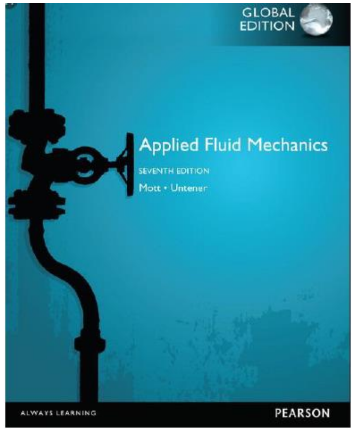


Volume $\forall = 0.095\ m^3$

$SG = 0.68$

weight $W = ?$

$$SG = \frac{\rho}{\rho_{H_2O}}$$

$$0.68 = \frac{\rho}{1000\ kg/m^3}$$

$$\rho = 680\ kg/m^3$$

$$\rho = \frac{m}{\forall}$$

$$680\ \frac{kg}{m^3} = \frac{m\ (kg)}{0.095\ m^3}$$

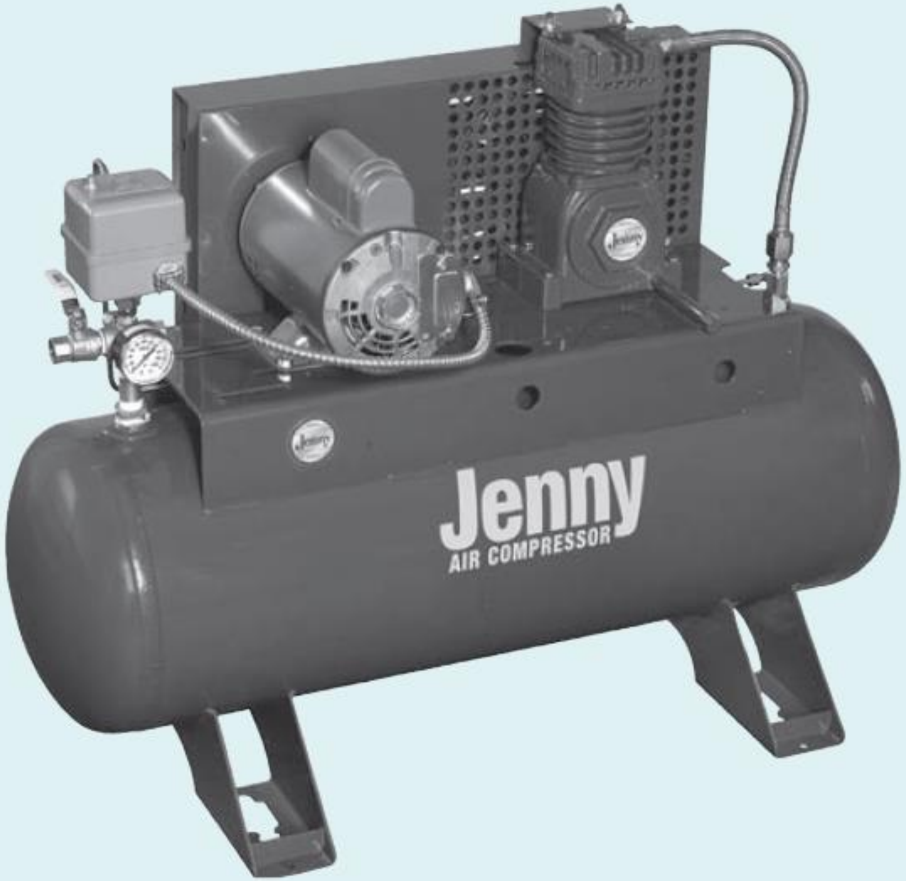
$$m = 64.6\ kg$$

$$\boxed{\begin{aligned} &\text{Weight} = m g \\ &W = 64.6\ kg\ \ 9.81\ \frac{m}{s^2} \\ &W = 633.7\ N \end{aligned}}$$

EXAMPLE 1.3 Ideal Gas Law

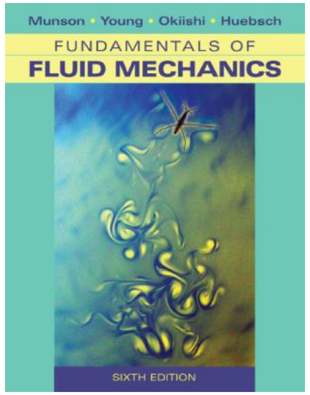
GIVEN The compressed air tank shown in Fig. E1.3*a* has a volume of 0.84 ft^3. The temperature is 70 °F and the atmospheric pressure is 14.7 psi (abs).

FIND When the tank is filled with air at a gage pressure of 50 psi, determine the density of the air and the weight of air in the tank.



■ FIGURE E1.3*a* (Photograph courtesy of Jenny Products, Inc.)

