Solution Manual for Fluid Mechanics 2nd Edition by Hibbeler ISBN 013464929X9780134649290

Full link download
Solution Manual:

1–1. Represent each of the following quantities with combinations of units in the correct SI form, using an appropriate prefix: (a) mm · MN, (b) Mg/mm, (c) km/ms, (d) kN/(mm)².

SOLUTION

a) $\text{mm} \cdot \text{MN} = (10^{-3}\,\text{m})(10^{6}\,\text{N}) = 10^{3}\,\text{N} \cdot \text{m} = \text{kN} \cdot \text{m}$ **Ans.**

b) $\text{Mg/mm} = (10^{6}\,\text{g})/(10^{-3}\,\text{m}) = 10^{9}\,\text{g/m} = \text{Gg/m}$ **Ans.**

c) $\text{km/ms} = (10^{3}\,\text{m})/(10^{-3}\,\text{s}) = 10^{6}\,\text{m/s} = \text{Mm/s}$ **Ans.**

d) $\text{kN/(mm)}^2 = (10^{3}\,\text{N})/(10^{-6}\,\text{m}^2) = 10^{9}\,\text{N/m}^2 = \text{GN/m}^2$ **Ans.**

Ans:
a) kN · m
b) Gg/m
c) Mm/s
d) GN/m²

1–2. Evaluate each of the following to three significant figures, and express each answer in SI units using an appropriate prefix: (a) [4.86(1O)] mm, (b) (348 mm), (e) (83700 mN.

SOLUTION

a) [4.86(1O)]mm = [4.86(1O)(1O'm) = 23.62(1O) m = 23.6 Gm **Ans.**

b) (348 mm)' = [348(1O)m]' = 42.14(1O)m' = 42.1(1O)m' **Ans.**

c) (83,700 mN) = [83,700(1O)N] = 7.006(1O)N = 7.01(10')N **Ans.**

Ans:
a) 23.6 Gm
b) 42.1(1O) m'
e) 7.01(10') N?

1–3. Evaluate each of the following to three significant figures, and express each answer in SI units using an appropriate prefix: (a) 749 μm/63 ms, (b) (34 mm)(0.0763 Ms)/263 mg, (c) (4.78 mm)(263 Mg).

SOLUTION

a) 749m/63 ms = 749(1O) m/63(1O)s = 11.88(1O) m/s

= 11.9 mm/s **Ans.**

b) (34 mm)(0.0763 Ms)/263 mg = [34(1O) m][0.0763(1O)s]/[263(1O)(10) g]

= 9.86(1O) m·s/kg = 9.86 Mm·s/kg **Ans.**

e) (4.78 mm)(263 Mg) = [4.78(1O)m][263(1O) g]

= 1.257(1O)g·m = 1.26Mg·m **Ans.**

Ans:
a) 11.9 mm/s
b) 9.86 Mm· s/kg
c) 1.26 Mg· m

1-4. Convert the following temperatures: (a) 250 K to degrees Celsius, (b) 322F to degrees Rankine, (c) 230°F to degrees Celsius, (d) 4OC to degrees Fahrenheit.

SOLUTION

a) $T = T_e + 273$; 250K = T + 273 $T = 23.0C$ **Ans.**

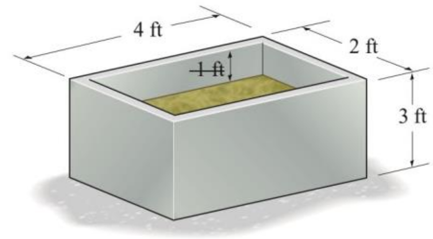
b) $T_r = T_r + 460$ = 322F + 460 = 782R **Ans.**

e) $T = \frac{5}{9}(\ , -32) -\}or -3s2) = 1orc$ **Ans.**

) $T\% = ;(r, -s2)$ 4rc= $(r, -32)$ T_r = 1+F **Ans.**

Ans:
a) −23.0°C
) 782R
e) 11OC
d) 104F

1–5. The tank contains a liquid having a density of 1.22 slug ft. Determine the weight of the liquid when it is at the level shown.



SOLUTION

The specific weight of the liquid and the volume of th liquid are

gr& = (122slug ft)(32.2n s) = 39.284 lb f'

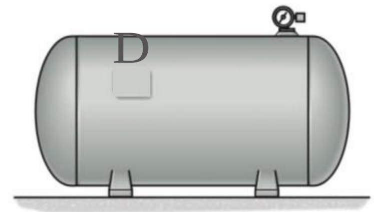
4 = (4f)(2f)(2f) = 16f

Then the weight of the liuid is

W = gl = (39.284lb ft)(16f) = 628.54 lb = 629 lb **Ans.**

Ans:
W = 62916

1-6. If air within the tank is at an absolute pressure of 680 kPa and a temperature of 70°C, determine the weight of the air inside the tank. The tank has an interior volume of 1.35 m'.



