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Topic I: Fluids

Chapter 1. Fluid Properties

Practice Problems

(Use $g = 32.2$ ft/sec^2 (9.81 m/s^2) unless told otherwise.)

1.

Atmospheric pressure is 14.7 lbf/in^2 (101.3 kPa). What is most nearly the absolute pressure in a tank if a gauge on the tank reads 8.7 lbf/in^2 (60 kPa) vacuum?

(A)

4 psia (27 kPa)

(B)

6 psia (41 kPa)

(C)

8 psia (55 kPa)

(D)

10 psia (68 kPa)

2.

Air is considered to be an ideal gas with a specific gas constant of 53.3 ft-lbf/lbm-°R (287 J/kg·K). What is most nearly the kinematic viscosity of air at 80°F (27°C) and 70 psia (480 kPa)?

(A)

3.5×10^{-5} ft^2/sec (3.0×10^{-6} m^2/s)

(B)

4.0×10^{-5} ft^2/sec (4.0×10^{-6} m^2/s)

(C)

5.0×10^{-5} ft^2/sec (5.0×10^{-6} m^2/s)

(D)

6.0×10^{-5} ft^2/sec (6.0×10^{-6} m^2/s)

3.

Three solutions of nitric acid are combined: one with 8% nitric acid by volume, one with 10% nitric acid by volume, and one with 20% nitric acid by volume. The combined solutions produce 100 mL of a solution that is 12% nitric acid by volume. The 8% solution contributes half of the total volume of nitric acid contributed by the 10% and 20% solutions. The volume of 10% solution in the 12% solution is most nearly

(A)

20 mL

(B)

30 mL

(C)

50 mL

(D)

80 mL
4.

A 25% (by volume) mixture of ethylene glycol and water is used in a solar heating application. The components are nonreacting. The mixture is intended to operate at standard atmospheric pressure and an average temperature of 140°F. If the specific gravity of ethylene glycol at 140°F is 1.107 relative to water at 60°F, what is most nearly the specific gravity of the mixture referred to water at 60°F?

(A)

1.005

(B)

1.015

(C)

1.021

(D)

1.043

Solutions

1.

Customary U.S. Solution

$$\begin{aligned} p_{\text{gage}} &= -8.7\ \text{lbf/in}^2 \\ p_{\text{atmospheric}} &= 14.7\ \text{lbf/in}^2 \end{aligned}$$

The relationship between absolute, gage, and atmospheric pressure is in *NCEES Handbook* table "Conversion Table for the Most Commonly Used Units of Pressure."

$$\begin{aligned} p_{\text{absolute}} &= p_{\text{gage}} + p_{\text{atmospheric}} \\ &= -8.7\ \frac{\text{lbf}}{\text{in}^2} + 14.7\ \frac{\text{lbf}}{\text{in}^2} \\ &= 6\ \text{lbf/in}^2 \quad (6\ \text{psia}) \end{aligned}$$

The answer is (B).

SI Solution

$$\begin{aligned} p_{\text{gage}} &= -60\ \text{kPa} \\ p_{\text{atmospheric}} &= 101.3\ \text{kPa} \end{aligned}$$

The relationship between absolute, gage, and atmospheric pressure is in *NCEES Handbook* table "Conversion Table for the Most Commonly Used Units of Pressure."

$$\begin{aligned} p_{\text{absolute}} &= p_{\text{gage}} + p_{\text{atmospheric}} = -60 \text{ kPa} + 101.3 \text{ kPa} \\ &= 41.3 \text{ kPa} \quad (41 \text{ kPa}) \end{aligned}$$

The answer is (B).

2.

Customary U.S. Solution

From the *PE Chemical Handbook: Temperature-Dependent Properties of Air* table, the absolute viscosity of air at 14.7 psia can be found using linear interpolation between the data points of 32°F and 100°F. The viscosity of air at 80°F is

$$\begin{aligned} \mu(32^\circ\text{F}) &= 1.15 \times 10^{-5} \text{ lbm/ft} - \text{sec} \\ \mu(100^\circ\text{F}) &= 1.28 \times 10^{-5} \text{ lbm/ft} - \text{sec} \\ \mu(80^\circ\text{F}) &= \mu(32^\circ\text{F}) + (80^\circ\text{F} - 32^\circ\text{F}) \frac{(\mu(100^\circ\text{F}) - \mu(32^\circ\text{F}))}{(100^\circ\text{F} - 32^\circ\text{F})} \\ &= \left(1.15 \times 10^{-5} \frac{\text{lbm}}{\text{ft} - \text{sec}}\right) + (48^\circ\text{F}) \left(\frac{(1.28 \times 10^{-5} - 1.15 \times 10^{-5}) \frac{\text{lbm}}{\text{ft} - \text{sec}}}{68^\circ\text{F}}\right) \\ &= 1.242 \times 10^{-5} \text{ lbm/ft} - \text{sec} \end{aligned}$$

The density of the air at 70 psia and 80°F is

$$\begin{aligned} \rho &= \frac{p}{RT} = \frac{\left(70 \frac{\text{lbf}}{\text{in}^2}\right)\left(12 \frac{\text{in}}{\text{ft}}\right)^2}{\left(53.3 \frac{\text{ft-lbf}}{\text{lbm-}^\circ\text{R}}\right)(80^\circ\text{F} + 460^\circ)} \\ &= 0.350 \text{ lbm/ft}^3 \end{aligned}$$

The kinematic viscosity, ν, is in *NCEES Handbook: Viscosity and Fluid Properties*

$$\begin{aligned} \nu &= \frac{\mu}{\rho} = \frac{1.242 \times 10^{-5} \text{ lbm/ft} - \text{sec}}{0.350 \text{ lbm/ft}^3} \\ &= 3.549 \times 10^{-5} \text{ ft}^2/\text{sec} \quad \left(3.5 \times 10^{-5} \text{ ft}^2/\text{sec}\right) \end{aligned}$$

The answer is (A).