Ideal Gas Law



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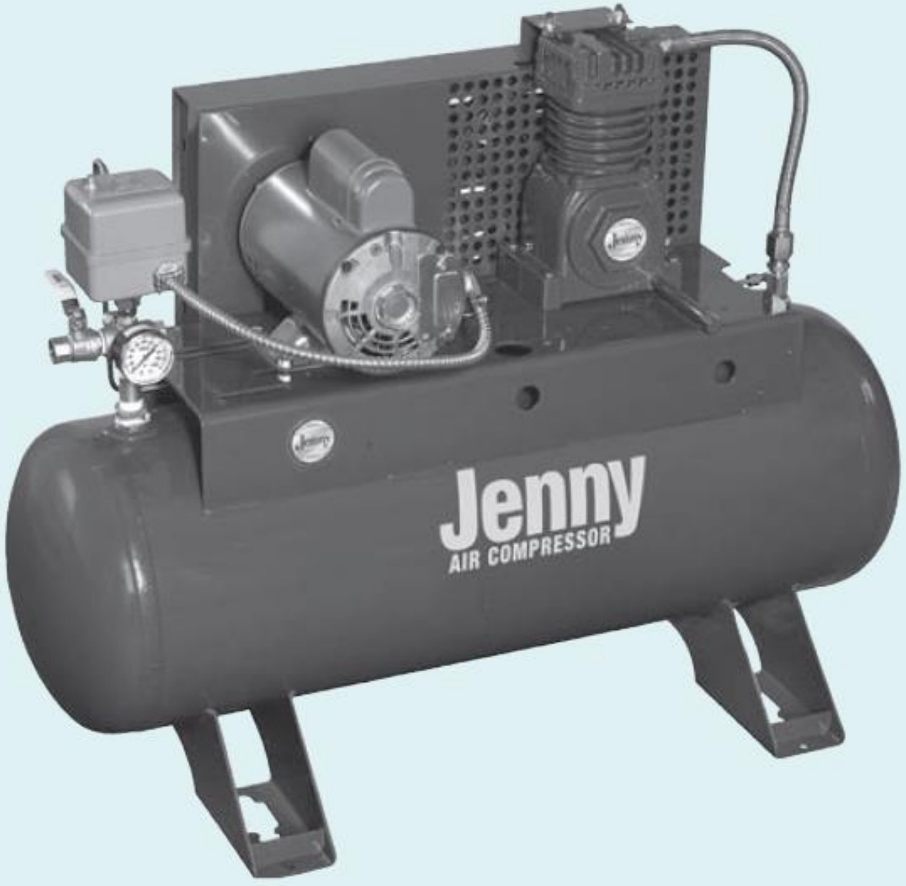


■ FIGURE E1.3*a* (Photograph courtesy of Jenny Products, Inc.)

Volume $\forall = 0.84 \text{ ft}^3$

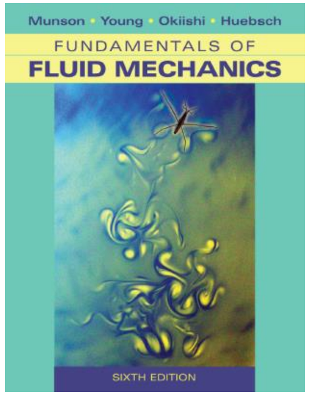
70 °F

Atmospheric pressure = 14.7 psi (abs)

Gage pressure of air = 50 psi

$\rho_{air} = ?$

$W_{air} = ?$

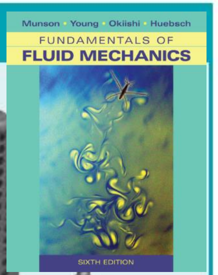


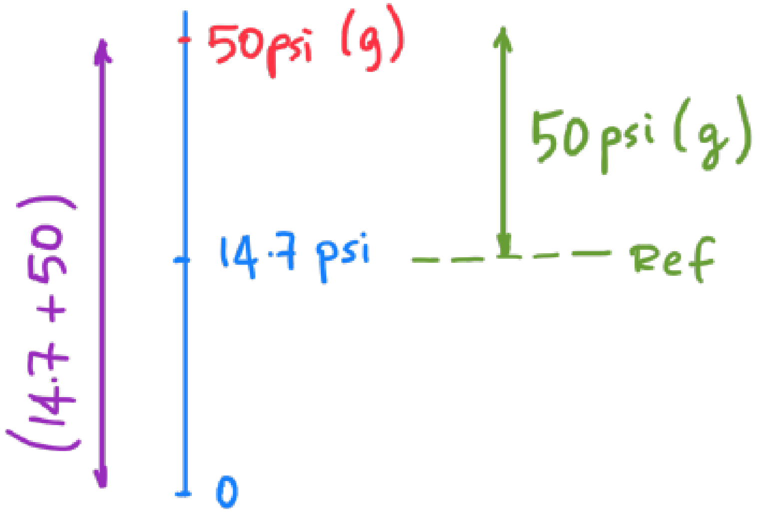
$$\boxed{\rho = \frac{P}{RT}}$$

EXAMPLE 1.3 Ideal Gas Law

GIVEN The compressed air tank shown in Fig. E1.3*a* has a volume of 0.84 ft^3. The temperature is 70 °F and the atmospheric pressure is 14.7 psi (abs).