SOLUTION

From the table in Appendix A, the gas constant for air is $R = 286.9$ /kg·K.

$$p = \rho RT$$

$$680(10') \text{ N/m} = \rho(286.9 \text{ J/kg}\cdot\text{K})(70° + 273)\text{K}$$

$$p = 6.910 \text{ kg/m}^3$$

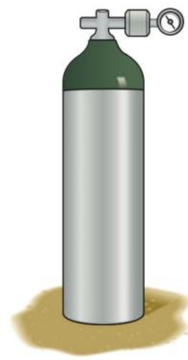
The weight of the air in the tank is

$$W = \rho g = (6910 \text{ kg/m'})(9.81 \text{ m/s})(1.35 \text{ m'})$$

$$= 91.5 \text{ N}$$ **Ans.**

Ans:
$W = 91.5$ N

1–7. The bottle tank has a volume of $0.35\ \text{m}^3$ and contains 40 kg of nitrogen at a temperature of 40°C. Determine the absolute pressure in the tank.



SOLUTION

The density of nitrogen in the tank is

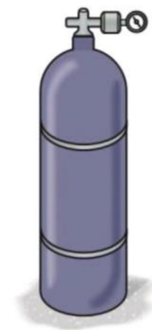
$$\rho = \frac{m}{V} = \frac{40\ \text{kg}}{0.35\ \text{m}^3} = 114.29\ \text{kg/m}^3$$

From the table in Appendix A, the gas constant for nitrogen is $R = 296.8\ \text{J/kg}\cdot\text{K}$. Applying the ideal gas law,

$$p = \rho R T$$
$$p = (114.29\ \text{kg/m}^3)(296.8\ \text{J/kg}\cdot\text{K})(40°\text{C} + 273)\ \text{K}$$
$$= 10.62(10^6)\ \text{Pa}$$
$$= 10.6\ \text{MPa}$$ **Ans.**

Ans:
$p = 10.6\ \text{MPa}$

1-8. The bottle tank contains nitrogen having a temperature of 60°C. Plot the variation of the pressure in the tank (vertical axis) versus the density for 0 = p = 5kg/m'. Report values in increments of Ap = 50 kPa.



SOLUTION

From the table in Appendix A, the gas constant for nitrogen is R = 296.8 J/kg·K. The constant temperature is T = (60°C + 273) K = 333 K. Applying the ideal gas law,

$$p = pRT$$

$$p = p(296.8\ \text{J/kg}\cdot\text{K})(333\ \text{K})$$

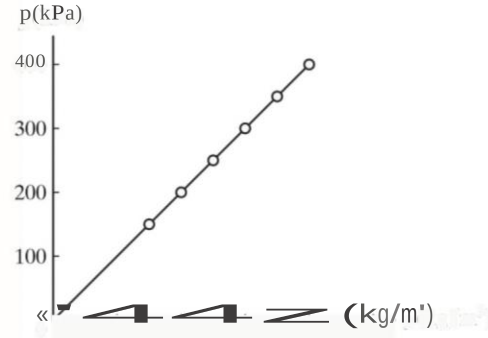
$$p = (98{,}834p)\ \text{Pa}$$

$$= (98.8p)\ \text{kPa}$$

Ans.

p(kPa)	150	200	250	300	350	400
p(kg/m')	1.52	2.02	2.53	3.04	3.54	4.05

The plot of p vs p is shown in Fig. a.



(a)

Ans:
p = (98.8p) kPa

1–9. Determine the specific weight of hydrogen when the temperature is 85 °C and the absolute pressure is 4 MPa.

SOLUTION

From the table in Appendix A, the gas constant for hydrogen is $R = 4124\ \text{J/kg}\cdot\text{K}$. Applying the ideal gas law,

$$p = \rho R T$$

$$4(10^6)\ \text{N/m}^2 = \rho(4124\ \text{J/kg}\cdot\text{K})(85^\circ\text{C} + 273)\ \text{K}$$

$$\rho = 2.7093\ \text{kg/m}^3$$

Then the specific weight of hydrogen is

$$\gamma = \rho g = (2.7093\ \text{kg/m}^3)(9.81\ \text{m/s}^2)$$

$$= 26.58\ \text{N/m}^3$$

$$= 26.6\ \text{N/m}^3 \qquad \textbf{Ans.}$$

Ans:
$\gamma = 26.6\ \text{N/m}^3$

1–10. Dry air at 25 °C has a density of 1.23 kg/m^3. But if it has 100% humidity at the same pressure, its density is 0.65% less. At what temperature would dry air produce this same smaller density?