SI Solution

From the *PE Chemical Handbook: Temperature-Dependent Properties of Air* table, the absolute viscosity of air at 0.1 MPa can be found using linear interpolation between the data points of 20°C and 40°C. The viscosity of air at 27°C is

$$\begin{aligned} \mu(20^\circ\text{C}) &= 18.2\mu\text{Pa·s} \\ \mu(40^\circ\text{C}) &= 19.1\mu\text{Pa·s} \\ \mu(27^\circ\text{C}) &= \mu(20^\circ\text{C}) + (27^\circ\text{C} - 20^\circ\text{C}) \frac{(\mu(40^\circ\text{C}) - \mu(20^\circ\text{C}))}{(40^\circ\text{C} - 20^\circ\text{C})} \\ &= \left(1.82 \times 10^{-5} \text{ Pa·s}\right) + (7^\circ\text{C}) \left(\frac{\left(1.91 \times 10^{-5} - 1.82 \times 10^{-5}\right) \text{Pa·s}}{20^\circ\text{C}}\right) \\ &= 1.852 \times 10^{-5} \text{ Pa·s} \end{aligned}$$

The density of the air at 480 kPa and 27°C is

$$\rho = \frac{p}{RT} = \frac{(480 \text{ kPa})\left(1000 \ \frac{\text{Pa}}{\text{kPa}}\right)}{\left(287 \ \frac{\text{J}}{\text{kg·K}}\right)(27^\circ\text{C} + 273^\circ)}$$
$$= 5.575 \text{ kg/m}^3$$

The kinematic viscosity, ν, is in *NCEES Handbook: Viscosity and Fluid Properties*

$$\nu = \frac{\mu}{\rho} = \frac{1.852 \times 10^{-5} \text{ Pa·s}}{5.575 \text{ kg/m}^3}$$
$$= 3.32 \times 10^{-6} \text{ m}^2/\text{s} \quad \left(3.0 \times 10^{-6} \text{ m}^2/\text{s}\right)$$

The answer is (A).
3.

Let

$$\begin{aligned} x &= \text{volume of 8\% solution} \\ 0.08x &= \text{volume of nitric acid contributed by 8\%} \\ &\quad \text{solution} \\ y &= \text{volume of 10\% solution} \\ 0.10y &= \text{volume of nitric acid contributed by 10\%} \\ &\quad \text{solution} \\ z &= \text{volume of 20\% solution} \\ 0.20z &= \text{volume of nitric acid contributed by 20\%} \\ &\quad \text{solution} \end{aligned}$$

The three conditions that must be satisfied are

$$\begin{aligned} x + y + z &= 100 \text{ mL} \\ 0.08x + 0.10y + 0.20z &= (0.12)(100 \text{ mL}) = 12 \text{ mL} \\ 0.08x &= \left(\frac{1}{2}\right)(0.10y + 0.20z) \end{aligned}$$

Simplifying these equations,

$$\begin{aligned} x + y + z &= 100 \\ 4x + 5y + 10z &= 600 \\ 8x - 5y - 10z &= 0 \end{aligned}$$

Adding the second and third equations,

$$\begin{aligned} 12x &= 600 \\ x &= 50 \text{ mL} \end{aligned}$$

Working with the first two equations,

$$\begin{aligned} y + z &= 100 - 50 = 50 \\ 5y + 10z &= 600 - (4)(50) = 400 \end{aligned}$$

Multiplying the top equation by −5 and adding to the bottom equation,

$$\begin{aligned} 5z &= 150 \\ z &= 30 \text{ mL} \end{aligned}$$

Using the first equation, the volume of 10% solution in the 12% solution is

$$y = 20 \text{ mL}$$

The answer is (A).

4.

From appendixCERM14A (also *NCEES Handbook* table “Physical Properties of Liquid Water”), the density of 140°F water is 61.38 lbm/ft^3. Consider 100 ft^3 of mixture. Since the mixture percentages are volumetric, there is 25 ft^3 of ethylene glycol and 75 ft^3 of water. The weight of 100 ft^3 is

$$\begin{aligned} m &= \rho_{\text{water}} V_{\text{water}} + \rho_{\text{glycol}} V_{\text{glycol}} \\ &= \left(61.38\ \frac{\text{lbm}}{\text{ft}^3}\right)\left(75\ \text{ft}^3\right) \\ &\quad + (1.107)\left(62.37\ \frac{\text{lbm}}{\text{ft}^3}\right)\left(25\ \text{ft}^3\right) \\ &= 6329.59\ \text{lbm} \end{aligned}$$

The specific gravity of the mixture is

$$\begin{aligned} \text{SG} &= \frac{\rho}{\rho_{\text{ref}}} = \frac{m}{V\rho_{\text{ref}}} = \frac{6329.59\ \text{lbm}}{\left(100\ \text{ft}^3\right)\left(62.37\ \frac{\text{lbm}}{\text{ft}^3}\right)} \\ &= 1.0148 \quad (1.015) \end{aligned}$$

The answer is (B).