FIND When the tank is filled with air at a gage pressure of 50 psi, determine the density of the air and the weight of air in the tank.





pressure 50 psi (gage) = 64.7 psi (abs)

↳ pounds per square inches

$$64.7 \frac{lb}{\cancel{in^2}} * \left|\frac{12\ \cancel{in}}{1\ ft}\right|^2$$

12 in = 1 ft

$$\boxed{64.7 \frac{lb}{in^2} = 9316.8 \frac{lb}{ft^2}}$$

$$\boxed{\rho = \frac{P}{RT}}$$

EXAMPLE 1.3 Ideal Gas Law

GIVEN The compressed air tank shown in Fig. E1.3*a* has a volume of 0.84 ft^3. The temperature is 70 °F and the atmospheric pressure is 14.7 psi (abs).

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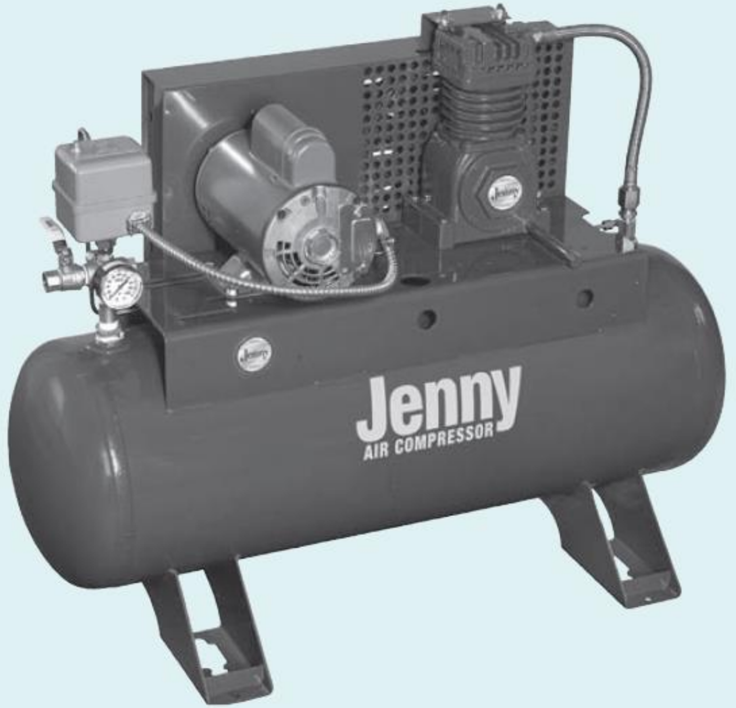


■ FIGURE E1.3*a* (Photograph courtesy of Jenny Products, Inc.)

70 °F $\longrightarrow$ °R = ?

°R = 70 + 460 = 530

gas constant $R = 1716 \dfrac{ft \cdot lb}{slug \cdot °R}$

$$\boxed{\rho = \frac{9316.8 \dfrac{\cancel{lb}}{ft^2}}{1716 \dfrac{ft \cdot \cancel{lb}}{slug \cdot \cancel{°R}} \times 530 \ \cancel{°R}} \qquad \rho = 0.0102 \ slugs/ft^3}$$

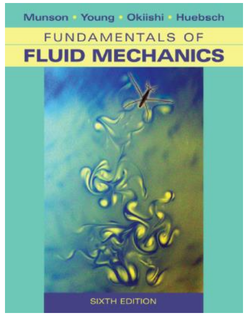


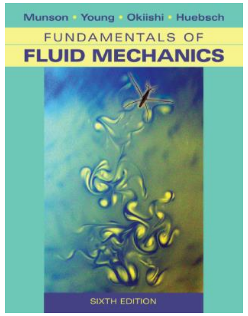
TABLE 1.7

Approximate Physical Properties of Some Common Gases at Standard Atmospheric Pressure (BG Units)

Gas	Temperature (°F)	Density, ρ (slugs/ft^3)	Specific Weight, γ (lb/ft^3)	Dynamic Viscosity, μ (lb · s/ft^2)	Kinematic Viscosity, ν (ft^2/s)	Gas Constant,[a] R (ft · lb/slug · °R)	Specific Heat Ratio,[b] k
Air (standard)	59	2.38 E − 3	7.65 E − 2	3.74 E − 7	1.57 E − 4	1.716 E + 3	1.40
Carbon dioxide	68	3.55 E − 3	1.14 E − 1	3.07 E − 7	8.65 E − 5	1.130 E + 3	1.30
Helium	68	3.23 E − 4	1.04 E − 2	4.09 E − 7	1.27 E − 3	1.242 E + 4	1.66
Hydrogen	68	1.63 E − 4	5.25 E − 3	1.85 E − 7	1.13 E − 3	2.466 E + 4	1.41
Methane (natural gas)	68	1.29 E − 3	4.15 E − 2	2.29 E − 7	1.78 E − 4	3.099 E + 3	1.31
Nitrogen	68	2.26 E − 3	7.28 E − 2	3.68 E − 7	1.63 E − 4	1.775 E + 3	1.40
Oxygen	68	2.58 E − 3	8.31 E − 2	4.25 E − 7	1.65 E − 4	1.554 E + 3	1.40

[a]Values of the gas constant are independent of temperature.

[b]Values of the specific heat ratio depend only slightly on temperature.



$$\rho = \frac{9316.8\ \frac{\cancel{lb}}{ft^2}}{1716\ \frac{ft \cdot \cancel{lb}}{slug\ \cancel{°R}} \times 530\ \cancel{°R}} \qquad \rho = 0.0102\ slugs/ft^3$$

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The compressed air tank shown in Fig. E1.3a has a 0.84 ft^3. The temperature is 70 °F and the atmospheric pressure is 14.7 psi (abs).