SOLUTION

For both cases, the pressures are the same. Applying the ideal gas law with $\rho = 1.23 \text{ kg/m}^3$, $\rho = (1.23 \text{ kg/m}^3)(1 - 0.0065) = 1.222005 \text{ kg/m}^3$ and $T_1 = (25°C + 273) = 298 \text{ K}$

$$P = \rho_1 RT_1 = (1.23 \text{ kg/m}^3)R(298 \text{ K}) = 366.54 R$$

Then

$$p = \rho_2 RT_2; \quad 366.54R = (1.222005 \text{ kg/m}^3)R(T_C + 273)$$

$$T_C = 26.9°C$$ **Ans.**

Ans:
$T_C = 26.9°C$

1–11. The tanker carries 900(10) barrels of crude oil in its hold. Determine the weight of the oil if its specific gravity 7.48 gal>ft. is 0.940. Each barrel contains 42 gallons, and there are

SOLUTION

The specific weight of the crude oil is

$$g_o = S_g = 0.940(62.4 \text{ lb/ft}) = 58.656 \text{ lb/ft}^3$$

The volume of the crude oil is

$$V = 3900(10) \text{ bl} 4a \ 1 \ 1b \ a7.48 \text{ gal}'b = 5.0535(10^6) \text{ ft } 42 \text{ gall}$$

ft

Then, the weight of the crude oil is

$$W = g_o V = 158.656 \quad 6 \quad \text{lb/ft } 235.0535110$$

2 f4

3

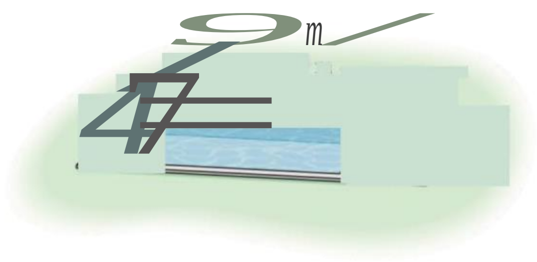
$$= 296.41(10\ ) \text{ lb}$$

$$= 296(10) \text{ lb } A$$

Ans:

$W = 296(10)$ lb

1–12. Water in the swimming pool has a measured depth of 3.03 m when the temperature is 5°C. Determine its approximate depth when the temperature becomes 35°C. Neglect losses due to evaporation.



SOLUTION

From Appendix A, at $T_1 = 5°C$, $(\rho_w)_1 = 1000.0\ \text{kg/m}^3$. The volume of the water is $\forall = Ah$. Thus, $\forall_1 = (9\ \text{m})(4\ \text{m})(3.03\ \text{m})$. Then

$$(\rho_w)_1 = \frac{m}{\forall_1}; \quad 1000.0\ \text{kg/m}^3 = \frac{m}{36\ \text{m}^2(3.03\ \text{m})}$$

$$m = 109.08(10^3)\ \text{kg}$$

At $T_2 = 35°C$, $(\rho_w)_2 = 994.0\ \text{kg/m}^3$. Then

$$(\rho_w)_2 = \frac{m}{\forall_2}; \quad 994.0\ \text{kg/m}^3 = \frac{109.08(10^3)}{(36\ \text{m}^2)h}$$

$$h = 3.048\ \text{m} = 3.05\ \text{m} \qquad \textbf{Ans.}$$

Ans:
$h = 3.05$ m

1–13. Determine the weight of carbon tetrachloride that should be mixed with 15 lb of glycerin so that the combined mixture has a density of 2.85 slug/ft^3.

SOLUTION

From the table in Appendix A, the densities of glycerin and carbon tetrachloride at s.t.p. are $\rho_g = 2.44\ \text{slug/ft}^3$ and $\rho_{ct} = 3.09\ \text{slug/ft}^3$, respectively. Thus, their volumes are given by

$$\rho_g = \frac{m_g}{V_g}; \quad 2.44\ \text{slug/ft}^3 = \frac{(15\ \text{lb})/(32.2\ \text{ft/s}^2)}{V_g} \quad V_g = 0.1909\ \text{ft}^3$$

$$\rho_{ct} = \frac{m_{ct}}{V_{ct}}; \quad 3.09\ \text{slug/ft}^3 = \frac{W_{ct}/(32.2\ \text{ft/s}^2)}{V_{ct}} \quad V_{ct} = (0.01005\,W_{ct})\ \text{ft}^3$$

The density of the mixture is

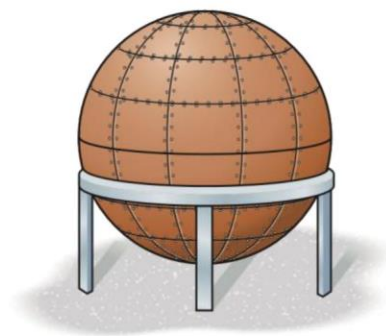
$$\rho_m = \frac{m_m}{V_m}; \quad 2.85\ \text{slug/ft}^3 = \frac{W_{ct}/(32.2\ \text{ft/s}^2) + (15\ \text{lb})/(32.2\ \text{ft/s}^2)}{0.1909\ \text{ft}^3 + 0.01005\,W_{ct}}$$

$$W_{ct} = 32.5\ \text{lb}$$

Ans.

Ans:
$W_{ct} = 32.5\ \text{lb}$

1–14. The tank contains air at a temperature of 18C and an absolute pressure of 160 kPa. If the volume of the tank is 3.48 m' and the temperature rises to 42°C, determine the mass of air that must be removed from the tank to maintain the same pressure.