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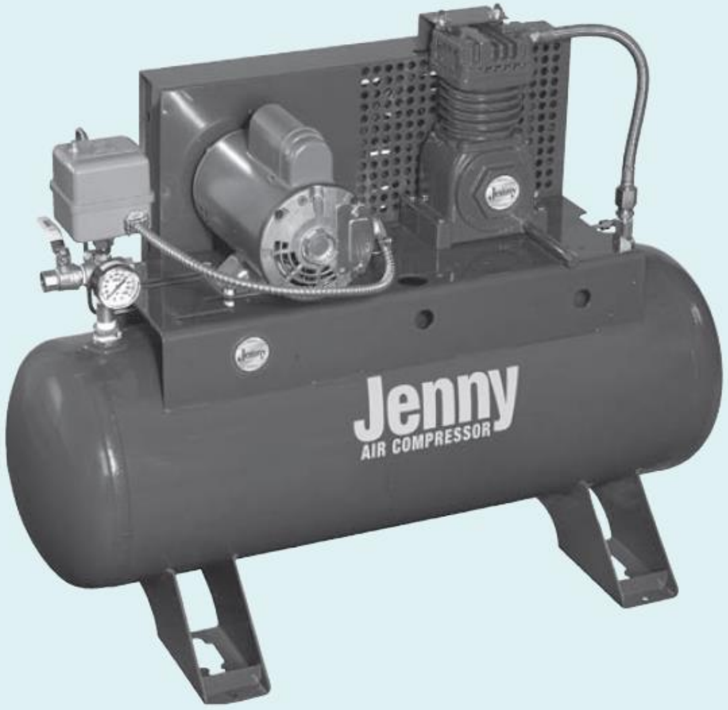


■ **FIGURE E1.3a** (Photograph courtesy of Jenny Products, Inc.)

weight of air ?

$$\gamma = \frac{W}{V} \qquad W = \gamma V, \quad \gamma \to \rho g$$

In BG :

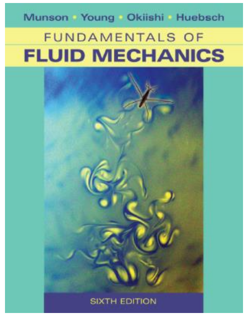
$$g = 32.2\ ft/s^2$$

$$W = 0.0102\ \frac{slug}{\cancel{ft^3}} \times 32.2\ \frac{ft}{s^2} \times 0.84\ \cancel{ft^3}$$

$$W = 0.276\ \frac{slug \cdot ft}{s^2}$$

$$W = 0.276\ lb \qquad \left(1\ lb = 1\ \frac{slug \cdot ft}{s^2}\right)$$

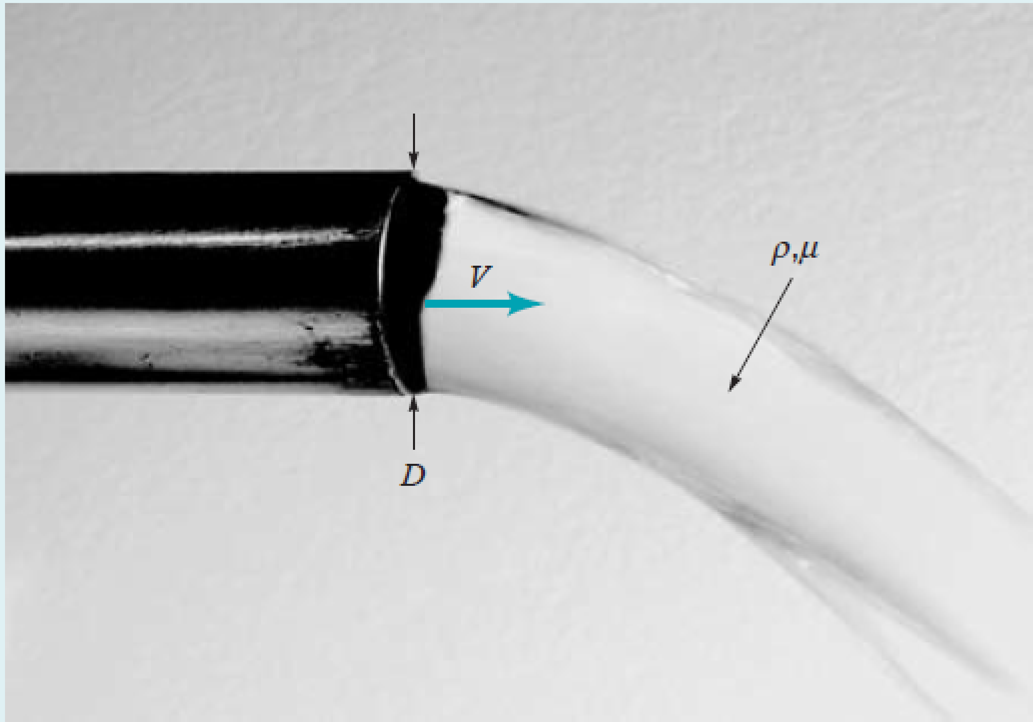
$$F = ma$$



EXAMPLE 1.4 Viscosity and Dimensionless Quantities

GIVEN A dimensionless combination of variables that is important in the study of viscous flow through pipes is called the *Reynolds number,* Re, defined as $\rho VD/\mu$ where, as indicated in Fig. E1.4, ρ is the fluid density, V the mean fluid velocity, D the pipe diameter, and μ the fluid viscosity. A Newtonian fluid having a viscosity of $0.38\ \text{N} \cdot \text{s/m}^2$ and a specific gravity of 0.91 flows through a 25-mm-diameter pipe with a velocity of 2.6 m/s.

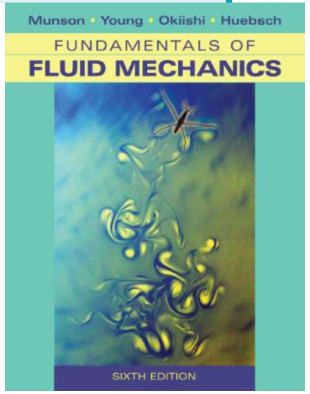
FIND Determine the value of the Reynolds number using (a) SI units, and (b) BG units.

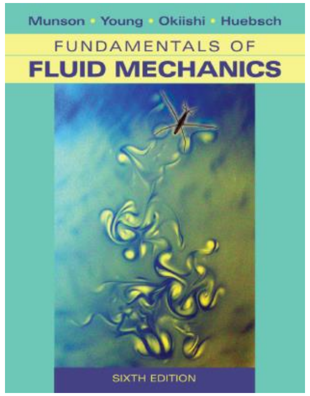


■ FIGURE E1.4

System of Units

Viscosity





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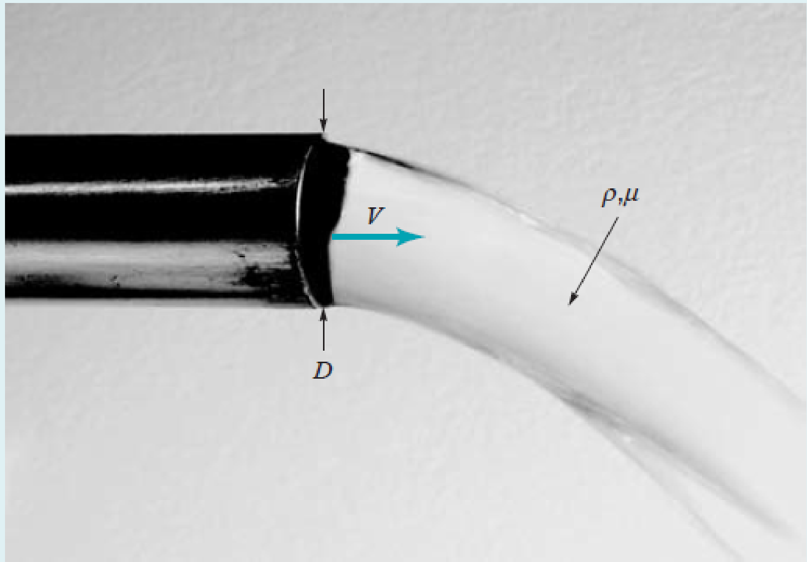


■ FIGURE E1.4

Reynolds Number $Re = \frac{\rho V D}{\mu}$

μ: viscosity $= 0.38 \frac{N \cdot s}{m^2}$

$F = ma$

$N = kg \frac{m}{s^2}$

$SG = 0.91$

Diameter $D = 25$ mm

Velocity $V = 2.6$ m/s

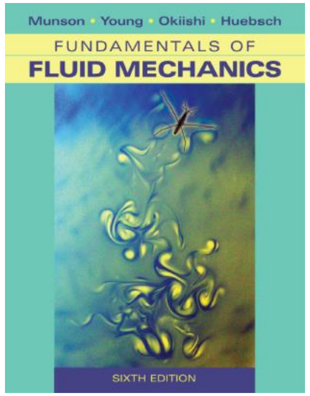
$$\mu = 0.38 \frac{kg \frac{\cancel{m}}{\cancel{s^2}} \cdot \cancel{s}}{m^{\cancel{2}}}$$