SOLUTION

For T_1 = (18°C + 273) K = 291 K and R = 286.9 J/kg·K for air (Appendix A). the ideal gas law gives

$$p_1 = \rho_1 R T_1; \qquad 160(10') \text{ N/m} = \rho_1(286.9 \text{ J/kg·K})(291 \text{ K})$$

$$\rho_1 = 19164 \text{ kg/m'}$$

Thus, the mass of the air at T_1 is

$$m_1 = \rho_1 V = (1.9164 \text{ kg/m'})(3.48 \text{ m'}) = 6.6692 \text{ kg}$$

For T_2 = (42C + 273) K = 315 K, and R = 2869 J/kg·K,

$$p = \rho RT; \qquad 160(10) \text{ N/m} = \rho_2(286.9 \text{ J/kg·K})(315 \text{ K})$$

$$\rho = 1.7704 \text{ kg/m'}$$

Thus, the mass of air at T is

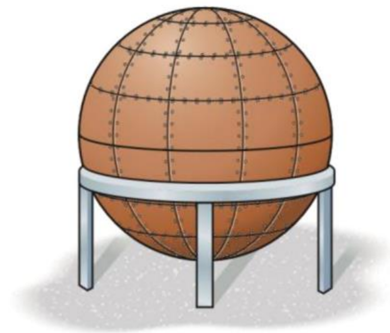
$$m = \rho V = (1.7704 \text{ kg/m})(3.48 \text{ m}) = 6.1611 \text{ kg}$$

Finally, the mass of air that must be removed is

$$\Delta m = m_1 - m_2 = 6.6692 \text{ kg} - 6.1611 \text{ kg} = 0.508 \text{ kg} \qquad \textbf{Ans.}$$

Ans:
Δm = 0.508 kg

1–15. The tank contains 4 kg of air at an absolute pressure of 350 kPa and a temperature of 18°C. If 0.8 kg of air is added to the tank and the temperature rises to 38°C, determine the resulting pressure in the tank.



SOLUTION

For $T_1 = (18°C + 273)\text{K} = 291\text{K}$, $p_1 = 350\text{kPa}$ and $R = 286.9\text{J/kg}\cdot\text{K}$ for air (Appendix A), the ideal gas law gives

$$p_1 = \rho_1 R T_1 \qquad 350(10^3)\ \text{N/m}^2 = \rho_1(286.9\ \text{J/kg}\cdot\text{K})(291\ \text{K})$$

$$\rho_1 = 4.1922\ \text{kg/m}^3$$

Since the volume is constant,

$$V = \frac{m_1}{\rho_1} = \frac{m_2}{\rho_2}; \quad \rho_2 = \frac{m_2}{m_1}\rho_1$$

Here, $m_1 = 4\text{kg}$ and $m_2 = (4 + 0.8)\text{kg} = 4.8\text{kg}$

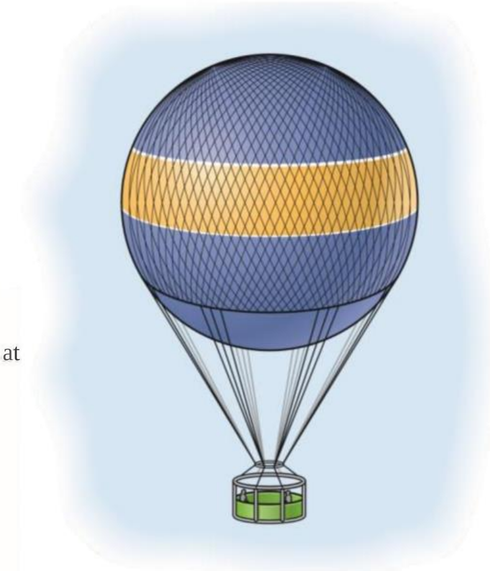
$$\rho_2 = \left(\frac{4.8\ \text{kg}}{4\ \text{kg}}\right)(4.1922\ \text{kg/m}^3) = 5.0307\ \text{kg/m}^3$$

Again, applying the ideal gas law with $T_2 = (38°C + 273)\text{K} = 311\ \text{K}$,

$$p_2 = \rho_2 R T_2 = (5.0307\ \text{kg/m}^3)(286.9\ \text{J/kg}\cdot\text{K})(311\ \text{K})$$
$$= 448.86(10^3)\ \text{Pa}$$
$$= 449\ \text{kPa}$$ **Ans.**

Ans:
$p = 449\text{kPa}$

1–16. The 8-m-diameter spherical balloon is filled with helium that is at a temperature of 28°C and an absolute pressure of 106 kPa. Determine the weight of the helium contained in the balloon. The volume of a sphere is $V = \frac{4}{3}\pi r^3$.