$$\mu = 0.38 \frac{kg}{m \cdot s}$$

$$SG = \frac{\rho}{\rho_{H_2O}}$$

$$\rho = 0.91 \times 1000 \frac{kg}{m^3}$$

$$\rho = 910 \text{ kg/m}^3$$



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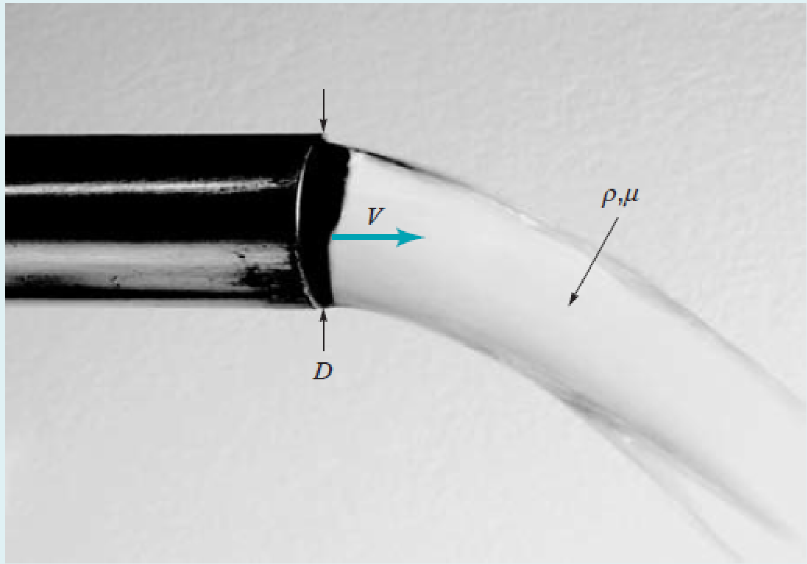
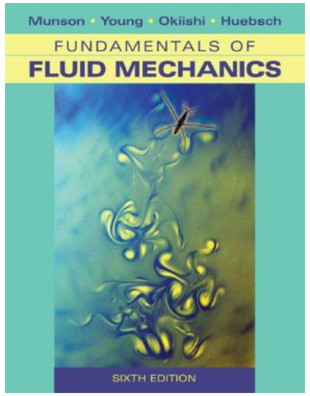


■ FIGURE E1.4

$$\boxed{\text{Reynolds Number} \quad Re = \frac{\rho V D}{\mu}}$$

$$Re = \frac{910 \frac{\cancel{kg}}{\cancel{m^3}} * 2.6 \frac{\cancel{m}}{\cancel{s}} * \left(25 \cancel{mm} * \frac{1 \cancel{m}}{1000 \cancel{mm}}\right)}{0.38 \frac{\cancel{kg}}{\cancel{m.s}}}$$

$$Re = 156$$



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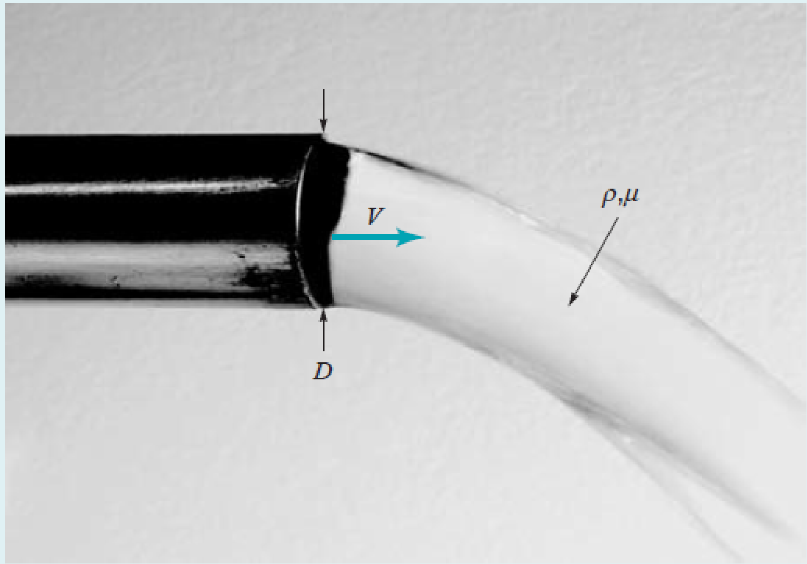


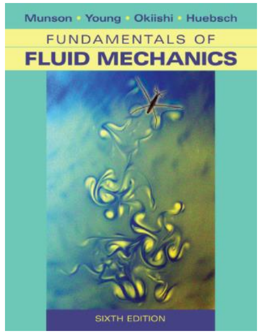
■ FIGURE E1.4

1 lb = 4.4482 N
1 ft = 0.3048 m
1 slug = 14.594 kg

$$\rho = 910\ \frac{\cancel{kg}}{\cancel{m^3}}\ \frac{1\ \text{slug}}{14.594\ \cancel{kg}}\left[\frac{0.3048\ \cancel{m}^{3}}{1\ \text{ft}^{3}}\right]^3$$

$$\rho = 1.77\ \text{slugs/ft}^3$$

$$V \simeq 2.6\ \frac{\cancel{m}}{s}\ \frac{1\ \text{ft}}{0.3048\ \cancel{m}} \qquad V = 8.53\ \text{ft/s}$$



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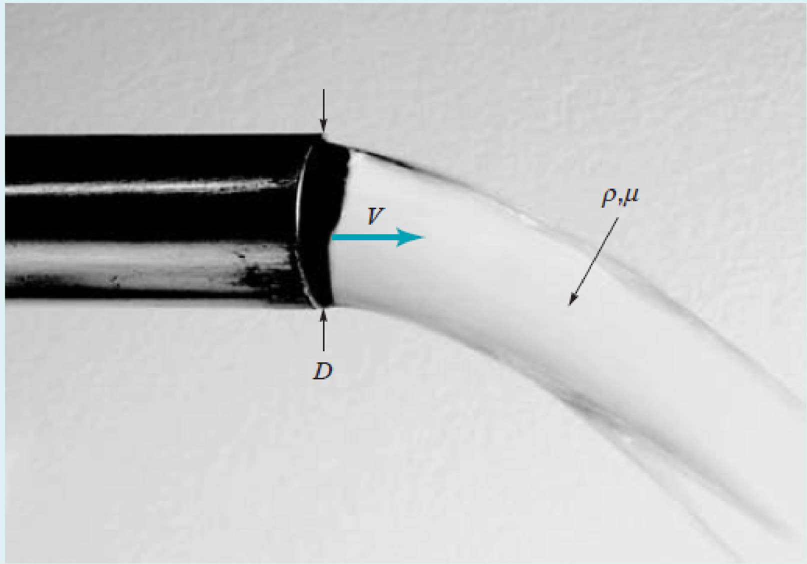

■ FIGURE E1.4

$$D = 25\ \cancel{\text{mm}}\ \frac{1\ \cancel{\text{m}}}{1000\ \cancel{\text{mm}}}\ \frac{1\ \text{ft}}{0.3048\ \cancel{\text{m}}}$$

$$D = 8.20 \times 10^{-2}\ \text{ft}$$

$$\mu = 0.38\ \frac{\cancel{\text{N}}\cdot\text{s}}{\cancel{\text{m}^2}}\ \frac{1\ \text{lb}}{4.4482\ \cancel{\text{N}}}\left[\frac{0.3048\ \cancel{\text{m}}}{1\ \text{ft}}\right]^{\cancel{2}}$$

$$\mu = 7.94 \times 10^{-3}\ \frac{\text{lb}\cdot\text{s}}{\text{ft}^2}$$

$$F = ma$$

$$\text{lb} = \text{slug}\ \frac{\text{ft}}{\text{s}^2}$$

$$\mu = 7.94 \times 10^{-3}\ \frac{\text{slug}\ \frac{\cancel{\text{ft}}}{\text{s}^{\cancel{2}}}\ \cancel{\text{s}}}{\text{ft}^{\cancel{2}}}$$

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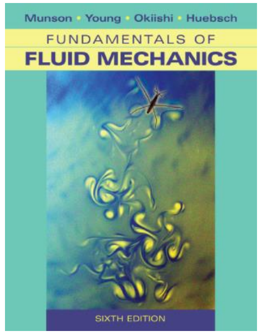

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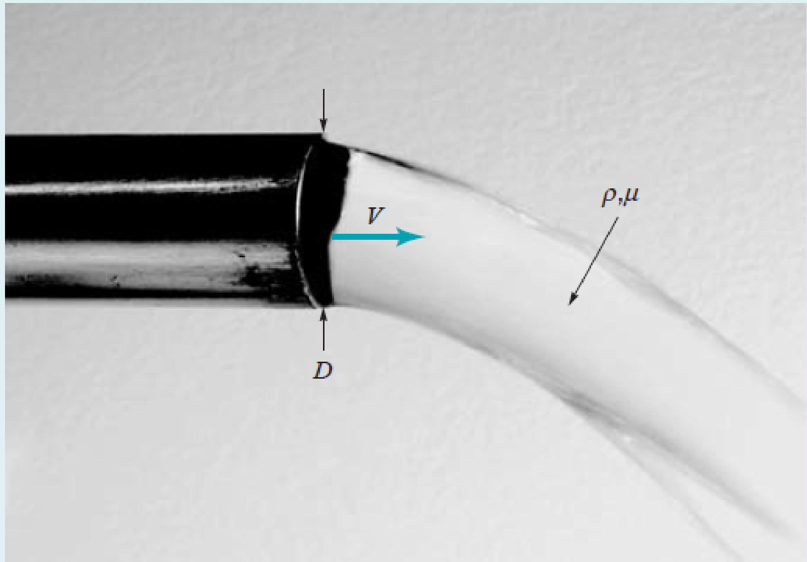


■ FIGURE E1.4

$$\boxed{Re = \frac{\rho V D}{\mu}}$$

$$Re = \frac{1.77\ \frac{\cancel{\text{slugs}}}{\cancel{\text{ft}^3}}\ \ 8.53\ \frac{\cancel{\text{ft}}}{\cancel{\text{s}}}\ \ 8.20 \times 10^{-2}\ \cancel{\text{ft}}}{7.94 \times 10^{-3}\ \frac{\cancel{\text{slugs}}}{\cancel{\text{ft}}\cdot\cancel{\text{s}}}}$$

$$Re \simeq 156$$

EXAMPLE 1.5 Newtonian Fluid Shear Stress

GIVEN The velocity distribution for the flow of a Newtonian fluid between two wide, parallel plates (see Fig. E1.5*a*) is given by the equation

$$u = \frac{3V}{2}\left[1 - \left(\frac{y}{h}\right)^2\right]$$

where V is the mean velocity. The fluid has a viscosity of $0.04\ \text{lb}\cdot\text{s/ft}^2$. Also, $V = 2$ ft/s and $h = 0.2$ in.

FIND Determine: (a) the shearing stress acting on the bottom wall, and (b) the shearing stress acting on a plane parallel to the walls and passing through the centerline (midplane).