SOLUTION

For helium, the gas constant is $R = 2077\ \text{J/kg}\cdot\text{K}$. Applying the ideal gas law at $T = (28 + 273)\ \text{K} = 301\ \text{K}$.

$$p = \rho RT; \qquad 106(10^3)\ \text{N/m}^2 = \rho(2077\ \text{J/kg}\cdot\text{K})(301\ \text{K})$$

$$\rho = 0.1696\ \text{kg/m}^3$$

Here,

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(4\ \text{m})^3 = \frac{256}{3}\pi\ \text{m}^3$$

Then, the mass of the helium is

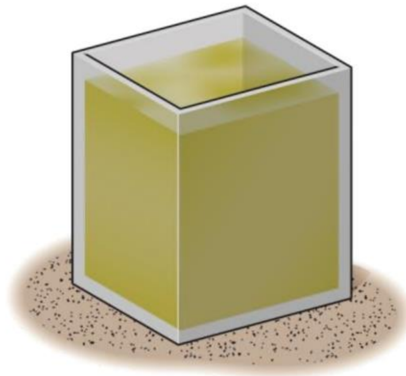
$$M = \rho V = (0.1696\ \text{kg/m}^3)\left(\frac{256}{3}\pi\ \text{m}^3\right) = 45.45\ \text{kg}$$

Thus,

$$W = mg = (45.45\ \text{kg})(9.81\ \text{m/s}^2) = 445.90\ \text{N} = 446\ \text{N}$$ **Ans.**

Ans:
$W = 446\ \text{N}$

1–17. Gasoline is mixed with $8\ \text{ft}^3$ of kerosene so that the volume of the mixture in the tank becomes $12\ \text{ft}^3$. Determine the specific weight and the specific gravity of the mixture at standard temperature and pressure.



SOLUTION

From the table in Appendix A, the densities of gasoline and kerosene at s.t.p. are $\rho_g = 1.41\ \text{slug/ft}^3$ and $\rho_k = 1.58\ \text{slug/ft}^3$, respectively. The volume of gasoline is

$$V_g = 12\ \text{ft}^3 - 8\ \text{ft}^3 = 4\ \text{ft}^3$$

Then the total weight of the mixture is therefore

$$W_m = \rho_g g V_g + \rho_k g V_k$$

$$= (1.41\ \text{slug/ft}^3)(32.2\ \text{ft/s}^2)(4\ \text{ft}^3) + (1.58\ \text{slug/ft}^3)(32.2\ \text{ft/s}^2)(8\ \text{ft}^3)$$

$$= 588.62\ \text{lb}$$

Thus, the specific weight and specific gravity of the mixture are

$$\gamma_m = \frac{W_m}{V_m} = \frac{588.62\ \text{lb}}{12\ \text{ft}^3} = 49.05\ \text{lb/ft}^3 = 49.1\ \text{lb/ft}^3$$ **Ans.**

$$S_m = \frac{\gamma_m}{\gamma_w} = \frac{49.05\ \text{lb/ft}^3}{62.4\ \text{lb/ft}^3} = 0.786$$ **Ans.**

Ans:
$\gamma_m = 49.1\ \text{lb/ft}^3$
$S_m = 0.786$

1–18. Determine the change in the density of oxygen when the absolute pressure changes from 345 kPa to 286 kPa, while the temperature *remains constant* at 25°C. This is called an *isothermal process*.

SOLUTION

Applying the ideal gas law with $T_1 = (25C + 273)K = 298K$, $p_1 = 345$ kPa and $R = 259.8$ J/kg·K for oxygen (table in Appendix A),

$$p_1 = \rho_1 RT_1; \qquad 345(10^3)\text{N/m}^2 = \rho_1(259.8\text{J/kg}\cdot\text{K})(298\text{ K})$$
$$\rho_1 = 4.4562 \text{ kg/m}^3$$

For $p_2 = 286$kPa and $T_2 = T_1 = 298$ K,

$$p_2 = \rho_2 RT_2; \qquad 286(10^3)\text{ N/m}^2 = \rho_2(259.8\text{ J/kg}\cdot\text{K})(298\text{ K})$$
$$\rho_2 = 3.6941 \text{ kg/m}^3$$

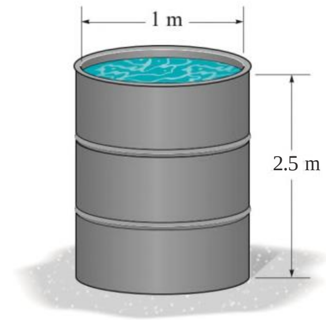
Thus, the change in density is

$$\Delta\rho = \rho_2 - \rho_1 = 3.6941 \text{ kg/m}^3 - 4.4562 \text{ kg/m}^3$$
$$= -0.7621 \text{ kg/m}^3 = -0.762 \text{ kg/m}^3 \qquad \textbf{Ans.}$$

The negative sign indicates a decrease in density.

Ans:
$\Delta\rho = -0.762$ kg/m^3

1–19. The container is filled with water at a temperature of 25 °C and a depth of 2.5 m. If the container has a mass of 30 kg, determine the combined weight of the container and the water.