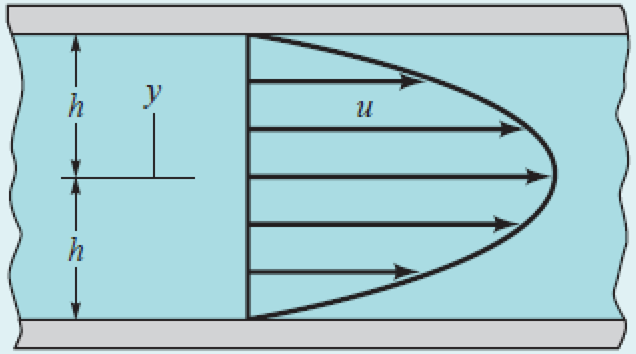
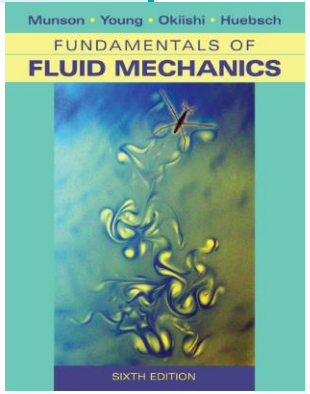


FIGURE E1.5*a*

Viscosity



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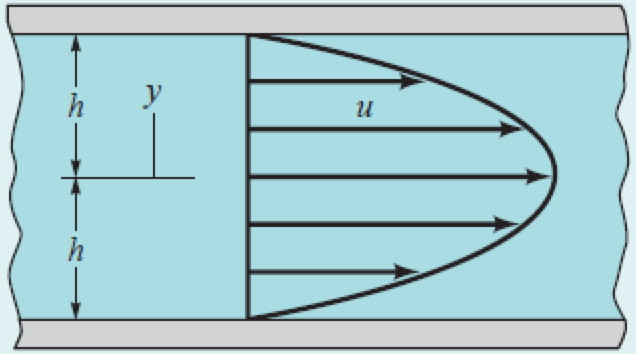
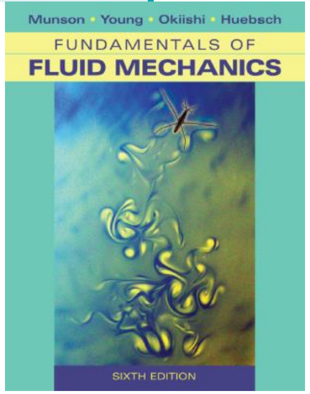


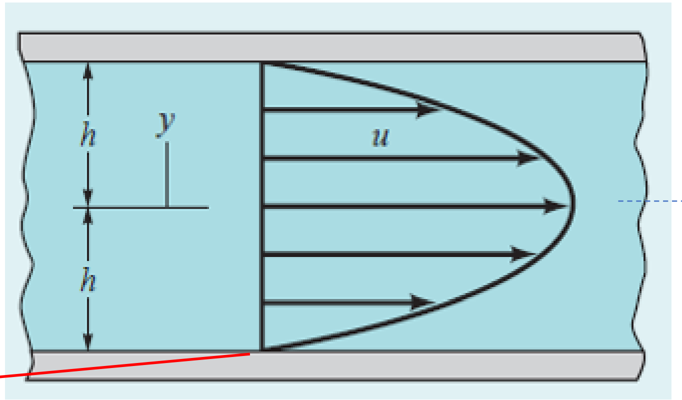
■ FIGURE E1.5*a*

$$\tau = \mu \frac{du}{dy}$$

$u = u(y)$ is known :

$$u = \frac{3V}{2}\left[1 - \left(\frac{y}{h}\right)^2\right]$$





Along the bottom wall

$y = -h$

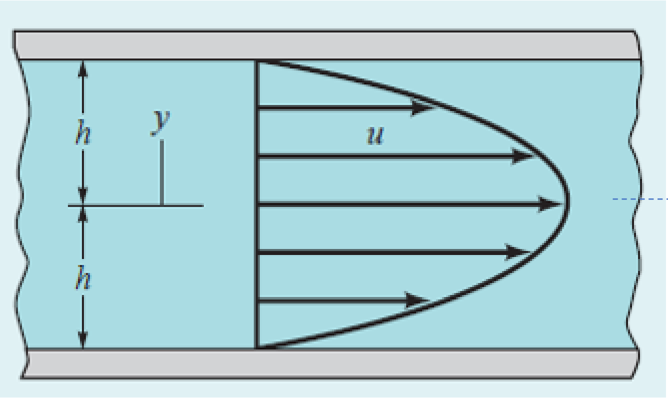
$$u = \frac{3V}{2}\left[1 - \left(\frac{y}{h}\right)^2\right]$$

$$\frac{du}{dy} = -\frac{3V}{h^2}(-h) = \frac{3V}{h}$$

$$\tau = \mu \frac{du}{dy}$$

$$\tau_{\substack{\text{bottom}\\ \text{wall}}} = \frac{0.04 \frac{lb \cdot \cancel{s}}{ft^2} \times 3 \times 2 \frac{\cancel{ft}}{\cancel{s}}}{0.2\ \cancel{in} \times \frac{1\ \cancel{ft}}{12\ \cancel{in}}}$$

$$\tau_{\substack{\text{bottom}\\ \text{wall}}} = 14.4\ \frac{lb}{ft^2}$$



Midplane:
y = 0

$$u = \frac{3V}{2}\left[1 - \left(\frac{y}{h}\right)^2\right]$$

Along the midplane where $y = 0$

$$\frac{du}{dy} = 0$$

so the shearing stress $\tau_{midplane} = 0$