SOLUTION

From Appendix A, $\rho_w = 997.1\ \text{kg/m}^3$ at $T = 25°\text{C}$. Here, the volume of water is

$$V = \pi r^2 h = \pi(0.5\ \text{m})^2(2.5\ \text{m}) = 0.625\pi\ \text{m}^3$$

Thus, the mass of water is

$$M_w = \rho_w V = 997.1\ \text{kg/m}^3(0.625\pi\ \text{m}^3) = 1957.80\ \text{kg}$$

The total mass is

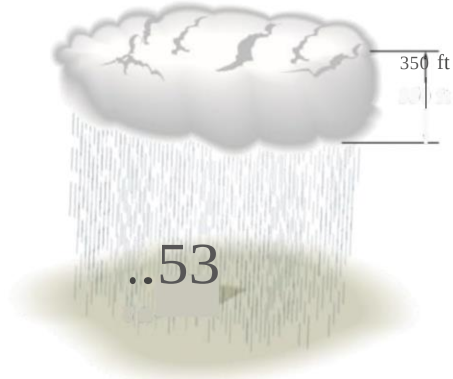
$$M_T = M_w + M_c = (1957.80 + 30)\ \text{kg} = 1987.80\ \text{kg}$$

Then the total weight is

$$W = M_T g = (1987.80\ \text{kg})(9.81\ \text{m/s}^2) = 19\,500\ \text{N} = 19.5\ \text{kN}$$ **Ans.**

Ans:
$W = 19.5\ \text{kN}$

1–20. The rain cloud has an approximate volume of 6.50 mile' and an average height, top to bottom, of 350 ft. If a cylindrical container 6 ft in diameter collects 2 in. of water after the rain falls out of the cloud, estimate the total weight of rain that fell from the cloud. 1 mile = 5280 ft.



SOLUTION

The volume of rain water collected is $\forall_w = \pi(3\,ft)^2(\frac{2}{12}\,ft) = 1.5\pi\ ft^3$. Then, the weight of the rain water is $W = \gamma_w \forall_w = (62.4\ lb/ft^3)(1.5\pi\ ft^3) = 93.6\pi\ lb$. Here, the volume of the overhead cloud that produced this amount of rain is

$$\forall_c' = \pi(3\,ft)^2(350\,ft) = 3150\pi\ ft^3$$

Thus,

$$\gamma = \frac{W}{\forall_c'} = \frac{93.6\pi\ lb}{3150\pi\ ft^3} = 0.02971\ lb/ft^3$$

Then

$$W_t = \gamma\forall_t = (0.02971)\left[6.50\left(\frac{5280^3}{1}\right)\right]$$

$$= 28.4(10^9)\ lb \qquad \textbf{Ans.}$$

Ans:
$W_t = 28.4(10^9)$ lb

1–21. A volume of $8\ m^3$ of oxygen initially at 80 kPa of absolute pressure and 15°C is subjected to an absolute pressure of 25 kPa while the temperature remains constant. Determine the new density and volume of the oxygen.

SOLUTION

From the table in Appendix A, the gas constant for oxygen is $R = 259.8\ \text{J/kg}\cdot\text{K}$. Applying the ideal gas law,

$$p_1 = \rho_1 R T_1;\quad 80(10^3)\ \text{N/m}^2 = \rho_1(259.8\ \text{J/kg}\cdot\text{K})(15^\circ\text{C} + 273)\ \text{K}$$

$$\rho_1 = 1.0692\ \text{kg/m}^3$$

For $T_1 = T_2$ and $p_2 = 25\ \text{kPa}$

$$\frac{p_1}{p_2} = \frac{\rho_1 R T_1}{\rho_2 R T_2};\quad \frac{p_1}{p_2} = \frac{\rho_1}{\rho_2}$$

$$\frac{80\ \text{kPa}}{25\ \text{kPa}} = \frac{1.0692\ \text{kg/m}^3}{\rho_2}$$

$$\rho_2 = 0.3341\ \text{kg/m}^3 = 0.334\ \text{kg/m}^3 \qquad \textbf{Ans.}$$

The mass of the oxygen is

$$m = \rho_1 V_1 = (1.0692\ \text{kg/m}^3)(8\ \text{m}^3) = 8.5536\ \text{kg}$$

Since the mass of the oxygen is constant regardless of the temperature and pressure,

$$m = \rho_2 V_2;\quad 8.5536\ \text{kg} = (0.3341\ \text{kg/m}^3)V_2$$

$$V_2 = 25.6\ \text{m}^3 \qquad \textbf{Ans.}$$

Ans:
$\rho_2 = 0.334\ \text{kg/m}^3$
$V_2 = 25.6\ \text{m}^3$

1–22. When a pressure of 650 psi is applied to a solid, its specific weight increases from 310 lb/ft' to 312 lb/ft³. Determine the approximate bulk modulus.

SOLUTION

Differentiatin$g = \frac{W}{Y}$ with respect toy, we obtain

$$d = -\frac{W}{y}dy$$

Then

$$E_v = -\frac{dp}{dV/V} = -\frac{dp}{\left[-\frac{W}{\gamma^2}d\gamma \Big/ (W/\gamma)\right]} = \frac{dp}{dy/y}$$

Therefore,

$$E_v = \frac{650\ \text{lb/in}}{\left(\frac{(312\ \text{lb/ft}^3 - 310\ \text{lb/ft}^3)}{310\ \text{lb/ft'}}\right)} = 100.75(10)\text{psi} = 101(10')\ \text{psi} \quad \textbf{Ans.}$$

The more precise answer can be obtained from

$$'' - \int^{p} \frac{dp}{@} \_pp, 6 \frac{50\text{lb/in}^{...2}}{2\ \text{lb/ft} \ /\ \text{lb}} = 101 \quad 7(^\circ) \quad - \quad \frac{1(3^\circ)}{10}\ s$$

~@j~uwe or

γ a4 "(sore

Ans:
E = 101(10') psi

1–23. Water at 20°C is subjected to a pressure increase of 44 MPa. Determine the percent increase in its density. Take E = 2.20GPa.

SOLUTION

$$\frac{\Delta\rho}{\rho} = \frac{m/\forall_2 - m/\forall_1}{m/\forall_1} = \frac{\forall_1}{\forall_2} - 1$$

To find $\forall_1/\forall_2$, use $E_\forall = -dp/(d\forall/\forall)$.

$$\frac{d\forall}{\forall} = -\frac{dp}{E_\forall}$$

$$\int_{\forall_1}^{\forall_2}\frac{d\forall}{\forall} = -\frac{1}{E_\forall}\int_{p_1}^{p_2} dp$$

$$\ln\left(\frac{\forall_1}{\forall_2}\right) = \frac{1}{E_\forall}\Delta p$$

$$\frac{\forall_1}{\forall_2} = e^{\Delta p/E_\forall}$$

So, since the bulk modulus of water at 20°C is E = 2.20 GPa,

$$\frac{\Delta\rho}{\rho} = e^{\Delta p/E} - 1$$

$$= e^{(44\text{ MPa})/2.20\text{ GPa})} - 1$$

$$= 0.0202 = 2.02\,\% \qquad \textbf{Ans.}$$

Ans:
$\frac{\Delta\rho}{\rho} = 2.02\%$

***1–24.** If the bulk modulus for water at 70 °F is 319 kip/in², determine the change in pressure required to reduce its volume by 0.3%.

SOLUTION

Use $E_V = -dp/(dV/V)$.

$d \text{—-}r,\{$

Ap

$$\int_{p_i}^{p_f} dp = -E_V \int_{V_i}^{V_f} \frac{dV}{V}$$

$$= -(319 \text{ kip/in}^2) \ln\left(\frac{V - 0.03V}{V}\right)$$

$= 0.958$ kip/in² (ksi) **Ans.**

Ans:
$\Delta p = 0.958$ kip/in² (ksi)

1–25. At a point deep in the ocean, the specific weight of seawater is 64.2 lb/ft^3. Determine the absolute pressure in lb/in^2 at this point if at the surface the specific weight is $\gamma = 63.6$ lb/ft^3 and the absolute pressure is $p_a = 14.7$ lb/in^2. Take $E = 48.7(10^6)$ lb/ft^2.

SOLUTION

Differentiating $\gamma = \dfrac{W}{V}$ with respect to γ, we obtain

$$d\mathcal{V} = -\frac{W}{\gamma^2}d\gamma$$

Then

$$E_V = -\frac{dp}{d\mathcal{V}/\mathcal{V}} = -\frac{dp}{\left(-\dfrac{W}{\gamma^2}d\gamma\right)\Big/(W/\gamma)} = \frac{dp}{d\gamma/\gamma}$$

$$dp = E_V\frac{d\gamma}{\gamma}$$

Integrate this equation with the initial condition at $p = p_0$, $\gamma = \gamma_0$, then

$$\int_{p_0}^{p} dp = E_V\int_{\gamma_0}^{\gamma}\frac{d\gamma}{\gamma}$$

$$p - p_0 = E_V \ln\frac{\gamma}{\gamma_0}$$

$$p = p_0 + E_V \ln\frac{\gamma}{\gamma_0}$$

Substitute $p_0 = 14.7\ \text{lb/in}^2$, $E_V = \left[48.7(10^6)\ \text{lb/ft}^2\right]\left(\dfrac{1\ \text{ft}}{12\ \text{in}}\right)^2 = 338.19(10^3)\ \text{lb/in}^2$,

$\gamma_0 = 63.6$ lb/ft^3 and $\gamma = 64.2$ lb/ft^3 into this equation,

$$p = 14.7\ \text{lb/in}^2 + \left[338.19(10^3)\ \text{lb/in}^2\right]\left[\ln\left(\frac{64.2\ \text{lb/ft}^3}{63.6\ \text{lb/ft}^3}\right)\right]$$

$= 3.190(10^3)$ psi

$= 3.19(10^3)$ psi **Ans.**

Ans:
$p = 3.19(10^3)$ psi

1–26. A 2-kg mass of oxygen is held at a constant temperature of 50 °C and an absolute pressure of 220 kPa. Determine its bulk modulus.

SOLUTION

$$E = \bullet \frac{\}}{dV \;¥} - - \frac{dp¥}{d\bullet}$$

$$p = RT$$

$$dp = d,RT$$

$$E_t = \frac{d,RT}{d\bullet} = -- d¥$$

$$= \frac{m}{4}$$

$$\mathbf{r}$$

$$d\mathbf{r} = -\frac{md¥}{¥^2}$$

$$E_¥ = \frac{md¥ \, p¥}{¥^2(m \;¥)d¥} = p = 220 \text{ kPa}$$ **Ans.**

Note: This illustrates a general point. For an ideal gas, the isothermal (constant temperature) bulk modulus equals the absolute pressure.

Ans:
$E_{\mathcal{V}}$ = 220 kPa

1–27. The viscosity of SAE 10 W30 oil is $\mu = 0.100\ N\cdot s/m^2$. Determine its kinematic viscosity. The specific gravity is $S_o = 0.92$. Express the answer in SI and FPS units.

SOLUTION

The density of the oil can be determined from

$$\rho_o = S_o \rho_w = 0.92(1000\ kg/m^3) = 920\ kg/m^3$$

Then,

$$\nu_o = \frac{\mu}{\rho_o} = \frac{0.100\ N\cdot s/m^2}{920\ kg/m^3} = 108.70(10^{-6})\ m^2/s = 109(10^{-6})\ m^2/s \quad \textbf{Ans.}$$

In FPS units,

•-[mi(a.:.)

$$= 1.170(10^{-3})\ ft^2/s = 1.17(10^{-3})\ ft^2/s \quad \textbf{Ans.}$$

Ans:
$\nu_o = 109(10^{-6})\ m^2/s$
$= 1.17(10^{-3})\ ft^2/s$

***1–28.** If the kinematic viscosity of glycerin is $\nu = 1.15(10^{-3})\ \mathrm{m^2/s}$, determine its viscosity in FPS units. At the temperature considered, glycerin has a specific gravity of $S_g = 1.26$.

SOLUTION

The density of glycerin is

$$\rho_g = S_g \rho_w = 1.26(1000\ \mathrm{kg/m^3}) = 1260\ \mathrm{kg/m^3}$$

Then,

$$\nu = \frac{\mu}{\rho_g};\quad 1.15\left(10^{-3}\right)\ \mathrm{m^2/s} = \frac{\mu_g}{1260\ \mathrm{kg/m^3}}$$

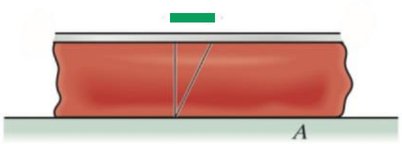
$$\mu_g = \left(1.449\ \frac{\mathrm{N\cdot s}}{\mathrm{m^2}}\right)\left(\frac{1\ \mathrm{lb}}{4.448\ \mathrm{N}}\right)\left(\frac{0.3048\ \mathrm{m}}{1\ \mathrm{ft}}\right)^2$$

$$= 0.03026\ \mathrm{lb\cdot s/ft^2}$$

$$= 0.0303\ \mathrm{lb\cdot s/ft^2}$$ **Ans.**

Ans:
$\mu_g = 0.0303\ \mathrm{lb\cdot s/ft^2}$

1-29. An experimental test using human blood at $T = 30°\text{C}$ indicates that it exerts a shear stress of $\tau = 0.15\ \text{N/m}$ on surface A, where the measured velocity gradient is $16.8\ \text{s}'$. Since blood is a non-Newtonian fluid, determine its *apparent viscosity* at A.



SOLUTION

Here, $\frac{du}{dy} = 16.8\ \text{s}^{-1}$ and $\tau = 0.15\ \text{N/m}^2$. Thus,

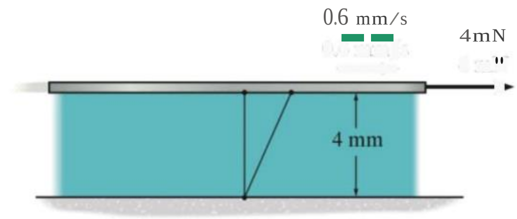
$$\tau = \mu_a \frac{du}{dy}; \qquad 0.15\ \text{N/m} = \mu_a (16.8\ \text{s}')$$

$$\mu_a = 8.93(10)\ \text{N}\cdot\text{s/m} \qquad \textbf{Ans.}$$

Realize that blood is a non-Newtonian fluid. For this reason, we are calculating the *apparent* viscosity.

Ans:
$\mu_a = 8.93(10)\ \text{N}\cdot\text{s/m}$

1–30. The plate is moving at 0.6 mm/s when the force applied to the plate is 4 mN. If the surface area of the plate in contact with the liquid is 0.5 m², determine the approximate viscosity of the liquid, assuming that the velocity distribution is linear.



SOLUTION

The shear stress acting on the fluid contact surface is

$$\tau = \frac{F}{A} = \frac{4(10^{-3})\text{ N}}{0.5\text{ m}^2} = 8.00(10^{-3})\text{ N/m}^2$$

Since the velocity distribution is assumed to be linear, the velocity gradient is a constant.

$$\tau = \mu\frac{du}{dy}; \qquad 8.00(10^{-3})\text{ N/m}^2 = \mu\left[\frac{0.6(10^{-3})\text{ m/s}}{4(10^{-3})\text{ m}}\right]$$

$$\mu = 0.0533\text{ N}\cdot\text{s/m}^2$$ **Ans.**

Ans:
$\mu = 0.0533\text{ N}\cdot\text{s/m}^2$